Final Report



Power System Master Plan 2016

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Contents

PART I PRINCIPLE OF THE MASTER PLAN [Chapter 1]
PART II POLICY [Chapter 2 to 4]
PART III ENERGY BALANCE [Chapter 5 to 10]
PART IV POWER BALANCE [Chapter 11 to 18]
PART V ENERGY COST AND TARIFF BALANCE [Chapter 19 to 21]
PART VI TECHNICAL SUPPORT [Chapter 22]
APPENDIX [Chapter 23]

Chapter 1 PSMP2016 Summary 1-1

1.1 Abstract 1-1

1.2 Background and Purpose 1-1

1.3 Vision Paper 1-3

1.4 Policy Vision 1-4
1.4.1 PSMP2016 Objective 1-4
1.4.2 Five Viewpoints of PSMP2016 1-5
1.4.3 Importance of Contribution and Responsibility to the International Community 1-6

1.5 Practical Vision 1-8
1.5.1 Relationships between the Five Key Viewpoints and the Master Plan Investigation Items 1-8
1.5.2 Methodologies for this Study 1-9
1.5.3 Scope of work 1-12
1.5.4 Survey Implementation Feamework 1-14
1.5.5 JICA Study Team 1-16
1.5.6 Past Activities 1-17

1.6 Focal points 1-21
1.6.1 PSMP 2010 Review 1-21
1.6.2 Economic Development Policy 1-25
1.6.3 Primary Energy 1-27
1.6.4 Natural Gas (Domestic) 1-30
1.6.5 Natural Gas (LNG Imports) 1-33
1.6.6 Coal 1-35
1.6.7 Oil and LPG 1-38
1.6.8 Power Development Plan 1-39
1.6.9 Hydropower development 1-57
1.6.10 Renewable Energy 1-61
1.6.11 Power Imports 1-63
1.6.12 Nuclear Power 1-66
1.6.13 Power System Plan 1-72
1.6.14 Improvement of Power Quality 1-77
1.6.15 O&M Legal Framework 1-84
1.6.16 Thermal Power Plant O&M 1-87
1.6.17 Tariff Policy 1-93

1.7 Road-map 1-99

Chapter 2 Energy and Power Sector Overview 2-1

2.1 Overall Entity 2-1
2.1.1 Ministry of Power, Energy and Mineral Resources (MoPEMR) 2-1
2.1.2 Bangladesh Energy Regulatory Comission (BERC) 2-1

2.2 Energy Sector Overview 2-2
2.2.1 Energy and Mineral Resources Division (Energy Division) 2-3
2.2.2 Petrobangla 2-3
2.2.3 Bangladesh Petroleum Corporation (BPC) 2-3
2.2.4 Other State-owned Entities 2-4

2.3 Power Sector Overview 2-5
2.3.1 Power Division 2-6
2.3.2 Sustainable and Renewable Energy Development Authority 2-6
2.3.3 Bangladesh Power Development Board (BPDB) 2-6
2.3.4 Power Generation Entities 2-7
2.3.5 Power Grid Company of Bangladesh (PGCB): 2-8
2.3.6 Distribution Entities and Rural Electrification 2-8
2.3.7 Infrastructure Development Company Limited (IDCOL) 2-9

Chapter 3 Energy and Power Policies 3-1

3.1 World Trend of Energy Policy ~ SDGs and COP21 3-1
3.1.1 Sustainable Development Goal 3-1
3.1.2 Paris Agreement 3-1

3.2 Road to the Vision 2041 3-2

3.3 7th Five Year Plan (2016~2020) 3-2

3.4 Energy Sector Policy 3-3

3.5 Power Sector Policy 3-4

3.6 Renewable Energy Policy and SREDA Act 3-4

3.7 Energy Efficiency and Conservation Policy 3-5

3.8 Role of PSMP2016 as Complemental Energy and Power Policies 3-5

Chapter 4 Environmental Policy 4-1

4.1 Current Position of Bangladeshi Government Concerning Greenhouse Gas Emission 4-1
4.1.1 Status of GHG emission in Bangladesh 4-1
4.1.2 Measures declared by GoB in INDC (Intended Nationally Determined Contributions) 4-2

4.2 Recent Trend and Future Prospects of UNFCCC and IPCC 4-4
4.2.1 IPCC Fifth Assessment Report (AR5) 4-4
4.2.2 Outcomes of COP21 4-5
4.2.3 Overview of INDCs submitted by other Asian Countries 4-6
4.2.4 Other environmental considerations 4-14

4.3 Implications for the PSMP 4-14

Chapter 5 Prospects of Economic Development 5-1

5.1 History of Bangladesh Economy 5-1

5.2 Scenario Analysis of Economic Development 5-2

5.3 Historical Trend of Economic Indices and Energy Demand in Southeast Asian Countries 5-3
5.3.1 Historical trend of economic indices in Southeast Asian countries 5-3
5.3.2 Historical trend of energy consumption 5-5

5.4 Study on the Economic Development Scenarios 5-6
5.4.1 Identification of the role model 5-6
5.4.2 Implications for the future scenarios of economic development in Bangladesh 5-10

5.5 Future Scenarios of Economic Development of Bangladesh 5-11
5.5.1 Manufacturing sector in Bangladesh 5-11
5.5.2 Roles and directions of manufacturing sector in Bangladesh 5-13
5.5.3 Positioning of Bangladesh in the process of industrialization and measures to be taken 5-15

5.6 Projections of GDP in Bangladesh up to 2041 5-16
5.6.1 Bangladesh Government's GDP growth target 5-16
5.6.2 Projections of international agencies 5-18
5.6.3 Projection in PSMP2016 5-18

5.7 Methodologies of GDP Projection in this Study 5-19
5.7.1 Population 5-19
5.7.2 Economic development scenario 5-20
5.7.3 GDP projection up to 2041 5-24
5.7.4 Sectorial breakdown of GDP 5-25
5.7.5 Projection of “High-growth Scenario” and “Low-growth Scenario” 5-28

Chapter 6 Prospects of Energy Supply and Demand 6-1

6.1 Overview of Energy Supply and Demand Balances of Bangladesh 6-1
6.1.1 Historical trend of primary energy supply 6-1
6.1.2 Historical trend of final energy consumption and sectorial breakdown 6-1
6.1.3 Historical trend of supply and demand for each fuel type 6-2
6.1.4 Historical trend of final energy consumption for each sector 6-4
6.1.5 Historical trend of electricity consumption and sectorial breakdown 6-7

6.2 Civilian Sector (Residential and Commercial/Public Services) 6-8
6.2.1 Current status of energy demand 6-8
6.2.2 Key factors that affect future prospects of energy demand 6-12
6.2.3 Projection of energy consumption 6-12

6.3 Industrial Sector 6-16
6.3.1 Current status of energy demand 6-16
6.3.2 Key factors that affect future prospects of energy demand 6-20
6.3.3 Projection of energy consumption 6-21

6.4 Transport Sector 6-23
6.4.1 Current status of energy demand 6-23

6.4.2 Key factors that affect future prospects of energy demand 6-28
6.4.3 Projection of energy consumption 6-31

6.5 Agricultural Sector 6-33
6.5.1 Current status of energy demand and key factors that affect future prospects 6-33
6.5.2 Projection of energy consumption 6-34

6.6 Total Energy Supply & Demand Balance Up to 2041 6-37
6.6.1 Projection of total final energy consumption 6-37
6.6.2 Projection of total primary energy supply 6-41

Chapter 7 Domestic Natural Gas Supply 7-1

7.1 Natural Gas Reserve 7-1
7.1.1 Gas field location 7-1
7.1.2 Gas reserve evaluation 7-2
7.1.3 Gas Reserves and Resources 7-5
7.1.4 Discovery of new gas field and probability 7-7

7.2 Petrobangla Companies and Cost Structure 7-8
7.2.1 Petrobangla companies 7-8
7.2.2 Gas price and cost structure 7-13
7.2.3 Financial status of companies under Petrobangla 7-15

7.3 Gas Production Forecast 7-16
7.3.1 Assessment of existing gas fields and fast track program 7-16
7.3.2 Production forecast for existing gas fields 2015-2019 7-18
7.3.3 Natural gas supply scenario 2015-2041 7-25
7.3.4 Cost estimate for future investment on gas field development 7-28
7.3.5 Condensate production 7-29

7.4 Gas Field Development and PSC 7-30
7.4.1 Future gas field development 7-30
7.4.2 2012 model PSC 7-31
7.4.3 Attractive PSC and partnership 7-32
7.4.4 Role of BAPEX 7-32

7.5 Improvement of Gas Supply Infrastructure and Gas Use Efficiency 7-33
7.5.1 Improvement of gas supply infrastructure 7-33
7.5.2 Improvement of gas use efficiency 7-34

7.6 Possible Assistance from Japan 7-35

7.7 Environmental and Social aspects of Natural Gas development 7-36
7.7.1 Environmental Impact Assessment 7-36
7.7.2 Experienced environmental and social impact of gas development 7-37
7.7.3 Environmental and social risk of gas development 7-39

Chapter 8 Liquefied Natural Gas Supply 8-1

8.1 Background of LNG Import in Bangladesh 8-1

8.2 Overview of LNG Terminal Development Plans 8-1

8.3 Status of FSRU Planning in Bangladesh 8-2

8.4 Status of Land-based LNG terminal Planning 8-3
8.4.1 Power Cell Project 8-3
8.4.2 Petrobangla Project 8-4

8.5 Economic Comparison between FSRU and Land-based LNG Receiving Terminal 8-4
8.5.1 Overview 8-4
8.5.2 Land-based LNG terminal specifications and construction cost 8-5
8.5.3 Operation cost comparison 8-5
8.5.4 Freight cost comparison 8-6
8.5.5 Operation cost comparison 8-7
8.5.6 Construction time schedule 8-8
8.5.7 Cyclone risks for FSRU 8-9
8.5.8 LNG Master Plan 8-9

8.6 LNG Trade Contract 8-10
8.6.1 Background of LNG pricing 8-10
8.6.2 LNG market 8-11
8.6.3 New LNG procurement strategy 8-12

8.7 Cross-border LNG Trade 8-13
8.7.1 Project overall 8-13
8.7.2 Executing agency 8-13
8.7.3 Progress status 8-13
8.7.4 Schedule 8-13
8.7.5 Construction cost 8-13

8.8 Land-based LNG Receiving Terminal Planning 8-14
8.8.1 General planning 8-14
8.8.2 Current planning status 8-14
8.8.3 Impact of the LNG vaporized gas to the existing gas distribution network 8-17
8.8.4 Specification of LNG tanker and harbor conditions 8-18
8.8.5 Ground level 8-29
8.8.6 Subsurface exploration 8-30
8.8.7 Earthquake 8-33
8.8.8 Countermeasures to Tsunami 8-36
8.8.9 CAPEX & OPEX of on shore LNG receiving terminal 8-36

8.9 Challenges and Issues of LNG Terminal Implementation 8-37
8.9.1 Preparation of Finance 8-37
8.9.2 Establishment of LNG value chain 8-37
8.9.3 Operation of LNG receiving terminal 8-38
8.9.4 Effective terminal management 8-39

Chapter 9 Coal Supply 9-1

9.1 National Coal Development Policy 9-1
9.1.1 Present situation of the coal policy 9-1
9.1.2 PSMP2010 review 9-1
9.1.3 Significance of the coal development 9-2

9.2 Current Situations and Issues of Supply and Demand of Domestic Coal 9-3
9.2.1 Coal reserve of each coal field and estimated minable coal reserve 9-3

9.2.2 Current situation and issue of Barapukuria coal mine 9-7
9.2.3 An aspect of undeveloped coal field 9-10
9.2.4 Forecast of domestic coal production 9-10

9.3 The Present Aspect and Issues of the Import coal 9-12
9.3.1 General view 9-12
9.3.2 Import coal price 9-14

9.4 Prediction of Coal Demand & Supply 9-16
9.4.1 Prediction of coal demand & supply 9-16
9.4.2 The issue of coal supply 9-17
9.4.3 Coal demand of industry 9-18
9.4.4 The quality of import coal for industry 9-18

9.5 Environmental and Social Aspects of Coal Development 9-19
9.5.1 Environmental Impact Assessment 9-19
9.5.2 Experienced environmental and social impact of coal development 9-20
9.5.3 Environmental and social risk of coal development 9-21

Chapter 10 Oil Products Supply 10-1

10.1 Forecast of Oil Import 10-1
10.1.1 Oil demand 10-1
10.1.2 Oil import supply – current status 10-3
10.1.3 Oil import supply – future projects 10-4
10.1.4 Oil supply and demand balance 10-6

10.2 Oil Refinery v.s. Oil Import 10-6

10.3 Refinery Development – World Trend and Implication to Bangladesh 10-8

10.4 LPG 10-11
10.4.1 LPG current status 10-11
10.4.2 LPG policy 10-12
10.4.3 LPG price 10-13
10.4.4 LPG future demand 10-13
10.4.5 LPG supply future plan 10-14
10.4.6 Issue of LPG 10-15
10.4.7 Pressure to the national coffer 10-16

Chapter 11 Power Development Plan 11-1

11.1 Power demand forecast 11-1

11.2 Peak demand projection 11-1
11.2.1 Implementation flow 11-1
11.2.2 Assumptions 11-2

11.3 Peak demand projection using gdp elasticity method 11-3
11.3.1 Economic development projection 11-3
11.3.2 Validation of gdp elasticity 11-4
11.3.3 Assumption of the effects of peak demand reduction 11-5
11.3.4 Peak demand projection using gdp elasticity method 11-5

11.4 Verifying the peak demand projection using sectorial analysis method 11-9
11.4.1 Steps in power demand projection 11-9
11.4.2 Peak Demand Projection Using Sectorial Analysis Method 11-9

11.5 Verifying the peak demand forecasting model 11-10
11.5.1 Peak demand for PSMP 2016 11-10
11.5.2 Integration of peak power demand projection and energy supply-demand projection 11-11

11.6 Power development planning 11-13

11.7 Review of PSMP 2010 11-14
11.7.1 Review of the power development plan 11-14
11.7.2 Review of gas supply 11-15
11.7.3 Review of coal supply 11-15
11.7.4 Relationship between fuel consumption in power and primary energy balance 11-15

11.8 Examination of existing generation capacity 11-16
11.8.1 Existing capacity (Total) 11-16
11.8.2 Gas-based power 11-17
11.8.3 Coal-based power 11-18
11.8.4 Oil-based power 11-18
11.8.5 Hydropower 11-19
11.8.6 Power import 11-19
11.8.7 Retirement Plan 11-19

11.9 Evaluation of the Plan Approved by the Government (Committed Plan) 11-20
11.9.1 Gas-bsed power 11-20
11.9.2 Coal-bsed power 11-20
11.9.3 Oil-based power 11-21
11.9.4 Hydropower 11-21
11.9.5 Power import 11-21
11.9.6 Nuclear power 11-21
11.9.7 Validation of commissioning date 11-22

11.10 Consistency with port infrastructure planning 11-25
11.10.1 Port infrastructure plan by JICA Southern Chittagong Master Plan 11-25
11.10.2 Allocation of natural gas supply 11-25
11.10.3 LNG terminal development scenario 11-26
11.10.4 Coal development scenario 11-29

11.11 Long and ultra-long term development plan (Candidate Plan) 11-31
11.11.1 Gas based 11-31
11.11.2 Coal based 11-32
11.11.3 Power Imports 11-32
11.11.4 Nuclear power 11-33
11.11.5 Summary of power development plan (Base case) 11-33

11.12 Preconditions for the estimation of the economic and environmental values 11-38
11.12.1 Daily load curve 11-38
11.12.2 Supply Reliability 11-41
11.12.3 Fuel Price Scenarios 11-42

11.13 Examination of economic and environmental value via power development planning simulation 11-44

11.14 Economic value 11-47
11.14.1 Economic value index 11-47
11.14.2 Concept of simulation for demand and supply planning 11-47
11.14.3 Optimum operation pattern 11-48
11.14.4 Transition of fuel consumption 11-49
11.14.5 Transition of generation cost 11-49

11.15 Environmental Value 11-51
11.15.1 CO2 emission value 11-51
11.15.2 Transition of CO2 emission 11-51
11.15.3 Quantitative evaluation of environment value 11-51

11.16 Energy Security Evaluation 11-53
11.16.1 Quantitative evaluation 11-53
11.16.2 Past Studies on the Quantitative Evaluation of Energy Security 11-54
11.16.3 Key Issues in Considering the Energy Security in Bangladesh 11-57
11.16.4 Methodologies of Evaluaion 11-58

11.17 3E Evaluation 11-61
11.17.1 Selection of the Optimum Scenario of Energy Mix Based on 3E Evaluation 11-61
11.17.2 Challenging for renewable energy expansion 11-62

11.18 General strategy for finding the optimum energy mix 11-66
11.18.1 Outline 11-66
11.18.2 Acchieve to best energy mix 11-67
11.18.3 Recommendations on the implementation & monitoring of the master plan 11-68

Chapter 12 Hydropower 12-1

12.1 Outline of Hydropower Potential Study 12-1
12.1.1 Background 12-1
12.1.2 Objective of the study 12-1
12.1.3 Study flow 12-1
12.1.4 Limitation in the study 12-1

12.2 Current Situation of Hydropower Development in Bangladesh 12-2
12.2.1 Outline of Karnafuli Hydropower Plant 12-2
12.2.2 Hydropower potential and hydropower development plan in Bangladesh 12-4

12.3 Environmental Law and Regulations 12-6
12.3.1 Environment Conservation Act 12-6
12.3.2 Environmental Impact Assessment Regulations and Guidelines 12-7
12.3.3 Relevant ministries and agencies to Environmental Conservation 12-8
12.3.4 Laws and regulations on Land acquisition and Resettlement 12-8

12.4 Selection of Hydropower Potential Sites for this Study 12-8
12.4.1 Identification of Pumped Storage Power Plant (PSPP) Sites 12-8
12.4.2 Selection of ordinary HP /SSHP potential sites for this study 12-10

12.5 Selection of Target Areas and Site Reconnaissance 12-11

12.6 Geology around the Potential Sites 12-11

12.7 Environmental and Social Considerations 12-12

12.7.1 Baseline of environmental and social information in and around the potential sites 12-12
12.7.2 Environmental and social impacts anticipated by project 12-30

12.8 Summary of Hydropower Potential Study 12-41
12.8.1 PSPP potential sites 12-41
12.8.2 Ordinary HP/SSHP Potential Sites 12-41

12.9 Recommendations for the Next Steps 12-43
12.9.1 Possibility of project implementation 12-43
12.9.2 Reference TOR for the future projects 12-43

Chapter 13 Renewable Energy 13-1

13.1 Environments around Renewable Energy 13-1
13.1.1 World trend 13-1
13.1.2 Renewable energy in India 13-2

13.2 Government Policy for Renewable Energy 13-3
13.2.1 Government policy and definition 13-3
13.2.2 Renewable energy promotion policy and regulation 13-5

13.3 Organization for Renewable Energy Deployment 13-6

13.4 Renewable Energy Potential in Bangladesh 13-7
13.4.1 Overview 13-7
13.4.2 Solar 13-8
13.4.3 Wind 13-8
13.4.4 Biomass and biogas power generation, and waste to energy 13-8
13.4.5 Hydropower 13-10
13.4.6 Biogas as cooking fuel 13-10
13.4.7 Biofuel 13-15

13.5 Gap between Planning and Potential 13-17
13.5.1 Approaches to closed the gap (RE technologies other than biogas and biofuels) 13-17
13.5.2 Biogas 13-18
13.5.3 Biofuel 13-19

13.6 Integration of the Renewable Energy into Power Development Planning 13-20

13.7 Substantial Renewable Energy into Grid Connections 13-21
13.7.1 Variable renewable energy grid connections 13-21
13.7.2 Large hydro via cross-border power import 13-22

Chapter 14 Power Import and Nuclear Power 14-1

14.1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh 14-1

14.2 Possibility of International power trading in Bangladesh 14-3

14.3 Selection of Hydropower Development Candidate Area for Bangladesh 14-4
14.3.1 Evaluation Criteria Setting 14-4
14.3.2 Possible Candidate Areas for Hydropower Development to be connected 14-4
14.3.3 Screening Based on the Evaluation Criteria 14-5

14.4 Selection of Hydropower Development Candidate Sites 14-7
14.4.1 Evaluation Criteria Setting 14-7
14.4.2 Comparison and Screening of Hydropower Development Sites alongside the Evaluation Criteria 14-9

14.5 Recommendations on Regional Power Interconnection 14-13
14.5.1 Challenges and Countermeasures of Power Imports 14-13
14.5.2 Proposals on Power Import Planning 14-14
14.5.3 Implementation Arrangement 14-18

14.6 Nuclear Power Generation 14-19
14.6.1 Nuclear Power Generation in PSMP2016 14-19
14.6.2 Development of Nuclear Power Generation in Bangladesh 14-19
14.6.3 Implementation framework 14-20
14.6.4 Ruppur Nuclear Power Plant Project 14-21
14.6.5 Challenges for Bangladesh 14-22
14.6.6 Roadmap 14-27

Chapter 15 Power System Plan/ Rural Electrification (Distribution) 15-1

15.1 Power Network System Plan Tasks 15-1

15.2 Power System Plan Examination Criteria 15-2
15.2.1 Examination Methods 15-2
15.2.2 System Plan by PGCB for 2020 15-2
15.2.3 Examination of Power System Plan in this Study 15-3
15.2.4 Maximum Power Demand Forecast 15-8
15.2.5 Power Generation Plan 15-14
15.2.6 Power Supply and Demand Balance by Region 15-15

15.3 Setting Plans for 2025 and 2035 15-17
15.3.1 The Plan for 2025 15-17
15.3.2 The Plan for 2035 15-23

15.4 Power System Analysis for 2025 and 2035 15-29
15.4.1 System Analysis Criteria 15-29
15.4.2 Power Flow Calculation 15-30
15.4.3 Fault Current Calculation 15-31
15.4.4 System Stability Calculation 15-32

15.5 Recommendations Regarding Power System Network Plan 15-36

15.6 Cost Estimation Assumptions 15-36

15.7 Power System Expansion 15-37
15.7.1 Amount of equipment expansion from FY2016 to FY2025 15-37
15.7.2 Amount of equipment expansion from FY2026 to FY2035 15-42

15.8 Development Costs Summary 15-45

15.9 Rural Electrification 15-45
15.9.1 Government policy and definition 15-45
15.9.2 Power distribution entities in Bangladesh 15-48
15.9.3 On-grid electrification (distribution line extension) 15-48

15.9.4 Off-grid electrification 15-51
15.9.5 Approach for "Electricity for All" 15-53
15.9.6 Demand estimation from electrification 15-53
15.9.7 Future grid connection 15-55
15.9.8 Concerns on future wastes from SHSs 15-56
15.9.9 Future issues to address 15-57

Chapter 16 Power Quality 16-1

16.1 Fundamentals of Electricity Demand/supply Operation Process 16-1
16.1.1 Demand/supply operation planning 16-1
16.1.2 Real-time operation 16-1

16.2 Present Status and Necessity of Improving Power Frequency Quality in Bangladesh 16-4
16.2.1 Electricity demand-supply operation in Bangladesh 16-4
16.2.2 The Actual Situation regarding Power Frequency Quality 16-6

16.3 Scope of This Investigation 16-9

16.4 Investigation of the Regulatory Framework for Electricity Business 16-10
16.4.1 Regulatory framework for power system planning/operation 16-10
16.4.2 Regulation by the Electricity Acts 16-13
16.4.3 Regulation by independent regulatory organization 16-17
16.4.4 Summary 16-20

16.5 Proposal for Frequency Quality Improvement Roadmap 16-27
16.5.1 Future electricity demand and power sources in Bangladesh 16-27
16.5.2 Reserves for power frequency control 16-28

16.6 Actual Condition of EMS/SCADA System in NLDC for Load Frequency Control (LFC) 16-43
16.6.1 Installed functions in NLDC system 16-43
16.6.2 Logic diagram of load frequency control in CLDO system in TEPCO 16-45
16.6.3 Early Applicableness of Load Frequency Control by NLDC System 16-46
16.6.4 Solution - Early Applicableness of FGMO 16-47

Chapter 17 O&M Legal Framework 17-1

17.1 Introduction 17-1
17.1.1 Purpose of this study 17-1
17.1.2 Solutions procedure 17-1
17.1.3 Cause and effect diagram 17-2
17.1.4 Scheme of O&M legal framework 17-3
17.1.5 Key factors for stable operation 17-4
17.1.6 General economic concept of O&M 17-5

17.2 Japanese O&M Legal Framework 17-7
17.2.1 General concept for regulations of O&M 17-7
17.2.2 Japanese government's main requirements for P/P 17-8
17.2.3 Main regulations for P/P 17-9
17.2.4 Laws, regulations and rules concerning inspection & maintenance 17-11
17.2.5 Safety requirements in Electricity Business Act 17-13
17.2.6 Details of safety requirements in Electricity Business Act 17-14
17.2.7 Safety regulations content defined in the Electricity Business Act 17-15
17.2.8 Internal rules 17-16

17.2.9 Licensed and qualified persons in power plant 17-17
17.2.10 Notification and reports system 17-18

17.3 Bangladesh O&M Legal Framework 17-18
17.3.1 Hierarchy of power sector 17-18
17.3.2 Laws and acts in Bangladesh 17-19
17.3.3 Electricity Act 1910 17-19
17.3.4 Bangladesh Energy Regulatory Commission Act 2003 17-22
17.3.5 Bangladesh Energy Regulatory Commission Act, 2003.(excerpt) 17-23

17.4 Comparison between Bangladesh and Japan 17-25

17.5 Suggestions 17-33
17.5.1 Review of research 17-33
17.5.2 Suggested O&M legal items 17-34
17.5.3 Recommended schedule of regulations 17-35

Chapter 18 Thermal Power Operations and Maintenance 18-1

18.1 Outline 18-1

18.2 Basic Survey for Bangladesh Thermal Power 18-2
18.2.1 Equipment 18-2

18.3 Actual O&M Situation 18-7
18.3.1 Power station situation 18-7
18.3.2 Summary of actual O&M situation 18-27
18.3.3 Staff 18-28
18.3.4 Facilities, repair plan 18-29
18.3.5 Budget 18-29
18.3.6 Information 18-29
18.3.7 Summary 18-30

18.4 Problems 18-30
18.4.1 Staff 18-30
18.4.2 Facilities, repair plan 18-30
18.4.3 Budget 18-31
18.4.4 Information 18-32
18.4.5 Problem Analysis 18-32

18.5 Solutions 18-35
18.5.1 Outline of solution proposals 18-35

18.6 Rehabilitation 18-40
18.6.1 Rehabilitation considerations 18-40
18.6.2 Cost-effectiveness 18-41
18.6.3 Power station comments 18-42

18.7 Combined Cycle Power Generation Remodeling Plan 18-42
18.7.1 Combined cycle power generation remodeling examination 18-42
18.7.2 Frequency instability problem in Bangladesh and small class gas turbine combined cycle generation plant 18-45
18.7.3 Cost-effectiveness 18-46

18.8 Information Strategy 18-47
18.8.1 Presumptions 18-47
18.8.2 Information management strategy 18-48
18.8.3 Goal and objectives 18-48
18.8.4 Integration of information management strategy 18-52
18.8.5 Implementation of information management system 18-54
18.8.6 Implementation proposal 18-62
18.8.7 Expected results 18-65

18.9 Training Center 18-70
18.9.1 Necessity of training center 18-70
18.9.2 Training course 18-70
18.9.3 Instructors 18-71
18.9.4 Training facility (simulator) 18-71
18.9.5 Training facility (maintenance) 18-72
18.9.6 Important points for training center 18-72
18.9.7 Schedule for training center construction 18-72

Chapter 19 Financial Performance of the Power Sector 19-1

19.1 Overview of the Electricity Tariff System in Bangladesh 19-1

19.2 Overview of Funding Related to the Power Sector 19-5
19.2.1 Donors' assistance programs for the Bangladeshi power sector 19-6
19.2.2 Financial support from the government of Bangladesh 19-9
19.2.3 Loan conditions of commercial banks to the power sector 19-10

19.3 Financial Performance of Main Players in the Power Sector 19-10
19.3.1 Financial performance of the overall power sector 19-10
19.3.2 Financial performance of BPDB 19-14
19.3.3 Financial performance of PGCB and distribution entities 19-18
19.3.4 Cost structure of power generation 19-25
19.3.5 Summary of the financial performance of the power sector 19-28

19.4 Estimation of the Future Costs of Electricity Supply 19-30
19.4.1 Projection of generation cost 19-30
19.4.2 Projection of transission and distribution costs 19-31
19.4.3 Results of the cost estimation 19-31

Chapter 20 Financial Performance of the Gas and Oil Sector 20-1

20.1 Natural Gas Tariff 20-1
20.1.1 Overview of natural gas tariff in Bangladesh 20-1
20.1.2 Comparison of natural gas tariff in Bangladesh with other countries 20-4

20.2 Financial Performance of Petrobangla and BPC 20-5
20.2.1 Petrobangla 20-5
20.2.2 Bangladesh Petroleum Corporation (BPC) 20-7

Chapter 21 Tariff Policy 21-1

21.1 Methodologies of the Analysis 21-1

21.2 Analysis on Electricity Tariff 21-2

21.2.1 Single-year analysis 21-2
21.2.2 Time-line analysis 21-4

21.3 Analysis on Gas Price 21-8
21.3.1 Single-year analysis 21-8
21.3.2 Time-line analysis 21-10

21.4 Policy Recommendations on Increase of Electricity Tariff 21-12
21.4.1 Electricity tariff reform 21-12
21.4.2 Capacity building of human resource for financial review 21-17
21.4.3 Gas price reform 21-17

Chapter 22 Recommendations on the Implementation & Monitoring of the Master Plan 22-1

22.1 Capacity building for master plan revision 22-1
22.1.1 Collaboration and Cooperation between Organizations 22-1
22.1.2 Periodical Rolling Revision of the Milestone Plan 22-1
22.1.3 Strengthening of integrated statistical processing functions 22-2
22.1.4 Introduction of Key Performance Indicators 22-2

22.2 Measures to Facilitate Improvement of Investment Climate 22-3
22.2.1 Outline 22-3
22.2.2 Project Implementation Structure 22-3
22.2.3 Risks directly concerned with the Government 22-4
22.2.4 Risks to be controlled mainly by contractors 22-5
22.2.5 Recommendations for Improvement 22-5

22.3 Economic Development 22-6

22.4 Domestic Natural Gas [Gas] 22-7

22.5 LNG Import [Gas] 22-10

22.6 Renewable Energy [Introduction of energy storage technology] 22-12

22.7 Power System Plan 22-14

22.8 O&M Legal Framework [O&M] 22-15

22.9 Thermal Power Plant O&M [O&M] 22-16

22.10 Tariff policy 22-20

22.11 Realization Of Low Energy Consumption Society 22-20
22.11.1 New Technologies for Power Generation with Different Energy Sources 22-20
22.11.2 New technologies in the electric power infrastructure sector 22-21
22.11.3 Responsible Energy Consumption and Development of Bangladesh 22-22

Chapter 23 Appendix 23-1

List of Tables

Page

Table 1-1 Link between PSMP2016 and the SDGs 1-7
Table 1-2 Contents of the Study 1-12
Table 1-3 PSMP2010 Review (Economic Development) 1-21
Table 1-4 PSMP2010 Review (Coal Supply) 1-22
Table 1-5 PSMP2010 Review (Gas Supply) 1-23
Table 1-6 Projection of GDP and GDP per capita up to 2041 1-25
Table 1-7 Projection of Primary Energy Supply – Scenario 3 1-29
Table 1-8 3E Evaluation Results of Each Power Development Scenario 1-53
Table 1-9 3E Evaluation Results of Each Power Development Scenario 1-54
Table 1-10 Renewable Energy Potential in Bangladesh 1-61
Table 1-11 Electrification Rate Calculation Details by Power Division 1-73
Table 1-12 Supply Trip Amount and Factors Which Should Be Considered in Each Year 1-82
Table 1-13 Problems in Organizational Resources 1-88
Table 1-14 Solution Proposals 1-89
Table 1-15 O&M Solution Proposals and Implementation Plans 1-90
Table 1-16 Impacts of Electricity Tariff Increase on Bangladesh National Economy (single-year analysis) 1-94
Table 1-17 Scenarios of Electricity Tariff Increase: Case 1 (cost increase) 1-94
Table 1-18 Scenarios of Electricity Tariff Increase: Case 2 (no cost increase) 1-95
Table 1-19 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 1) 1-95
Table 1-20 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 2) 1-95
Table 1-21 Impacts of Gas Price Increase on Bangladesh National Economy 1-96
Table 1-22 Scenarios of Gas Price Increase 1-96
Table 1-23 Impacts of Gas Price Increase on Bangladesh National Economy 1-96
Table 1-24 Example of Scenarios for Electricity Tariff Increase 1-98
Table 1-25 Scenarios of Gas Price Increase 1-98
Table 1-26 Roadmap for PSMP2016 1-100
Table 3-1 Other Countries' Per Capita GDP (current USD) and Energy Consumption Historical Situation 3-2
Table 3-2 Complementarity of PSMP2016 and Existing Policies/plans 3-6
Table 4-1 Greenhouse Gas Emissions in Bangladesh (million t-CO2e, as of 2010) 4-1
Table 4-2 Outline of INDC by GoB and Assumed Actions Related to Power Sectors 4-2
Table 4-3 Projected Emissions Reductions in Power, Transport and Industrial Sectors by 2030 in INDC by GoB 4-3
Table 4-4 Classifications of GHG Emissions Scenarios in IPCC-AR5 4-4
Table 4-5 Articles Related to Long Term GHG Reduction Goal in Paris Agreement 4-5
Table 4-6 Articles Related to Global Stocktake in Paris Agreement 4-5

Table 4-7 Outline of INDCs Submitted by Other Asian Countries 4-7
Table 5-1 Key Ecnomic Indocators during the Past Five-Year Plan Periods 5-1
Table 5-2 Sectorial Share of GDP Since 1995..... 5-2
Table 5-3 Outline of Industrial Development Policy Stipulated in National Economic and Social Development Plan (from 1st to 11th) 5-9
Table 5-4 Challenges for Bangladesh to Achieve Long-term Economic Development 5-11
Table 5-5 Gross Value Added in Large & Medium Scale Manufacturing Sector..... 5-11
Table 5-6 Trends of Exports in Bangladesh 5-13
Table 5-7 Projection of GDP Growth Rate in Bangladesh:Comparison with International Organizations (real GDP) 5-18
Table 5-8 Population Projection Up to 2041 (Medium Variant Scenario)..... 5-20
Table 5-9 Projection of GDP per Capita Up to 2041 (Real Basis at 2005 Price) 5-22
Table 5-10 Projection of GDP per Capita Up to 2041 (Nominal Basis)..... 5-23
Table 5-11 Real GDP Projection (constant at 2005 price)..... 5-24
Table 5-12 Nominal GDP Projection (current price)..... 5-24
Table 5-13 GDP Projection (PPP, constant at 2011 price)..... 5-24
Table 5-14 GDP Projection (PPP, current price) 5-25
Table 5-15 Real GDP Projection (constant at 2005 price) – High-growth Scenario 5-29
Table 5-16 Nominal GDP Projection (current price) – High-growth Scenario 5-29
Table 5-17 Real GDP Projection (constant at 2005 price) – Low-growth Scenario..... 5-29
Table 5-18 Nominal GDP Projection (current price) – Low-growth Scenario..... 5-29
Table 6-1 Household Electrification Rate for Each Administrative District 6-10
Table 6-2 Annual Energy Consumption per Capita in Rural Area (surveyed in 2004) 6-11
Table 6-3 Sectorial Composition of GDP in 2014..... 6-16
Table 6-4 Growth Rate of Manufacturing and Total GDP (real base)..... 6-16
Table 6-5 Sectorial Share of Employment (2010)..... 6-17
Table 6-6 Number of Registered Motor Vehicles in Bangladesh 6-27
Table 6-7 Comparison of Transportation Related Data between Bangladesh and Thailand 6-29
Table 6-8 Measures Taken in Bangkok for Mitigating Traffic Congestion 6-30
Table 6-9 Outline of Eco car Project Conducted in Thailand..... 6-30
Table 6-10 Projection of Total Final Energy Consumption – BAU Scenario..... 6-37
Table 6-11 Sector-wise Energy Efficiency Target 6-40
Table 6-12 Projection of Total Final Energy Consumption – Energy Efficiency Scenario 6-40
Table 6-13 Energy Supply and Demand Balances in 2021 –All Scenarios..... 6-42
Table 6-14 Projection of Total Primary Energy Supply –Scenario 1 6-43
Table 6-15 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 1..... 6-43
Table 6-16 Projection of Total Primary Energy Supply –Scenario 2 6-44
Table 6-17 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 2..... 6-44
Table 6-18 Projection of Total Primary Energy Supply –Scenario 3 6-45
Table 6-19 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 3..... 6-45

Table 6-20 Projection of Total Primary Energy Supply –Scenario 4 6-46
Table 6-21 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 4..... 6-46
Table 6-22 Projection of Total Primary Energy Supply –Scenario 5 6-47
Table 6-23 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 5..... 6-47
Table 7-1 Comparison of Natural Gas Reserves Estimated by HCU and Petrobangla 7-4
Table 7-2 Yet to Find Resources..... 7-6
Table 7-3 Gas Price by Sector 7-13
Table 7-4 Gas Price Component..... 7-14
Table 7-5 Gas Price Component..... 7-14
Table 7-6 Comparison between Actual Average Daily Production and PSMP2010 Forecasts 7-17
Table 7-7 Daily Gas Production Forecast for 2015-2019..... 7-20
Table 7-8 Estimate of Gas Production Profile 2016～2041..... 7-23
Table 7-9 Gas Supply Scenario -New Domestic Gas Field and Gas Import 2016～2041 7-26
Table 7-10 Total Investment Costs for Gas Development..... 7-29
Table 7-11 EIA Categories and Required Clearance and Documents 7-36
Table 7-12 EIA Guidelines for Gas and Coal Sector..... 7-37
Table 7-13 Rates of Gas Component by Gas Fields..... 7-37
Table 7-14 Main Blowouts in Bangladesh 7-38
Table 7-15 Possible Gas Fields and Protected Areas and Protected Mammals..... 7-41
Table 7-16 Possible Gas Fields and Land Use 7-43
Table 8-1 LNG Terminal Development Plans 8-1
Table 8-2 Four Immediate Future LNG Import Projects..... 8-2
Table 8-3 Operation Cost Comparison between FSUR and Land-based LNG Terminal 8-6
Table 8-4 CIF at Asia for LNG from US..... 8-11
Table 8-5 Design Criteria for Terminal Layout and Main Facility..... 8-15
Table 8-6 Main Facility Specifications..... 8-16
Table 8-7 Sector Wise Gas Demand and Supply..... 8-18
Table 8-8 LNG Tanker Size..... 8-18
Table 8-9 Reference Values of Threshold Wave Height for Cargo Handling Works Not Affected by Swell, or Long Period Waves 8-19
Table 8-10 Specification of LNG Harbor for Receiving Q-Flex Class LNG Tanker 8-19
Table 8-11 Calmness Condition in the Channel and Basins..... 8-19
Table 8-12 Candidates of LNG Receiving Terminal LNG and Harbor/jetty Design Conditions..... 8-26
Table 8-13 Case1-1 Jointly Owned Port Plan in Matarbari (Excavated Type Plan)..... 8-27
Table 8-14 Case1-2 Matarbari Plan (Conventional Type Plan：Without Breakwater)..... 8-27
Table 8-15 Case1-3 Matarbari Port Plan (Conventional Type Plan：Breakwater Construction) 8-27
Table 8-16 Case2 North Maheshkhali Plan 8-28
Table 8-17 Case3 Kutubdia Channel Plan..... 8-28
Table 8-18 Candidate Site Evaluation Result..... 8-28
Table 8-19 Storm Surge Height..... 8-29

Table 8-20 Subsurface Data (part.1) 8-30
Table 8-21 CAPEX Estimation 8-37

Table 9-1 Comparison of Forecasted Domestic Coal Production between PSMP2010 and This Investigation 9-1
Table 9-2 Coalfield Development Status in Bangladesh 9-5
Table 9-3 Minable Coal Reserve depending on Mining Method 9-6
Table 9-4 Coal Production and Sales Records at Barapukuria Coal Mine 9-8
Table 9-5 Change of the coal sales price to PDB (Barapucuria power station) 9-8
Table 9-6 Performance and Forecast of Domestic Coal Production 9-11
Table 9-7 Quantity of Import Coal of Asian Countries in Non-OECD without China, India and Others for the Past 5 Years 9-13
Table 9-8 Weight of Coal Price by Calorific Value by ICI, Indonesia 9-15
Table 9-9 Forecast of Coal Price of 1,000kcal/kg to High Grade Coal and Low Grade Coal 9-15
Table 9-10 Total Cost including FOB, Freight, Insurance and Handling Cost from Australia 9-16
Table 9-11 Total Cost including FOB, Freight, Insurance and Handling Cost from Indonesia 9-16
Table 9-12 Prediction of Coal Demand & Supply 9-16
Table 9-13 Data of Quantity of Import Coal by Bangladesh Bureau of Statistics 9-18
Table 9-14 Coal Quality for a Brick Factory 9-19
Table 9-15 EIA Categories and Required Clearance and Documents 9-19
Table 9-16 EIA Guidelines for Gas and Coal Sector 9-20
Table 9-17 Reported Environmental and Social impact by Barapukuria Coal Mine 9-20
Table 9-18 Reported Social Conflict of Barapukuria Coal Mine 9-21
Table 9-19 Main Environmental and Social Impact Described in the EIA Report of 9-22
Table 10-1 Major Components of SPM System 10-4
Table 10-2 Expected Configuration of Refinery 10-5
Table 10-3 Pros and Cons of Constructing a Refinery compared with Product Import 10-7
Table 10-4 Per MJ Price Difference 10-15
Table 11-1 Peal load estimation 2005-2015 11-3
Table 11-2 Real GDP Growth Rate Projection (constant at 2005 price) 11-3
Table 11-3 Nominal GDP Growth Rate Projection (current price) 11-4
Table 11-4 Historical Trend of GDP Elasticity of Power Demand in Bangladesh 11-4
Table 11-5 Actual Energy-GDP Elasticity in ASEAN Countries 11-5
Table 11-6 Peak Demand Projection Using GDP Elasticity Method (base cases) 11-6
Table 11-7 Peak Demand Projection Using GDP Elasticity Method (high cases) 11-7
Table 11-8 Peak Demand Projection Using GDP Elasticity Method (low cases) 11-8
Table 11-9 Peak Demand Projection for Each Scenario Using Sectorial Analysis Method 11-10
Table 11-10 Projection of Available Power Supply from the Grid, Total Electricity Consumption and Consumption from Captive Power Generation 11-12
Table 11-11Existing capacity as of FY2015 [MW] 11-16

Table 11-12 Existing gas-based capacity as of FY2015 [MW] 11-17
Table 11-13Existing coal-based capacity as of FY2015 [MW] 11-18
Table 11-14Existing oil-based capacity as of FY2015 [MW] 11-18
Table 11-15Existing hydropower capacity as of FY2015 [MW] 11-19
Table 11-16 Existing power import capacity as of FY2015 [MW] 11-19
Table 11-17 Comitted generation plan [MW] 11-19
Table 11-18 Comitted plan of gas-fired generation [MW] 11-20
Table 11-19 Comitted plan of coal-fired generation [MW] 11-20
Table 11-20 Comitted plan of oil-fired generation [MW] 11-21
Table 11-21 Comitted plan of hydropower generation [MW] 11-21
Table 11-22 Comitted plan of power import [MW] 11-21
Table 11-23 Comitted plan of nuclear power [MW] 11-21
Table 11-24 Development status of gas-bsed power generation projects 11-23
Table 11-25 Development status of gas-bsed power generation projects 11-24
Table 11-26 Development scenario for LNG terminals 11-26
Table 11-27 New LNG Terminals to be developed in the Matarbari Area 11-27
Table 11-28 Candidate gas-fired power plants (Candidate) 11-31
Table 11-29 Candidate coal-fired power plants (Candidate) 11-32
Table 11-30 Candidate power import plans (Candidate) 11-32
Table 11-31 Candidate nuclear power plants (Candidate) 11-33
Table 11-32 List of power development plan 11-35
Table 11-33 Maximum power demand from 2015 to 2041 (Unit: MW) 11-40
Table 11-34 Ratio of crude oil price 11-43
Table 11-35 Long-term scenarios of the fuel prices 11-43
Table 11-36 Fuel-wise CO2 emission value 11-51
Table 11-37 CO2 emiaaion value by IEA World Enwegy Outlook 2015 11-52
Table 11-38 An Example of Classifying Risks of Energy Security 11-53
Table 11-39 Past Studies on Quantitative Evaluation of Energy Security 11-55
Table 11-40 Past Studies on Energy Security in Bangladesh 11-58
Table 11-41 Assumption of Supplier Countries and Volume of Fossil Fuel Supply 11-60
Table 11-42 Assumption of Export Suspension Risk 11-60
Table 11-43 Results of 3E Evaluation for Each Power Development Scenario 11-61
Table 11-44 3E evaluation of each scenario with renewable energy 11-63
Table 11-45Road map of power development plan 11-66
Table 12-1 SSHP Potential Sites List in the Country (excluding Chittagong Hilly Area) 12-4
Table 12-2 Ordinary HP Potential Sites List in Chittagong Hilly Area 12-5
Table 12-3 Criteria for Finding PSPP Potential Sites 12-9
Table 12-4 River System and Potential Sites 12-14
Table 12-5 Designated Area by Wildlife (Preservation) Act, 1973 12-16
Table 12-6 Designated Area by the Other Acts 12-17

Table 12-7 Key Biodiversity Areas in Bangladesh 12-19
Table 12-8 Number of IUCN Red List Species Recorded in Bangladesh 12-20
Table 12-9 Known Distribution Area of Endangered Mammals and Potential Sites 12-20
Table 12-10 Administrative Jurisdiction of the Potential Sites 12-23
Table 12-11 Village (Union/Mouza) Population of Potential Sites 12-24
Table 12-12 Percentage of Electrification around the Potential Sites 12-25
Table 12-13 Land Use of the Related Sub-district 12-26
Table 12-14 Ethnicity around the Potential Site 12-27
Table 12-15 Religions around the Potential Site 12-28
Table 12-16 Literacy Rate around the Potential Sites 12-29
Table 12-17 Feature of PSPP No.6 12-30
Table 12-18 Feature of PSPP No. 10 12-31
Table 12-19 Feature of PSPP No.12 12-32
Table 12-20 Feature of PSPP No.13 12-33
Table 12-21 Feature of PSPP No.14 12-34
Table 12-22 Feature of PSPP No.15 12-35
Table 12-23 Feature of PSPP No.16 12-36
Table 12-24 Feature of PSPP No.17 12-37
Table 12-25 Feature of PSPP No. 18 12-38
Table 12-26 Summary of Environmental Impact of SSHPs 12-39
Table 12-27 Comparison of PSPP Potential Sites 12-42
Table 12-28 TOR for Feasibility Study on PSPP Project (1) 12-43
Table 12-29 TOR for Feasibility Study on PSPP Project (2) 12-44
Table 13-1 Installed Renewable Energy Capacity (as of April 2016) 13-4
Table 13-2 SREDA Renewable Energy Year-Wise Targeted Plan (Only additions, not cumulative) 13-4
Table 13-3 RE Project Models and Power Purchase Pricing Mechanism Plan 13-5
Table 13-4 Renewable Energy Potential in Bangladesh 13-7
Table 13-5 Roadmap to Microalgae-based Biodiesel Sustainable Production (Reference) 13-19
Table 14-1 Evaluation Criteria for Candidate Area Selection for Hydropower Development 14-4
Table 14-2 Candidate Areas for Hydropower Development to be Connected with the Bangladesh System 14-4
Table 14-3 Screening Results 14-7
Table 14-4 Evaluation Criteria for Hydropower Development Candidate Sites 14-7
Table 14-5 Hydropower Development Potential Candidate Sites in East Bhutan 14-9
Table 14-6 Evaluation Results for Potential Hydropower Sites in East Bhutan 14-9
Table 14-7 Hydropower Development Potential Candidate Sites in Meghalaya 14-11
Table 14-8 Evaluation Results for Potential Hydropower Sites in Meghalaya 14-11
Table 14-9 Power Import Plan (High Case Scenario) 14-14
Table 14-10 Power Import Plan (Low Case Scenario) 14-15
Table 14-11 PSMP2016 Scenario 14-17

Table 15-1 On-going Projects by PGCB as of March 2016 15-5
Table 15-2 Projects Planned by PGCB as of April 2016 15-6
Table 15-3 Maximum Power Demand used for Power System Plan 15-8
Table 15-4 Planned 132kV Substations and Maximum Power Demand (Bogra) 15-9
Table 15-5 Planned 132kV Substations and Maximum Power Demand (Chittagong) 15-10
Table 15-6 Planned 132kV Substations and Maximum Power Demand (Comilla) 15-11
Table 15-7 Planned 132kV Substations and Maximum Power Demand (DESCO/DPDC) 15-12
Table 15-8 Planned 132kV Substations and Maximum Power Demand (Dhaka) 15-13
Table 15-9 Capacities of Generators as Modeled by Systems Analysis Data 15-14
Table 15-10 Power Supply and Demand Balance by Region in 2025 15-15
Table 15-11 Power Supply and Demand Balance by Region in 2035 15-15
Table 15-12 Three Phase Short Circuit Currents of 400kV / 230kV Buses in 2025 (Over 40kA) ... 15-31
Table 15-13 Three Phase Short Circuit Currents of 400kV / 230kV Buses in 2035 (Over 40kA) ... 15-31
Table 15-14 Unit Cost Table 15-37
Table 15-15 230kV transmission lines required from FY2016 to FY2025 15-37
Table 15-16 400kV transmission lines required from FY2016 to FY2025 15-39
Table 15-17 230kV/132kV substations required from FY2016 to FY2025 15-40
Table 15-18 400kV/230kV, 132kV Substations Required from FY2016 to FY2025 15-41
Table 15-19 Capacitors required from FY2016 to FY 2025 15-42
Table 15-20 230kV transmission lines required from FY2026 to FY2035 15-42
Table 15-21 400kV transmission lines required from FY2026 to FY2035 15-43
Table 15-22 765kV transmission lines required from FY2026 to FY2035 15-43
Table 15-23 230kV/132kV substations required from FY2026 to FY2035 15-43
Table 15-24 400kV/230kV, 132kV substations required from FY2026 to FY2035 15-44
Table 15-25 765kV/400kV substations required from FY2026 to FY2035 15-44
Table 15-26 Capacitors required from FY2026 to FY2035 15-44
Table 15-27 Cost estimation summary 15-45
Table 15-28 Electrification Rate Calculation Detail by Power Division 15-46
Table 15-29 Annual Status of Power Sector (2005-2014) 15-47
Table 15-30 Rural Electrification Plan up to 2041 15-50
Table 15-31 Power Utility Plan by Year 15-51
Table 16-1 Target Frequency Deviation Values of Japan, North America, and Europe 16-7
Table 16-2 Examples of Adverse Influence of Power Frequency Fluctuation on Industries 16-8
Table 16-3 Example of Operational Restrictions of Synchronous Generators 16-8
Table 16-4 Rough Comparison of the Electricity Act between Japan and Bangladesh 16-14
Table 16-5 Comparison between the Terms of Electricity Business Act 16-15
Table 16-6 Outline of Grid Codes concerning Supply-demand Operation and Frequency Control. 16-17
Table 16-7 Grid Code concerning the Demand Forecast/Demand Estimation 16-21
Table 16-8 Submission of Outage Plans to General Utilities (Japan) 16-25
Table 16-9 Submission of Supply-demand Plans by Each Utility (Japan) 16-25

Table 16-10 Submission of Generation Schedule by Each Supplier (Japan) 16-25
Table 16-11 Integration of Supply-demand Plans (Japan)..... 16-25
Table 16-12 Generation Scheduling by Licensee (Bangladesh)..... 16-25
Table 16-13 Details of Information Publication Rules in OCCTO Grid Code..... 16-26
Table 16-14 The List of Existing Units Which are Expected to Perform..... 16-29
Table 16-15 The List of Existing Units Which Obey Instructions of Output Adjustment 16-30
Table 16-16 Available Primary Reserve List..... 16-31
Table 16-17 List of Primary Reserve by FGMO Only 16-32
Table 16-18 Outline of Frequency Control Test in Khulna Power Station..... 16-36
Table 16-19 Supply Tripping Amount and Factors That Should Be Considered in Each Year 16-39
Table 16-20 Functions of SCADA/EMS and Current Status of Usage 16-44
Table 17-1 Conditions 17-6
Table 17-2 Safety Rules Related Electricity Business Act 17-12
Table 17-3 Electricity Act 1910..... 17-19
Table 17-4 Comparison between Bangladesh and Japan..... 17-25
Table 18-1 Rauzan Thermal Power Station..... 18-8
Table 18-2 Ashuganj Thermal Power Station..... 18-10
Table 18-3 Siddhirganj Thermal Power Station 18-12
Table 18-4 Barapukuria Thermal Power Station 18-14
Table 18-5 Chandpur Thermal Power Station 18-16
Table 18-6 Ghorasal Thermal Power Station 18-18
Table 18-7 Baghabari Thermal Power Station 18-20
Table 18-8 Shahjibazar Thermal Power Station..... 18-22
Table 18-9 Fenchuganj Thermal Power Station 18-24
Table 18-10 Sylhet Thermal Power Station..... 18-26
Table 18-11 Summary of BPDB Thermal Power Stations 18-27
Table 18-12 Summary 18-30
Table 18-13 Summary 18-32
Table 18-14 Problems in Organizational Resources..... 18-34
Table 18-15 Solution Proposals..... 18-35
Table 18-16 Conventional Information Management Practices and Risk Factors 18-47
Table 18-17 Obstructive Factors Found in the Survey 18-51
Table 18-18 Key Problems in the Three Key Activity Areas 18-52
Table 18-19 Examples of Performance Indicators and Data Sources..... 18-56
Table 18-20 Items Expected to be Addressed in Further Survey 18-63
Table 18-21 Implementation Options and Process Modification Options..... 18-64
Table 19-1 Major Tariff Policies..... 19-1
Table 19-2 Tariff Policies 19-2
Table 19-3 Electricity Retail Tariff Structures in Bangladesh (as of 2015)..... 19-3
Table 19-4 Tariff Policies 19-4

Table 19-5 Recent Major Financing Projects by Development Partners in the Bangladeshi Power Sector 19-7
Table 19-6 Loan Conditions of WB, ADB and JICA Loans 19-9
Table 19-7 Loan Conditions of Government of Bangladesh (Case of loan to BPDB) 19-9
Table 19-8 Loan Conditions of Commercial Banks 19-10
Table 19-9 Generation Cost, Supply Cost, and Bulk Supply Tariff 19-12
Table 19-10 Balances of the Entire BPDB (million BDT) 19-14
Table 19-11 Overall Balances of BPDB (Distribution) 19-15
Table 19-12 Budgetary Support from the Government to BPDB (billion BDT) 19-17
Table 19-13 Overview: Balances of WZPDCL 19-20
Table 19-14 Overview: Balances of DESCO 19-21
Table 19-15 Overview: Balances of DPDC 19-23
Table 19-16 Overview: Balances of REB 19-24
Table 20-1 BERC's Missions 20-1
Table 20-2 Natural Gas Tariff Rates Since1969 20-3
Table 20-3 Comparison of Gas Tariff Rates in Bangladesh with other Asian countries 20-4
Table 20-4 Breakdown of Taxes and Duties Paid by Petrobangla 20-7
Table 20-5 Subsidies for Imported Diesel Oil and Furnace Oil 20-8
Table 21-1 Impacts of Electricity Tariff Increase on Bangladesh National Economy 21-3
Table 21-2 Impacts of Electricity Tariff Increase on Each Sector production and consumption 21-3
Table 21-3 Impacts of Electricity Tariff Increase on Each Sector export and import 21-3
Table 21-4 Scenarios of Electricity Tariff Increase: Case 1 (cost increase) 21-4
Table 21-5 Scenarios of Electricity Tariff Increase: Case 2 (no cost increase) 21-4
Table 21-6 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 1) 21-6
Table 21-7 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 2) 21-7
Table 21-8 Impacts of Gas Price Increase on Bangladesh National Economy (single year analysis) 21-9
Table 21-9 Impacts of Gas Price Increase on Each Sector 21-9
Table 21-10 Impacts of Gas Price Increase on Each Sector 21-9
Table 21-11 Scenarios of Gas Price Increase 21-10
Table 21-12 Impacts of Gas Price Increase on Bangladesh National Economy 21-11
Table 21-13 GDP per Capita and Electricity Tariff 21-15
Table 21-14 Proposed Scenario of Electricity Tariff Increase 21-16
Table 22-1 Items Required in Feasibility Assessment 22-18
Table 22-2 Areas of research by type of energy 22-21
Table 22-3Areas of assistance in research in the electric power infrastructure sector 22-21

List of Figures

Page

Figure 1-1 Overall Workflow for This Study 1-9
Figure 1-2 Steering Committee and Working Groups 1-15
Figure 1-3 PSMP2010 Review (Economic Development) 1-21
Figure 1-4 PSMP2010 Review (Coal Supply) 1-22
Figure 1-5 PSMP2010 Review (Gas Supply) 1-23
Figure 1-6 PSMP2010 Review (Power Development Plan) 1-24
Figure 1-7 Value Added by Large and Middle Scale Manufacturing Industries 1-26
Figure 1-8 Illustration of Industrial Development in Bangladesh Toward 2041 1-26
Figure 1-9 Stages of Industrial Development and Necessary Policy Measures to Support This 1-27
Figure 1-10 Projection of Final energy Consumption (BAU Scenario) 1-27
Figure 1-11 Projection of Final Energy Consumption (Energy Efficiency Scenario) 1-28
Figure 1-12 Projection of Primary Energy Supply – Scenario 3 1-29
Figure 1-13 Gas Resource Balance 1-30
Figure 1-14 Gas Supply Forecast 2016~2041 1-33
Figure 1-15 Forecast of Coal Demand and Supply 1-35
Figure 1-16 Oil Demand and Supply Balance, 2014 to 2041 1-38
Figure 1-17 Power Development Planning Flow 1-40
Figure 1-18 Estimated Composite Daily Load Curve in the Summer in Bangladesh 1-41
Figure 1-19 Comparision of peak power demand in both models 1-42
Figure 1-20 Relationship between the Time Scale and the Change in PDP 1-43
Figure 1-21 Annual Trend of Each Power Plants（MW） 1-45
Figure 1-22 Transition of estimated power demand during 2015-2041 (Unit: MW) 1-45
Figure 1-23 Reserve Margin 1-46
Figure 1-24 IEACrude Oil Scenario 1-47
Figure 1-25 Simulation schem of the supply/demand operation 1-48
Figure 1-26 Generation pattern in 2041 1-49
Figure 1-27 Image for demand and supply simulation 1-49
Figure 1-28 Annual Trend of Energy Mix in Different Scenarios 1-50
Figure 1-29 Power generation cost under each scenario and Ratio of coal （US cent/kWh） 1-50
Figure 1-30 Scenario-Wise CO2 Emissions（CO2 kg-C/kWh） 1-51
Figure 1-31 Physical Energy Delivery Routes and Risks 1-52
Figure 1-32 An Example of Probability Density of Energy Delivery 1-52
Figure 1-33 3E Evaluation Results (Each Value) Figure 1-34 3E Evaluation Results (Total) .. 1-53
Figure 1-35 3E Evaluation Results (Each Value) 1-54
Figure 1-36 3E Evaluation Results (Total) 1-54
Figure 1-37 3E Evaluation Results (Total) 1-55
Figure 1-38 Best mix including expansion of renewable enegy 1-56

Figure 1-39 Location Map of Potential PSPP Sites 1-58
Figure 1-40 Location Map of Potential Sites for Ordinary and Small Scale Hydropower 1-59
Figure 1-41 Future Power Import Volume and its Share (High Case Scenario) 1-64
Figure 1-42 Future Power Import Volume and its Share (Low Case Scenario) 1-65
Figure 1-43 Nuclear Power Development on PSMP2016 1-66
Figure 1-44 Structure of IAEA Safety Standards 1-67
Figure 1-45 Nuclear Industry Information Center 1-69
Figure 1-46 Asian Nuclear Safety Network (ANSN) 1-70
Figure 1-47 Roadmap for nuclear power development 1-71
Figure 1-48 The Existing Bulk Power Network System of Bangladesh (2014) 1-72
Figure 1-49 Development of Access to Electricity (BPDB definition) 1-74
Figure 1-50 BREB On-grid Extension Plan Comparison 1-75
Figure 1-51 Number of SHS under IDCOL Program 1-75
Figure 1-52 Conceptual Map of Locations of Large Scale Power Stations Planned Up to 2035 1-76
Figure 1-53 Comparison between the Necessary Reserves and the Available Reserves 1-80
Figure 1-54 Trend of Power Frequency Quality Improvement 1-81
Figure 1-55 Schematic Diagram of the Frequency Deviation Immediately 1-82
Figure 1-56 Trend of minimum values of frequency immediately 1-82
Figure 1-57 Schedule for Legal Reform 1-86
Figure 1-58 Site Selection 1-87
Figure 1-59 Target Site List 1-88
Figure 1-60 O&M Efficiency Improvement Supported by Information Management 1-91
Figure 1-61 Demand/Supply and Shutdown Planning 1-91
Figure 1-62 Thermal Power Plant O&M Roadmap 1-92
Figure 2-1 Bangladesh Energy Sector Overview 2-2
Figure 2-2 Overview of Bangladesh Power Sector 2-5
Figure 2-3 Distribution Companies and Areas 2-9
Figure 2-4 PBS 2-9
Figure 2-5 Process Flow for Renewable Energy Project 2-10
Figure 4-1 Greenhouse Gas Emissions in Bangladesh (as of 2010) 4-1
Figure 4-2 Historical Trend of Breakdown of Total GHG Emissions by Gas 4-2
Figure 4-3 Projection of GHG Emissions in Power, Transport and Industrial Sectors from 4-3
Figure 4-4 Allowance of CO2 Emission in 2050 for Each Mitigation Scenario (IPCC-AR5) 4-4
Figure 4-5 Schedules of INDCs and Global Stocktake Determined in Paris Agreement 4-6
Figure 4-6 Difference between 2 Degree Scenario and INDCs 4-6
Figure 5-1 Sectorial Share of GDP Since 1995 5-2
Figure 5-2 Trend of GDP per Capita (current USD) in Southeast Asian Countries and Bangladesh 5-3
Figure 5-3 Trend of GDP per Capita (constant 2005 USD) in Southeast Asian Countries and Bangladesh 5-4
Figure 5-4 Historical Trend of GDP Growth Rate in Southeast Asian Countries and Bangladesh 5-4

Figure 5-5 Trend of Energy Use per Capita in Southeast Asian Countries 5-5
Figure 5-6 Trend of GDP per Unit of Energy Use in Southeast Asian Countries 5-5
Figure 5-7 Historical Trend of GDP Growth Rate of Thailand 5-6
Figure 5-8 Historical Trend GDP, Import and Export of Thailand 5-7
Figure 5-9 Historical Trend of Sectorial Share in Merchandise Export 5-8
Figure 5-10 Historical Trend of Sectorial Share in Merchandise Export in GDP 5-8
Figure 5-11 Share of Agriculture in Total Employment 5-9
Figure 5-12 Gross Value Added in Large & Medium Scale Manufacturing Sector 5-12
Figure 5-13 Composition of the Share of Each Products (2014-2015) 5-13
Figure 5-14 Future Image of Industrial Development in Bangladesh Towards 2041 5-14
Figure 5-15 Image of Industrial Structure in Early-2020s 5-15
Figure 5-16 Image of Industrial Structure in 2041 5-15
Figure 5-17 Stages of Industrialization and Necessary Policy Measures 5-16
Figure 5-18 Projection of GDP Growth Rate in the Seventh Five-Year Plan 5-17
Figure 5-19 Comparison between the Government's Projection and Actual Performance during the Period of Sixth Five-Year Plan 5-17
Figure 5-20 GDP Projection Up to 2041 5-19
Figure 5-21 Population Projection Up to 2041 5-19
Figure 5-22 Historical Trend of GDP per Capita (real GDP) of Bangladesh and ASEAN Countries 5-20
Figure 5-23 Industrial Sector's Share in GDP and GDP per Capita (real GDP) of Bangladesh and ASEAN Countries (1960-2014) 5-21
Figure 5-24 Historical Trend of GDP per Capita of Bangladesh and Thailand 5-22
Figure 5-25 Historical Trend and Projection of GDP per Capita (Nominal Base) 5-23
Figure 5-26 Share of Agriculture in GDP: Bangladesh (red) and Thailand (blue) 5-25
Figure 5-27 Share of Agriculture in GDP: Bangladesh (red) and Thailand (blue) 5-26
Figure 5-28 Share of Industrial Sector in GDP: Bangladesh (red) and Thailand (blue) 5-26
Figure 5-29 Share of Industrial Sector in GDP: Bangladesh (red) and Thailand (blue) 5-27
Figure 5-30 Share of Commercial & Public Services in GDP: Bangladesh and Thailand 5-27
Figure 5-31 Sectorial Breakdown of GDP Projection (Real GDP, constant at 2005 price) 5-28
Figure 6-1 Historical Trend of Total Primary Energy Supply in Bangladesh (1990-2013) 6-1
Figure 6-2 Historical Trend of Total Final Energy Consumption in Bangladesh (1990-2013) 6-2
Figure 6-3 Historical Trend of Natural Gas Supply and Demand (1990-2013) 6-2
Figure 6-4 Historical Trend of Coal Supply and Demand (1990-2013) 6-3
Figure 6-5 Historical Trend of Oil (Crude Oil & Oil Products) Supply and Demand (1990-2013) 6-4
Figure 6-6 Total Final Energy Consumption Broken Down by Modes of Supply (1990-2013) 6-4
Figure 6-7 Historical Trend of Residential Sector Energy Consumption (1990-2013) 6-5
Figure 6-8 Historical Trend of Commercial/Public Services Sector Consumption (1990-2013) 6-5
Figure 6-9 Historical Trend of Industrial Sector Energy Consumption (1990-2013) 6-6
Figure 6-10 Historical Trend of Transport Sector Energy Consumption (1990-2013) 6-6
Figure 6-11 Historical Trend of Other Sectors (e.g. Agriculture) Energy Consumption (1990-2013) 6-7

Figure 6-12 Historical Trend of Electricity Consumption in Bangladesh (1990-2013) 6-7
Figure 6-13 Trend of Residential Sector Energy Consumption (excluding Biofuels and waste) 6-8
Figure 6-14 Historical Trend of Residential Sector Electricity Consumption per Capita 6-9
Figure 6-15 Household Electrification Rate (2001 and 2011) 6-9
Figure 6-16 Status of Access to Gas Supply in Urban and Rural Areas 6-10
Figure 6-17 Final Energy Consumption per GDP in Commercial Sector 6-11
Figure 6-18 Energy Consumption and GDP in Residential Sector 6-12
Figure 6-19 Electricity Consumption and GDP in Residential Sector 6-13
Figure 6-20 Energy Demand Projection in Residential Sector 6-14
Figure 6-21 Energy Consumption Pattern of Urban and Rural Households 6-14
Figure 6-22 Energy Demand Projection in Commercial & Public Services Sector 6-15
Figure 6-23 Sectorial Composition of GDP in 2014 6-16
Figure 6-24 Sectorial Share of Employment (2010) 6-17
Figure 6-25 Industrial Sector's Energy Consumption per Sectorial Value Added 6-21
Figure 6-26 Projection of Industrial Sector's Energy Consumption per Sectorial Value Added 6-22
Figure 6-27 Projection of Industrial Sector's Energy Consumption 6-22
Figure 6-28 Historical Trend of Transport Sector's Energy Consumption in Bangladesh 6-23
Figure 6-29 Share of Road Transport in Transport Sector's Energy Consumption 6-24
Figure 6-30 Value Added of Transport Sector with Modal Breakdown 6-24
Figure 6-31 Number of Vehicles Owned in Bangladesh 6-25
Figure 6-32 Motorization Rate of Bangladesh and ASEAN Countries 6-25
Figure 6-33 Historical Trend of GDP per Capita (PPP) and Motorization Rate 6-26
Figure 6-34 Historical Trend of GDP per Capita (PPP) and Transport Sector's Energy Consumption per Capita in Bangladesh and ASEAN Countries 6-31
Figure 6-35 Projection of Transport Sector's Energy Consumption per Capita 6-32
Figure 6-36 Projection of Transport Sector's Energy Consumption 6-32
Figure 6-37 Historical Trend of Agricultural Production (Turnover) in Bangladesh 6-33
Figure 6-38 Historical Trend of Agricultural Products Export in Bangladesh 6-34
Figure 6-39 Agricultural Sector's Energy Consumption per Sectorial Value Added 6-35
Figure 6-40 Agricultural Sector's Energy Consumption per Sectorial Value Added 6-35
Figure 6-41 Projection of Agricultural Sector's Energy Consumption per Sectorial Value Added 6-36
Figure 6-42 Projection of Agricultural Sector's Energy Consumption 6-36
Figure 6-43 Projection of Total Final Energy Consumption – BAU Scenario 6-37
Figure 6-44 Historical Trend and Projection of Energy Intensity – BAU Scenario 6-38
Figure 6-45 Historical Trend and Projection of Energy Intensity - Energy Efficiency Scenario 6-39
Figure 6-46 Projection of Total Final Energy Consumption – Energy Efficiency Scenario 6-40
Figure 6-47 Projection of Electricity Consumption – Energy Efficiency Scenario 6-41
Figure 6-48 Projection of Total Primary Energy Supply –Scenario 1 6-43
Figure 6-49 Projection of Total Primary Energy Supply –Scenario 2 6-44
Figure 6-50 Projection of Total Primary Energy Supply –Scenario 3 6-45

Figure 6-51 Projection of Total Primary Energy Supply –Scenario 4 6-46
Figure 6-52 Projection of Total Primary Energy Supply –Scenario 5 6-47
Figure 7-1 Gas Field Location Map 7-1
Figure 7-2 Yet to Find Resources 7-5
Figure 7-3 Gas Resource Balance 7-6
Figure 7-4 GIIP, 2P Gas Reserves 2P and Remaining 2P Gas Reserves 7-7
Figure 7-5 Gas Production in Dec 2014- by Company 7-9
Figure 7-6 Condensate and NGL Production in Dec 2014- by Company 7-9
Figure 7-7 Gas Transmission by GTCL- by Customer 2014 FY 7-10
Figure 7-8 GTCL Gas Transmission System 7-11
Figure 7-9 Gas Sale by Gas Distribution Companies in 2014FY 7-13
Figure 7-10 Gas Consumption by Sector in FY2014 7-15
Figure 7-11 Gas Price Comparison 7-16
Figure 7-12 Formula for Estimating Gas Production Profile 7-21
Figure 7-13 Gas Production Profile of Each Producing Gas Field 7-24
Figure 7-14 Gas Supply Scenarios 2016-2041 7-27
Figure 7-15 Comnparison between Gas Supply Scenarios and Gas Demand Projection 7-28
Figure 7-16 Overview of Condensate Marketing 7-30
Figure 7-17 Offshore Concession Blocks 7-32
Figure 7-18 Comparison of Urea Efficiency 7-35
Figure 7-19 Methane Gas Concentration by Human Activities in Asia 7-39
Figure 7-20 Protected Areas and Possible Gas Fields 7-40
Figure 7-21 Habitat of Protected Mammals and Possible Gas Fields 7-40
Figure 7-22 Land Use and Possible Gas Fields 7-42
Figure 8-1 Overview of LNG Receiving Terminal Owned by Osaka Gas 8-1
Figure 8-2 FSUR Image 8-2
Figure 8-3 Structure of On-shore LNG Terminal and IPPs 8-3
Figure 8-4 Transport Cost (USD/MMTBU)by Tanker Size 8-6
Figure 8-5 Operation Cost Comparison (USD/MMBTU) between FSRU and Land LNG Terminal 8-7
Figure 8-6 Time Schedule for FSRU Construction 8-8
Figure 8-7 Time Schedule for Land-based LNG Terminal Construction 8-8
Figure 8-8 Cyclone Outbreak in Bay of Bengal 8-9
Figure 8-9 Asia Premium April 2012-Mar 2013 8-10
Figure 8-10 Fluidization of LNG Market 8-11
Figure 8-11 Cross-border LNG Schematic Diagram 8-13
Figure 8-12 Flow Diagram of LNG Receiving Terminal 8-14
Figure 8-13 Typical Plot Plan of LNG Receiving Terminal (50ha, 10MTPA) 8-17
Figure 8-14 Chart of Candidate Site 8-20
Figure 8-15 Deep Water Waves Data 8-21
Figure 8-16 Occurrence of Wind Speed 8-23

Figure 8-17 Occurrence of Wind Direction 8-25
Figure 8-18 Candidate Sites of Land-based LNG Receiving Terminal 8-26
Figure 8-19 Drilling Log 8-31
Figure 8-20 Subsurface Data (Part2, 3) 8-32
Figure 8-21 Worldwide Hypocenter Distribution (for Magnitude 6 and Higher Earthquakes) and Plate Boundaries 8-33
Figure 8-22 Structure of Earthquake- resistant LNG Storage Tank 8-34
Figure 8-23 Overview of Above Ground Dome Roof Type PC LNG Storage Tank 8-35
Figure 8-24 Tsunami Hazard Map in the Indian Ocean and Bay of Bengal 8-36
Figure 9-1 Comparison with PS2010 9-2
Figure 9-2 Locations of Coal Fields in Bangladesh 9-4
Figure 9-3 Expansion Plan of Barapukuria 9-9
Figure 9-4 Expansion Plan of South Area (at left) and North Area (at right) 9-9
Figure 9-5 Forecast of Coal Demand in the World 9-12
Figure 9-6 Forecast of Coal Demand in Non-OECD Countries in Asia 9-13
Figure 9-7 Quantity of Import Coal of Southeast Asian Countries in Non-OECD without China, ... 9-13
Figure 9-8 Coal Price of 1,000kcal/kg Movement at Newcastle Port in Australia 9-15
Figure 9-9 Forecast of Coal Price of 1,000kcal/kg 9-15
Figure 9-10 Coal Supply 9-17
Figure 9-11 Possible Coal Mines and Protected Areas 9-23
Figure 9-12 Possible Coal Mines and Land Use 9-23
Figure 10-1 Oil Demand by Products (2012-2013) 10-1
Figure 10-2 Bangladesh's Historical Oil Demand by Sector 10-2
Figure 10-3 Oil Demand Projection (Power and Non-Power) 10-2
Figure 10-4 Oil Demand Projection for Non-Power Sectors, 2014 to 2041 10-3
Figure 10-5 Total Oil Demand & Supply Projection from 2014 to 2041 10-6
Figure 10-6 Crude Oil and Oil Products Trade 10-8
Figure 10-7 Refinery Throughput Trend 10-9
Figure 10-8 Refining Margin 10-9
Figure 10-9 Refinery Payout 10-10
Figure 10-10 LPG Status in Bangladesh 10-11
Figure 10-11 LPG Demand Projection (Household + Transport) from 2014 to 2041 10-14
Figure 11-1 Power demand forecasting flow 11-1
Figure 11-2 Estimated Composite Daily Load Curve in the summer in Bangladesh 11-2
Figure 11-3 Peak Demand Projection Using GDP Elasticity Method (case comparision) 11-9
Figure 11-4 Peak Demand Projection for Each Scenario Using Sectorial Analysis Method 11-10
Figure 11-5 Comparison of Peak Demand Projection Results 11-11
Figure 11-6 Projection of Total Electricity Consumption 11-12
Figure 11-7 Power Development Planning flow 11-13
Figure 11-8 Relationship between the Time Scale and the Change 11-14

Figure 11-9 Review of the power development plan..... 11-15
Figure 11-10 Review of the coal and gas supply..... 11-16
Figure 11-11 Esisting capacity considering retirement plan 11-19
Figure 11-12 Port infrastructure plan (2031/41) by JICA Southern Chittagong Master Plan 11-25
Figure 11-13 Allocaion of natural gas 11-25
Figure 11-14 Gas Supply Scheme 11-27
Figure 11-15 Scenario to Develop Imported Gas in Each Region 11-28
Figure 11-16 Scenario to Develop Imported Gas in Each Region (Unit: mmctd) 11-28
Figure 11-17 Estimated Coal Demands for Power Supply (k tons) 11-30
Figure 11-18 Prospective imported coal amounts by 2041 (Unit: kTon) 11-30
Figure 11-19 2015～2041 Power development plan（MW） 11-34
Figure 11-20 Daily load curve in Bangladesh (Performance record for 2015..... 11-38
Figure 11-21 Estimated daily load curve for 2015-2041 period in Bangladesh..... 11-39
Figure 11-22 Maximum power demand from 2015 to 2041 (Unit: MW) 11-40
Figure 11-23 Transition of power demand in 2015-2041 in Bangladesh (Unit: MW)..... 11-40
Figure 11-24 Reserve Margin..... 11-42
Figure 11-25 IEACrude Oil Scenario..... 11-43
Figure 11-26 Fuel-wise composition of power development plan 11-45
Figure 11-27 Methodology for demand and supply simulation 11-45
Figure 11-28 Fuel-wise composition of power development plan（MW） 11-46
Figure 11-29 simulation of the supply/demand operation..... 11-47
Figure 11-30 Power development plan(MW)..... 11-48
Figure 11-31 Total power generation (GWh) 11-48
Figure 11-32 Transition of daily load curve 11-49
Figure 11-33 Scenario-wise gas and coal consumption (Unit / kTon of oil equivalent) 11-49
Figure 11-34 Power generation cost under each scenario and Ratio of coal..... 11-50
Figure 11-35 Scenario-wise CO2 Emissions..... 11-51
Figure 11-36 Diagram of Indices that Form ACC's "Index of US Energy Security Risk" 11-56
Figure 11-37 METI's Evaluation on the Status of Energy Security in Japan..... 11-56
Figure 11-38 IEA's Schematic Diagram for Analyzing the Energy Security of Crude Oil 11-57
Figure 11-39 Current energy suppliers to Bangladesh in 2013 11-58
Figure 11-40 Physical Energy Delivery Routes and Risks..... 11-59
Figure 11-41 An Example of Probability Density of Energy Delivery 11-59
Figure 11-42 3E value (each value)..... 11-61
Figure 11-43 3E value (total value)..... 11-61
Figure 11-44 Simulation pattern..... 11-62
Figure 11-45 Power Source Composition in FY 2041 (as shown above)..... 11-62
Figure 11-46 Renewable energy typical generation cost..... 11-63
Figure 11-47 3E value (each value)..... 11-64
Figure 11-48 3E value (total value)..... 11-64

Figure 11-49 3E value (total value) 11-64
Figure 11-50 Operation pattern in case of renewable energy installation 11-66
Figure 11-51 Best mix including expansion of renewable enegy 11-67
Figure 11-52 PSMP2010 Review (Demand and Power development plan) 11-70
Figure 11-53 Organaization of IPP 11-71
Figure 12-1 Flowchart of Hydropower Potential Study 12-2
Figure 12-2 Karnafuli Hydro Station Reservoir Operation Rule Curve and its Records 12-3
Figure 12-3 Location Map of SSHP Potential Sites in the Country 12-5
Figure 12-4 Location Map of Ordinary HP Potential Sites in Chittagong Hilly Area 12-6
Figure 12-5 PSPP Potential Sites 12-10
Figure 12-6 Ordinary HP Potential Sites in Chittagong Hilly Area 12-10
Figure 12-7 Geological Map of Chittagong Hilly Area 12-11
Figure 12-8 Temperature and Rainfall in Chittagong (average from 1971 to 2000) 12-12
Figure 12-9 Annual Sum Rainfall around the Survey Area 12-12
Figure 12-10 Main Rivers on Chittagong Hill Tracts 12-13
Figure 12-11 Flood Affected Area in August 2007 12-14
Figure 12-12 Saline Affected Area 12-15
Figure 12-13 Domestic Protected Areas around the Hydropower Potential Sites 12-18
Figure 12-14 KBA around Hydropower Potential Sites 12-19
Figure 12-15 Known Distribution Area of Indian Hog Deer and Asian Elephant 12-21
Figure 12-16 Vegetation around the Hydropower Potential Sites by GlobCover (2009) 12-22
Figure 12-17 Administrative Boundaries around the Hydropower Potential Sites 12-23
Figure 12-18 Population by Divisions around the Hydropower Potential Sites 12-24
Figure 12-19 Main Roads around the Hydropower Potential Sites 12-25
Figure 12-20 Land Use around the Potential Sites 12-26
Figure 12-21 Ethnicity around the Potential Sites 12-27
Figure 12-22 Religions around the Potential Sites 12-28
Figure 12-23 Poverty Gap Index around the Hydropower Potential Sites 12-29
Figure 12-24 PSPP No.6 12-30
Figure 12-25 PSPP No.10 12-31
Figure 12-26 PSPP No.12 12-32
Figure 12-27 PSPP No.13 12-33
Figure 12-28 PSPP No.14 12-34
Figure 12-29 PSPP No.15 12-35
Figure 12-30 PSPP No.16 12-36
Figure 12-31 PSPP No.17 12-37
Figure 12-32 PSPP No.18 12-38
Figure 13-1 Evolution of Energy Technology Costs per Unit in the New Policies Scenario, 2014-2040 13-1
Figure 13-2 India’s TPED Breakdown, 2013 (actual) and 2040 (projection) 13-2

Figure 13-3 India's Power Generation Development (GW) 13-3
Figure 13-4 Share of Renewable Energy Projection 13-5
Figure 13-5 Wind Power Density 13-8
Figure 13-6 Wind Speed 13-8
Figure 13-7 Biomass Energy Potential in Bangladesh and IDCOL's Program and Projects 13-9
Figure 13-8 Biofuel Sources and Implication to Bangladesh 13-16
Figure 13-9 Gap among Project Pipeline, Target and Potential) 13-17
Figure 13-10 Solar PV Gap among Project Pipeline, Target and Potential 13-18
Figure 13-11 Microalgae Biofuel Cultivation Image 13-20
Figure 13-12 Peak of Solar Supply and Electricity Consumption 13-21
Figure 14-1 Electric Power Supply and Demand Situation(2014) 14-1
Figure 14-2 Electric Power Supply and Demand Situation (2030) 14-2
Figure 14-3 Grand Design of Bangladesh – India Interconnection Line 14-3
Figure 14-4 Connection Illustration of Hydropower Development Areas with Bangladesh 14-5
Figure 14-5 Outline of Kuri I Project 14-10
Figure 14-6 Three Candidate Sites for PSPP in Meghalaya 14-12
Figure 14-7 Future Power Import Volume and its Share (High Case Scenario) 14-14
Figure 14-8 Future Power Import Volume and its Share (Low Case Scenario) 14-15
Figure 14-9 Power Import Situation 14-16
Figure 14-10 PSMP2016 Scenario 14-17
Figure 14-11 Nuclear Power Development on PSMP2016 14-19
Figure 14-12 Nuclear Energy Program and Implementation Organization (NEPIO) 14-21
Figure 14-13 Location of RNPP 14-22
Figure 14-14 Structure of IAEA Safety Standards 14-23
Figure 14-15 Nuclear Industry Information Center 14-25
Figure 14-16 Asian Nuclear Safety Network (ANSN) 14-26
Figure 14-17 Roadmap for nuclear power development 14-27
Figure 15-1 Plan for Power Transmission System by PGCB 15-4
Figure 15-2 Power Supply and Demand Balance by Region 15-16
Figure 15-3 Map of Bangladesh System with Expected Power Flow in 2025 (Nation-wide) 15-18
Figure 15-4 400kV System Diagram for Bangladesh with Expected Power Flow in 2025 15-19
Figure 15-5 Map of Bangladesh System with Expected Power Flow in 2035 (Dhaka Area) 15-20
Figure 15-6 400kV System Diagram for Chittagong with Expected Power Flow in 2025 15-21
Figure 15-7 400kV System Diagram for Khulna with Expected Power Flow in 2025 15-22
Figure 15-8 Map of Bangladesh System with Expected Power Flow in 2035 (Nation-wide) 15-24
Figure 15-9 400kV System Diagram for Bangladesh with Expected Power Flow in 2035 15-25
Figure 15-10 Map of Bangladesh System with Expected Power Flow in 2035 (Dhaka Area) 15-26
Figure 15-11 400kV System Diagram for Chittagong with Expected Power Flow in 2035 15-27
Figure 15-12 400kV System Diagram for Khulna with Expected Power Flow in 2035 15-28

Figure 15-13 Power Angle Oscillation of a Rooppur Nuclear Power Generator in Case of Double Circuit Fault at 400kV Transmission Lines of Rooppur-Kaliakoir and Rooppur-Aminbazar (2025) 15-33
Figure 15-14 Power Angle Oscillation of a Rooppur Nuclear Power Generator in Case of Double Circuit Fault at 400kV Transmission Lines of Rooppur-Kaliakoir and Rooppur-Aminbazar (2035) 15-33
Figure 15-15 Power Angle Oscillation of a Pyra Thermal Power Generator in Case of Single Circuit Fault at 400kV Transmission Line of Gopalganj-Aminbazar (2025) 15-34
Figure 15-16 Power Angle Oscillation of a Pyra Thermal Power Generator in Case of Single Circuit Fault at 765kV Transmission Line of Pyra-Aminbazar (2035) 15-34
Figure 15-17 Power Angle Oscillation of a Matabari Thermal Power Generator in Case of Single Circuit Fault at 400kV Transmission Line of Matabari-Madunaghat (2025) 15-35
Figure 15-18 Power Angle Oscillation of Mohesikali Thermal Power Generator in Case of Single Circuit Fault at 765kV Transmission Line of Mohesikali-Bhulta (2035) 15-35
Figure 15-19 Development of Access to Electricity (BPDB definition) 15-47
Figure 15-20 BREB's Distribution Line Extension Progress 15-49
Figure 15-21 BREB On-grid Extension Plan Comparison 15-50
Figure 15-22 Number of SHS under IDCOL Program 15-52
Figure 15-23 Status of SHS Installation 15-52
Figure 15-24 Projection of Access to Electricity (On-grid + Off-grid SHS) 15-53
Figure 15-25 Line Extension and Sales Growth 15-54
Figure 15-26 Relation between Line Extension and Sales Grows 15-54
Figure 15-27 Relation between Non Electrified Energy and Demand 15-55
Figure 15-28 Estimation of Progress of Grid Connection 15-56
Figure 16-1 Flow Diagram of Day-ahead Demand/supply Planning Process 16-2
Figure 16-2 Example of Typical Daily Load Curve and Allocation of Power Sources in Japan 16-3
Figure 16-3 Conceptual Diagram of Role Sharing for Each Control Method 16-3
Figure 16-4 Monthly Trend of Peak Load Power Sources in Bangladesh 16-4
Figure 16-5 Situation of Supply/Demand Balance on the Day of Maximum Peak Demand 16-5
Figure 16-6 Actual Situation of Frequency Adjustments in Bangladesh 16-6
Figure 16-7 Conceptual Diagram of Frequency vs Continuous Operable Time Characteristics of Synchronous Generator 16-9
Figure 16-8 Regulatory Framework for Electricity Supply Industry in Japan 16-10
Figure 16-9 Ten General Electricity Utilities and their Service Areas 16-11
Figure 16-10 Schedule of Deregulation and Unbundling in Japanese Electricity Industry 16-12
Figure 16-11 Regulatory Framework for Electricity Supply Industry in Bangladesh 16-12
Figure 16-12 Prospect of Demand and Supply Balance to 2041 (PSMP2016) 16-27
Figure 16-13 Details of Planned Power Sources after 2015 16-28
Figure 16-14 The Necessary Reserve to Improve 0.1[Hz] of Frequency Fluctuation 16-34
Figure 16-15 Impact of Tripping HVDC Link (System Frequency & Generation Records) 16-34
Figure 16-16 Impact of Tripping Generators on the System Frequency 16-35

Figure 16-17 Frequency Fluctuation Record during Test Operation in Khulna Power Station..... 16-37
Figure 16-18 Power System Diagram of Bangladesh 16-38
Figure 16-19 Time-shift Illustration of Frequency Fluctuation at the Time of Generation Tripping 16-39
Figure 16-20 Trend of Bottom of Frequency Immediately 16-40
Figure 16-21 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator: 100%) 16-41
Figure 16-22 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator: 80%) 16-41
Figure 16-23 Future Roadmap of Improving Frequency Quality..... 16-42
Figure 16-24 Flow Diagram for LFC in TEPCO 16-46
Figure 17-1 Purpose of O&M Legal Framework..... 17-1
Figure 17-2 O&M Legal Solutions Procedure 17-1
Figure 17-3 Problems and O&M Legal Solutions..... 17-2
Figure 17-4 Concrete Measures 17-3
Figure 17-5 Philosophical Approach..... 17-3
Figure 17-6 Key Factors for O&M..... 17-4
Figure 17-7 Details of Key Factors for O&M..... 17-4
Figure 17-8 Profit and Loss Affected by Maintenance Period Rate..... 17-5
Figure 17-9 Output and Profit 17-6
Figure 17-10 Government Involvement or Self-responsibility 17-7
Figure 17-11 Legal Framework in Japan..... 17-8
Figure 17-12 O&M Legal Framework in Japan..... 17-11
Figure 17-13 Government Safety Requirements for P/P (1) 17-13
Figure 17-14 Government Safety Requirements for P/P (2) 17-13
Figure 17-15 Problems and O&M Legal Solutions (excerpt) 17-15
Figure 17-16 Internal Manuals in P/P 17-16
Figure 17-17 Hierarchy of Power Section in Bangladesh..... 17-18
Figure 17-18 Bangladesh Energy Regulatory Commission Act 2003 (Front) 17-22
Figure 17-19 Recommended Schedule..... 17-36
Figure 18-1 List of Existing Power Plants 18-3
Figure 18-2 List of Planned Power Plants..... 18-4
Figure 18-3 Site Selection..... 18-6
Figure 18-4 Target Site List..... 18-6
Figure 18-5 Rauzan Organization Chart..... 18-7
Figure 18-6 Ashuganj Organization Chart 18-9
Figure 18-7 Siddhirganj Organization Chart..... 18-11
Figure 18-8 Barapukuria Organization Chart..... 18-13
Figure 18-9 Chandpur Organization Chart..... 18-15
Figure 18-10 Ghorasal Organization Chart..... 18-17
Figure 18-11 Baghabari Organization Chart 18-19

Figure 18-12 Shahjibazar Organization Chart 18-21
Figure 18-13 Fenchuganj Organization Chart 18-23
Figure 18-14 Sylhet Organization Chart 18-25
Figure 18-15 Education and Organization 18-28
Figure 18-16 Problem Tree Analysis 18-33
Figure 18-17 Steam Turbine Rehabilitation 18-36
Figure 18-18 Combined Cycle Power Generation Remodeling Plan 18-37
Figure 18-19 O&M Best Practice Supported by Information Sharing System 18-38
Figure 18-20 Illustration 18-39
Figure 18-21 Long-Mid List Selection Illustration 18-40
Figure 18-22 Mid-Short List Selection Illustration 18-41
Figure 18-23 Cost-effectiveness of Turbine Rehabilitation 18-41
Figure 18-24 Application Judgment by Each case 18-43
Figure 18-25 B&S Schedule with Power Output 18-43
Figure 18-26 B&S Image on Old Haripur Area 18-44
Figure 18-27 Haripur Layout 18-44
Figure 18-28 150MW Combined Cycle Layout Image 18-45
Figure 18-29 Short Start Time Characteristics and Efficiency 18-45
Figure 18-30 Efficiency Comparison 18-46
Figure 18-31 Frequency Fluctuation Record during Test Operation in Khulna Power Station 18-46
Figure 18-32 Current Situation and Obstructive Factors 18-48
Figure 18-33 Problem Tree Analysis and Key Problems 18-50
Figure 18-34 Business Process Cycle in the Power Generating Business 18-53
Figure 18-35 Information Sharing Framework for Maintenance Activities 18-55
Figure 18-36 Conceptual Model of the Information Sharing Platform 18-57
Figure 18-37 Scope of Information Sharing System and SCADA System 18-58
Figure 18-38 System Functions and Data Flows for a Power Plant in Bangladesh 18-59
Figure 18-39 Modern Information Management System in Japan 18-61
Figure 18-40 Improvement Cycle and Otcomes 18-65
Figure 18-41 Implementation of Information Management System at Matarbari Power Plant 18-67
Figure 18-42 Future of the Power Plant Information Management System 18-69
Figure 18-43 Information Management towards a Best Practice of O&M 18-69
Figure 18-44 Sample of Training Curriculum 18-71
Figure 18-45 Training Center Construction Schedule Image 18-73
Figure 19-1 Hierarchy of Governance for Transmission 19-4
Figure 19-2 Cash Flow of Bangladesh Power Sector for Operation Phase 19-5
Figure 19-3 Cash Flow of Bangladesh Power Sector for Capital Investment 19-6
Figure 19-4 Flow of Power Supply and Flow of Billing 19-10
Figure 19-5 Overview of Power Supply Flow (2015 Snapshot) 19-11
Figure 19-6 Overview of Financial Situation (2015 Snapshot) 19-11

Figure 19-7 Supply Cost, Bulk Supply Tariff, and Retail Tariff of Electricity (FY2014-2015)..... 19-12
Figure 19-8 Consolidated Balances of the Bangladesh Power Sector (billion BDT)..... 19-13
Figure 19-9 Consolidated Balances of the per Electricity Sales (BDT/kWh) 19-13
Figure 19-10 Operating Expenses of the Entire BPDB..... 19-14
Figure 19-11 Revenues and Expenses of per Electricity Sales(BDT/kWh) 19-15
Figure 19-12 Revenue and Expenses per Energy Sales (BDT/kWh)..... 19-16
Figure 19-13 Cash Flow of the Entire BPDB..... 19-17
Figure 19-14 Balance Sheet of the Entire BPDB 19-18
Figure 19-15 PGCB's Revenue and Cost Balances per Energy Supply (BDT/kWh) 19-19
Figure 19-16 PGCB Cash Flow..... 19-19
Figure 19-17 WZPDCL Balances per Energy Sales..... 19-20
Figure 19-18 WZPDCL Cash Flow..... 19-21
Figure 19-19 DESCO Balances per Energy Sales (BDT/kWh) 19-22
Figure 19-20 DESCO Cash Flow..... 19-22
Figure 19-21 Balances of DPDC per Energy Sales (BDT/kWh) 19-23
Fiure 19-22 DPDC Cash Flow 19-24
Fiure 19-23 Balances of REB per Energy Sales (BDT/kWh) 19-25
Fiure 19-24 Balances of BPDB (Generation Division) per Electricity Sales (BDT/kWh) 19-25
Fgure 19-25 BPDB Electricity Procurement (Breakdown by Plant Owner)..... 19-26
Fiure 19-26 BPDB Electricity Purchase Cost (by Plant Owner)..... 19-26
Fiure 19-27 Generation Cost of BPDB's Own Plants 19-27
Fiure 19-28 Breakdown of Electricity Generation by Fuel in BPDB Owned Plants 19-27
Fiure 19-29 Generation Cost of BPDB's Own Plants (by Fuel)..... 19-28
Figure 19-30 Projection Method of Electricity Supply 19-30
Figure 19-31 Projection of Generation Cost by Fuel (USD)..... 19-32
Figure 19-32 Projection of Generation Cost by Fuel (BDT)..... 19-32
Figure 19-33 Projection of Electricity Supply Cost (USD)..... 19-33
Figure 19-34 Projection of Electricity Supply Cost (BDT)..... 19-33
Figure 20-1 Process of Determining Natural Gas Tariff in Bangladesh..... 20-2
Figure 20-2 Trend of Average Gas Price Indexized with 1997 Price Level 20-5
Figure 20-3 Sectorial Breakdown of Natural Gas Consumption in FY2014-2015 20-5
Figure 20-4 Taxes and Suties Paid by Petrobangla to the Government of Bangladesh..... 20-6
Figure 20-5 Historical Trend of BPC's Annual Loss (Unit: million BDT) 20-9
Figure 21-1 Scenario of Increase of Electricity Tariff (Case 1) 21-5
Figure 21-2 Scenario of Increase of Electricity Tariff (Case 2) 21-5
Figure 21-3 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 1)..... 21-6
Figure 21-4 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 2)..... 21-7
Figure 21-5 Scenario of Increase of Gas Price..... 21-10
Figure 21-6 Impacts of Gas Price Increase on Bangladesh National Economy 21-11
Figure 21-7 Positive Impact of Electricity Tariff Increase on National Economy of Bangladesh ... 21-12

Figure 21-8 Historical Trend of Electricity Tariff in Japan 21-13
Figure 21-9 Historical Trend of GDP per Capita in Japan 21-13
Figure 21-10 GDP per Capita and Electricity Tariff..... 21-14
Figure 22-1 PSMP2010 Review (Power Development Plan) 22-3
Figure 22-2 Organaization of IPP..... 22-4
Figure 22-3 Advanced Electronic Mapping - Object Model System 22-8
Figure 22-4 Introduction of energy storage technology (1) 22-12
Figure 22-5 Introduction of energy storage technology (2) 22-13
Figure 22-6 Introduction of energy storage technology (3) 22-13
Figure 22-7 Steam Turbine Rehabilitation Plan 22-16
Figure 22-8 Combined Cycle Power Generation Remodeling Plan..... 22-16
Figure 22-9 Training Course Plan 22-17
Figure 22-10 System Functions and Data Flows for a Power Plant in Bangladesh 22-19

Abbreviations

Abbreviation	Full Tytle
ACC	American Chamber of Commerce
ADB	Asian Development Bank
ADF	Asian Development Fund
ADP	Annual Development Programme
AGC	Automatic Generation Control
AHWR	Advanced Heavy Water Reactor
AMD	Acid Mine Drainage
API	American Petroleum Institute
APSCL	Ashuganj Power Station Company
AR5	The Fifth Assessment Report
ASEAN	Association of Southeast Asian Nations
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATC	Available Transfer Capability
AZEs	Alliance for Zero Extinction Sites
Bangladesh	the People's Republic of Bangladesh
BAPEX	Bangladesh Petroleum Exploration & Production Company Limited
BAU	Business as Usual
bbl	Barrel
bpd	Barrel per Day
BCMCL	Barapukuria Coal Mine Company Limited
BBS	Bangladesh Bureau of Statistics
BCBJ	Back Contact Back Junction
BCF	Billion Cubic Feet
BDT	Bangladesh Taka
BERC	Bangladesh Energy Regulatory Commission
BGFCL	Bangladesh Gas Fields Company Ltd.
BNBC	Bangladesh National Building Code
BOP	Bottom of Pyramid
BPC	Bangladesh Petroleum Corporation
BPDB	Bangladesh Power Development Board
BREB	Bangladesh Rural Electrification Board
BST	Bulk Supply Tariff
BTK	Bull's Trench Kiln
CBM	Coal Bed Methane
CBM	Condition Based Maintenance
CC	Combine Cycle
CCAC	Climate and Clean Coalition
CCGT	Combined Cycle Gas Turbine
CCPP	Combined Cycle Power Plant
CCT	Clean Coal Technologies
CEB	Ceylon Electricity Board

Abbreviation	Full Tytle
CGE	Computable General Equilibrium
CHT	Chittagong Hill Tracts
CLDO	Central Load Dispatching Office
CNG	Compressed Natural Gas
COD	Commercial Operation Day
COD	Commercial Operations Date
COP	Conference of the Parties
C/P	Counterpart
CRT	Cathode-Ray Tube
CTT	Coal Transshipment terminal
DAC	Development Assistance Committee
DESCO	Dhaka Electricity Supply Company Limited
DFR	Draft Final Report
DOE	Department of Environment
DOF	Department of Forest
DPDC	Dhaka Power Distribution Company Limited
DSM	Demand Side Management
EBA	Electricity Business Act
ECC	Environment Clearance Certificate
ECMP	Energy Efficiency and Conservation Master Plan
EDC	Economical load Dispatching Control
EEC	Energy Efficiency and Conservation
EGAT	Electricity Generating Authority of Thailand
EGB	Exhaust Gas Boilers
EGCB	Electricity Generation Company of Bangladesh
EIA	Environmental Impact Assessment
EIA	Energy Information Administration, USA
ELBL	Eastern Lubricants Blenders Limited
EMRD	Energy and Mineral Resources Division
EMS	Enegry Management System
EN	European Norm (European Standards)
EOI	Expression of Interest
EPZ	Export Processing Zone
ERD	Economic Relation Division
ERL	Eastern Refinery Limited
ESMAP	Energy Sector Management Assistance Programme
EST	Environmentally Sound Technology
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FBR	Fast Breeder Reactor
FC	Frequency Convertor
FCK	Fixed Chimney Kiln
FD	Finance Division
FDI	Foreign Direct Investment

Abbreviation	Full Tytle
FGMO	Free Governor Mode Operation
FIDC	Forest Industries Development Corporation
FLEGT	Forest Law Enforcement Governance Trade
FR	Final Report
F/S	Feasibility Study
FSRU	Floating Storage Regasification Unit
FY	Fiscal Year
GCF	Green Climate Fund
GDF	Gas Development Fund
GDP	Gross Domestic Product
GE	General Electric
GEF	Global Environment Facility
GHG	Greenhouse Gas
GNI	Gross National Income
GOB	Government of Bangladesh
GPS	Ghorasal Thermal Power Station
GSRR	Gas Sector Reform Roadmap
GTAP	Global Trade Analysis Project
GTCL	Gas Transmission Company Limited
ha	Hectare
HCU	Hydrocarbon Unit
HHI	Herfindahl-Hirschman Index
HIES	Household Income and Expenditure Survey
HIT	Heterojunction with Intrinsic Thin-layer
HRSG	Heat Recovery Steam Generator
HSD	High Speed Diesel
HVDC	High Voltage Direct Current transmission line
Hz	Hertz
IAEA	International Atomic Energy Agancy
IBRD	International Bank for Reconstruction and Development
I&C	Instrument & Control
ICI	Indonesian Coal Index
IcR	Inception Report
ICT	Information and Communication Technology
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IEE	Initial Environmental Examination
IEEE	Institute of Electrical and Electronics Engineers
IGCC	Integrated Gasifier Combined Cycle
IGFC	Integrated Gasifier Fuel Cell
IISD	International Institute for Sustainable Development
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IOC	International Oil Company

Abbreviation	Full Tytle
ItR	Interim Report
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IRR	Internal Rate of Return
ISO	International Organization for Standardization
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JMAR	Japan Management Association Research Institute Inc.
JOCL	Jamuna Oil Company Limited
JST	JICA Survey Team
KBA	Key Biodiversity Areas
KPC	Kuwait Petroleum Corporation
ktoe	Kilo tonne of Oil Equivalent
KV	Kilovolt
kWh	Kilowatt Hour
LED	Light Emitting Diode
LFC	Load Frequency Control
LMZ	Leningradsky Metallichesky Zavod
LN	Natural Logarithm
LNG	Liquefied Natural Gas
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LPG	Liquefied Petroleum Gas
LPGL	LP Gas Limited
LTCC	Longwall Top Coal Caving
LTSA	Long Term Service Agreement
MCF	Million Cubic Feet
MDGs	Millennium Development Goals
METI	Ministry of Economy, Trade and Industry
MF	Ministry of Finance
MLJPA	Ministry of Law, Justice, & Parliamentary Affairs
mm	millimeter
MMBTU	Million British Thermal Unit
mmcf	Million Cubic Feet
mmscfd	Million Standard Cubic Feet per Day
MMTPA	Million Metric Ton per Annam
MOI	Ministry of Industries
MoPEMR	Ministry of Power, Energy and Mineral Resources
MPL	Meghna Petroleum Limited
MPM&P	Management, Production, Maintenance & provisioning Services
MPR	Maintenance Period Rate
MRT	Mass Rapid Transit
MW	Megawatt
MWh	Megawatt Hour

Abbreviation	Full Tytle
MWR	Ministry of Water Resources
NLDC	National Load Dispatching Center
NM	Nautical Mile
NOC	No Objection Certificate
NRECA	National Rural Electrification Cooperative Association
NSAPR II	National Strategy for Accelerated Poverty Reduction II
NWPGCL	North West Power Generation Company
O&M	Operation and Maintenance
OCCTO	Organization of Cross-regional Coordination of Transmission Operations
OCR	Ordinary Capital Resources
O/C	Open Cut
ODA	Official Development Assistance
OECD	Organization for Economic Co-operation and Development
OICA	International Organization of Motor Vehicle Manufacturers
p.a.	Per Annum
PAS	Protected Area Systems
PBS	Palli Bidyuit Samity
PC	Power Cell
PCFBC	Pressurized Circulating Fluidized Bed Combustion
PCJSS	United People's Party of the Chittagong Hill Tracts (Parbatya Chattagram Jana Sanghati Samiti)
PD	Power Division
PDCA	Plan, Do, Check, Action
PDP	Power Development Plan
PEMFC	Polymer Electrolyte Membrane Fuel Cell
PGCB	Power Grid Company of Bangladesh Limited
PM	Particulate Matter
POCL	Padma Oil Company Limited
P/P	Power Plant
PPA	Power Purchase Agreement
PPP	Power Purchasing Parity
PPP	Public Private Partnership
PRF	Protected Public Forest
PSA	Production Sharing Agreements
PSC	Product Sharing Contract
PSMP	Power System Master Plan
PSPP	Pumped Storage Power Plant
PSS/E	Power System Simulator for Engineering
PV	Photo Voltaic
Q & A	Questions & Answers
R&D	Research and Development
Re	Relaiability
REB	Rural Electrification Board
RES	Renewable Energy power Source

Abbreviation	Full Tytle
RF	Reserved Forest
RHD	Road and Highways Department
RMG	Ready-Made Garment
SAOCL	Standard Asiatic Oil Company Limited
SARI/EI	South Asia Regional Initiative for Energy Integration
SC	Steering Committee
SC	Super Critical
SCADA	Supervisory Control And Data Acquisition
SCC	Site Clearance Certificate
SD/VAT	Supplementary Duty/Value Added Tax
SDGs	Sustainable Development Goals
SEC	Specific Energy Consumption
SEZ	Special Economic Zone
SGFL	Sylhet Gas Fields Limited
SHS	Solar Home System
SIPP	Small Independent Power Producers
SME	Small and Medium Enterprise
SOFC	Solid Oxide Fuel Cell
SPM	Single Point Mooring
SREDA	Sustainable and Renewable Energy Development Authority
SSHP	Small Scale Hydropower Plant
ST	Steam Turbine
TCF	Trillion Cubic Feet
TDS	Transmission and Distribution Sector (in General Electricity Utility)
Tk	Taka
TEPCO	Tokyo Electric Power Company, Inc.
TEPSCO	Tokyo Electric Power Services Co., Ltd.
TFC	Total Final Consumption
T/D	Transmission and Distribution
TNA	Technology Needs Assessment
TOR	Terms of Reference
TPES	Total Primary Energy Supply
UAE	United Arab Emirates
UCG	Underground Coal Gasification
UCTE	Union for the Co-ordination of Transmission of Electricity
UFR	Under Frequency Relay
U/G	Under Ground
UMIC	Upper Middle Income Countries
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Reducing Emissions from Deforestation and forest Degradation
USD	United States Dollar
USC	Ultra Super Critical

Abbreviation	Full Tytle
WB	World Bank
WEO	World Energy Outlook
WG3	Working Group 3
WPP	World Population Prospects
WZPDCL	West Zone Power Distribution Company Limited
YTF	Yet to find
η	Efficiency

PART I PRINCIPLE OF THE MASTER PLAN

Chapter 1 PSMP2016 Summary

1.1 Abstract

The Power System Master Plan (PSMP) 2016, sponsored by Japan International Cooperation Agency (JICA), aims at assisting the Bangladesh in formulating an extensive energy and power development plan up to the year 2041, covering energy balance, power balance, and tariff strategies.
Bangladesh has an aspiration to become a high-income country by 2041. The development of energy and power infrastructure therefore pursues not only the quantity but also the quality to realize the long-term economic development.
Since Bangladesh is facing to the depletion of domestic gas supply, various issues such as sustainable development harmonizing with economic optimization, improvement of power quality for the forthcoming high-tech industries, and the discipline of operation and maintenance (O&M) for power plants need to be addressed holistically.
Furthermore, energy subsidy is also a tough challenge, because there's always a concern that drastic increase of fuel and electricity prices may trigger another negative effect on the national economy. A meticulous analysis is required to find the best pathway to attain the sustainability of the energy and power sectors in balancing with the economic growth.
The new PSMP study covers all the aforementioned challenges comprehensively, and come up with feasible proposals and action plans for Bangladesh to implement.

1.2 Background and Purpose

The energy source of the People's Republic of Bangladesh (hereinafter "Bangladesh") mainly depends on Domestic Natural Gas. The Government of Bangladesh formulated the Power System Master Plan 2010 (PSMP2010) targeting, among others, for a long term energy diversification due to the foreseen decrease in the production volume of Natural Gas.
However, energy development is not on track compared with the PSMP2010 plan, because various assumptions about expected sources for base load energy have subsequently changed. In particular, a review is needed reflecting namely exponential increasing of oil based rental power plants and development constraints of domestic primary energy.
Currently, many of power plants in Bangladesh cannot generate electricity as specified in terms of power, thermal efficiency etc. for each unit. Daily shortage of power does not allow to stop facilities and to undertake periodical maintenance in a planned way. Legal framework does not stipulate preventive maintenance works as an obligation for plant owner. Low financial soundness of public generating companies due to low electricity tariff does not permit to purchase in advance necessary spare parts. In order to secure a stable electricity supply, we need to find out solutions to all of these issues and to establish a comprehensive institutional framework. Moreover, hydro power generation studies (on small scale hydropower plants of 30 kW ～ 5MW and a pumped storage power plant as a regulator between demand and supply) have become an urgent issue through the government's renewable energy promotion policy.
Based on the aid policy of the Government of Japan for Bangladesh, the Japan International Cooperation Agency (JICA) is considering the power sector as one of priority areas assisting Bangladesh not only by Yen Loans to the construction of power plants (gas combined cycle, super-critical using import coal and hydropower), transmission and distribution lines and development of renewable energy but also by Technical Assistance such as the master plan for energy efficiency. JICA is thus supporting the entire power and energy sector. It was under such circumstances that JICA decided to undertake the Power System Master Plan 2016 (PSMP2016) in order to grasp middle to long term development issues and risks and to formulate a comprehensive and result-oriented aid strategy for the energy sector by examining effective approaches for each issue.
After the start of this survey, however, the Government of Bangladesh announced, in its new policy"Vision 2041", an important target of becoming one of the developed nations by 2041. Consequently, for the power and energy sector which receives quite dominant development budget, it has become newly necessary to secure the consistency between the economic development strategy of

the country toward joining the developed countries and the master plan of the power and energy sector (PSMP). With such consistency only, JICA will be able to make the best use of the result of this survey as basic information for the future cooperation.

To study consistency between an economic growth strategy and PSMP, an additional survey on estimated changes of the industrial structure that will be brought by the coming strategy and a precise forecast of future demand of primary energy and corresponding supply policy must be added to this survey, since the power sector is one of the largest sectors which consume primary energy. It was therefore decided to estimate in this survey the most rational and probable demand and supply scenarios of primary energy for other sectors than power sector such as fertilizer, industry, commerce, and transportation.

Moreover, the power sector will be required to cope with the changes of industrial structure in line with the economic growth as expected in order for Bangladesh to join the developed nations. Specifically, improvement of the quality of electricity is indispensable given the view of the government that sophistication of industries is generally essential for the nation to become one of the developed countries.

After the commencement of this survey, Bangladesh started considering also a specific plan to expand power import from neighbouring countries such as India, Bhutan and Nepal. Usually, international cooperation in power system is oriented toward direct cooperation by means of alternate current and, to do so, quality of electricity is required to be equivalent or better than that of counterpart countries. It is therefore necessary for the promotion of international cooperation to improve the quality of electricity. Since this issue will be a concern to the entire power sector in revising PSMP, it was also decided to add to this survey collection of additional basic information and examination of feasible measures responding to the specific needs of quality improvement.

Therefore, the collection and analysis of the information on the plan for the supply and demand for primary energy sources and the needs for the improvement of the quality of power supply were included in this survey that had consisted of the revision of power development plan and the studies on the institutional reform for the improvement of O&M and the introduction of hydropower generation. This inclusion of the new survey subject enabled the formulation of a new master plan that covers not only the power sector but also the energy sector comprehensively and describes the interface between the two sectors. The new master plan is the output of the first joint survey of the two divisions in the Ministry of Power, Energy and Mineral Resources (MoPEMR), Power Division and Energy Division, and this survey is expected to serve as a good precedent of the cooperation between them in the implementation of policies in the power and energy sectors.

1.3 Vision Paper

VISION 2041: POWER SYSTEM MASTER PLAN 2016

Value-up Plan 1 Robust Infrastructure for Primary Energy Import

Value-up Plan 2 Domestic Energy Resource Development and Efficient Use

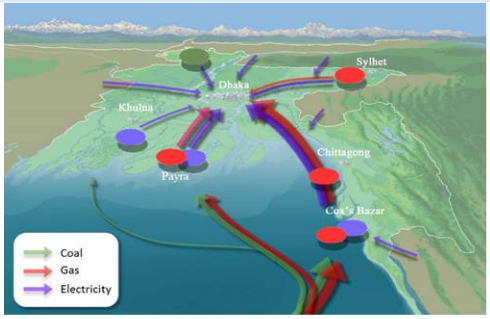
Value-up Plan 3 High-Quality and Robust Power System Development

Value-up Plan 4 Advanced Deployment of Green Energy

Value-up Plan 5 Policy and Human Capital Development for Stable Energy Supply

PSMP2016 Structure

PART Ⅰ PRINCIPLE OF THE MASTER PLAN [Ch. 1]	
Chapter 1	PSMP2016 Summary
PART Ⅱ POLICY [Ch. 2-4]	
Chapter 2	Energy and Power Sector Overview
Chapter 3	Energy and Power Policies
Chapter 4	Environmental Policy
PART Ⅲ PRIMARY ENERGY BALANCE [Ch. 5-10]	
Chapter 5	Prospects of Economic Development
Chapter 6	Prospects of Energy Supply and Demand
Chapter 7	Domestic Natural Gas Supply
Chapter 8	Liquefied Natural Gas Supply
Chapter 9	Coal Supply
Chapter 10	Oil Products Supply
PART Ⅳ POWER BALANCE [Ch. 11-18]	
Chapter 11	Power Development Plan
Chapter 12	Hydropower
Chapter 13	Renewable Energy
Chapter 14	Power Import and Nuclear Power
Chapter 15	Power System Plan/ Rural Electrification (Distribution)
Chapter 16	Power Quality
Chapter 17	O&M Legal Framework
Chapter 18	Thermal Power Operations and Maintenance
PART Ⅴ ENERGY COST AND TARIFF BALANCE [Ch. 19-21]	
Chapter 19	Financial Performance of the Power Sector
Chapter 20	Financial Performance of the Gas and Oil Sector
Chapter 21	Tariff Policy
PART Ⅵ Technical Support [Ch. 22]	
Chapter 22	Continuous Technical Support for PSMP2016



Abstract

The Power System Master Plan (PSMP) 2016, sponsored by Japan International Cooperation Agency (JICA), aims at assisting the Bangladesh in formulating an extensive energy and power development plan up to the year 2041, covering energy balance, power balance, and tariff strategies.

Bangladesh has an aspiration to become a high-income country by 2041. The development of energy and power infrastructure therefore pursues not only the quantity but also the quality to realize the long-term economic development.

Since Bangladesh is facing to the depletion of domestic gas supply, various issues such as sustainable development harmonizing with economic optimization, improvement of power quality for the forthcoming high-tech industries, and the discipline of operation and maintenance (O&M) for power plants need to be addressed holistically.

Furthermore, energy subsidy is also a tough challenge, because there's always a concern that drastic increase of fuel and electricity prices may trigger another negative effect on the national economy. A meticulous analysis is required to find the best pathway to attain the sustainability of the energy and power sectors in balancing with the economic growth.

The new PSMP study covers all the aforementioned challenges comprehensively, and come up with feasible proposals and action plans for Bangladesh to implement.

Achievement: High-Income Country

Value-up Plan 1 & Value-up Plan 2

Primary Energy Demand
- Energy intensity [3.42→2.56 toe/million BDT]

Gas/LNG
- Domestic gas [2,500→2,000 mmcfd incl. YTF]
- Imported LNG [0→4,000 mmcfd]

Coal
- Domestic coal [0.7→ 11 million tons/year]
- Imported coal [0→ 60 million tons/year]

Oil
- Imported oil [5→ 30 million tons/year]

Value-up Plan 3

Power Generation
- Tokyo size power capacity [8,000 MW→50,000 MW]
- Complete phase-out of rental power [3,000 MW→0 MW]
- Electricity for all [250→1,500 kWh/person/year]

Power Quality
- No power shortage [500 MW→0 MW]
- Fluctuation of world top quality [± 1.5 Hz→ ± 0.2 Hz]

Operations and Maintenance
- High thermal efficiency [30%→50%]

Power Import/ Nuclear Power
- Import [500 →9,000 MW]/ Nuclear [0 →7,200 MW]

Value-up Plan 4

Renewable Energy
- Maximizing RE generation potential under limited land
- Bio-gas [4→62 mmcfd]

Value-up Plan 5

Energy Tariff Policy
- No gap between tariff and supply costs
  [Power: 2.6%/year until 2031 and 1.5%/year afterwards]
  [Gas: 10-20%/year increase until 2031 and 1.5%/year afterwards]

Human Capital Development
- Training centers
- Internationally recognized qualifications
- Professional engineers

Policy Vision

1.4 Policy Vision

The Government of Bangladesh declared its intention to develop the country in order to become one of the advanced countries by 2041 as the key goal of VISION2041. To achieve the VISION, this master plan defines the intended goal and "five key viewpoints" that are to be kept in mind by all the members who are involved in the realization of the goal.

1.4.1 PSMP2016 Objective

To show the targets and approach in the Energy and Power Sectors in order to achieve Bangladesh's national goal: to achieve VISION2041 and become a high-income country by 2041



1.4.2 Five Viewpoints of PSMP2016

1 Enhancement of imported energy infrastructure and its flexible operation

For Bangladesh to become one of the high-income nations by 2041, the country needs to achieve continuous economic growth of 7.4% annually for the period from 2016 to 2020 to initially reach the standard of the medium to high income nations. Subsequently, its GDP would then grow steadily although the growth rate may slow down slightly. With this economic growth, the demand for primary energy, in particular in the industrial sector and the transport sector, is expected to increase sharply under both the BAU and the energy efficiency scenario.

To meet this rapidly increasing demand for primary energy, the country needs to undergo a major change from its existing dependency on domestic natural gas to a dependency on various imported energies. During the period where imported energies are consumed in large quantities, the existing inefficient energy resource consumption would directly lead to an enormous amount of economic loss. In the future, the efficient use of energy, its supporting infrastructure and improvements to related policies and systems will be essential. The infrastructure improvements include the domestic facilities as well as interaction with neighboring countries. The policy and system improvements include the strategic positioning of various energy resources and a legal system that promotes efficient use of energy by revising the current inefficient practices.

2 Efficient development and utilization of domestic natural resources (gas and coal)

While the amount of deposits of natural gas discovered domestically is decreasing, the limited resources must be utilized to the maximum by developing an efficient development structure. Achievements in mining and the development of undiscovered resources are limited under the existing structure and a drastic review is necessary, such as PSC reform and the introduction of technologies from other countries. In addition, as mentioned in "1", development of an infrastructure for the economical and efficient use of gas and development and implementation of the system are necessary.
Since the domestically produced coal is of a high quality and the reserves are abundant, the future development of an economical domestic coal development structure is important. Since domestic coal development has a serious impact on the surrounding environment and society and requires a long period of time, the necessary actions must be taken sufficiently in advance in anticipation of VISION2041.

3 Construction of a robust, high-quality power network

To meet the rapidly increasing demand for power and to realize its stable supply, large-scale power supply development and construction of system facilities are necessary. In terms of new issues and opportunities for power supply development, power imports from neighboring countries (international cooperation), and nuclear power generation can be considered. System enhancement is essential in addition to these power supply developments.
In order to realize future rapid economic development, industrial development such as the transition to higher value-added industries is essential for Bangladesh, necessitating high-quality power to support such an advancement. Therefore, in the future, Bangladesh requires improvements in its infrastructure and the development and implementation of a system that provides high-quality power for electrical frequency stabilization, as well as the development of the power system.

4 Maximization of green energy and promotion of its introduction

For Bangladesh, which is susceptible to climate change, the development of low-carbon energies is

extremely desirable, not simply from the aspect of the international trend, recommending renewable energies and energy diversification, but from the point of improving energy access for rural people. Therefore, development of domestic renewable energies is indispensable.
However, there is a limit to the introduction of renewable energies on a large scale in Bangladesh due to the availability of appropriate land. Importing power from neighboring countries using hydroelectric power generation has much greater possibility than supplementation programs for the limited degree of renewable energy introduction in Bangladesh.

5 Improvement of human resources and mechanisms related to the stable supply of energy

To realize advanced utilization and the stable supply of energy and power for Bangladesh, non-material support such as reform of the existing system, development of a new system, and development of human resources for their implementation is essential, as well as material support such as the construction of infrastructure. In particular, to cope with the coming era of mass consumption of imported energy, efficiency improvement of gas fired power plants, and the development of legal systems and human resources for its realization, are urgently necessary.

In the same way, significant improvements are required in many aspects of international cooperation and nuclear power generation from Bangladesh's existing power supply development and system operation. Although the development of legal systems and human resources relating to international cooperation and nuclear power generation is an extremely difficult task for Bangladesh, this task needs to be achieved.

For power rates, structural reform of the existing below-cost power rates is necessary in terms of the sustainability of the power sector. In the future, an increase mainly in household power rates is required, which does not inhibit Bangladesh's economic growth. In this case, cost reduction measures must be taken by analyzing the possibility of cost reductions in the power generation, supply, and distribution sectors prior to the decision-making on an increase in power rates, while alleviating the impact on the lower socio-economic classes.

1.4.3 Importance of Contribution and Responsibility to the International Community

In 2015, the United Nations adopted the Sustainable Development Goals (SDGs) as the international development goals. These goals have been established by using the development goals for the period from 2000 to 2015, Millennium Development Goals (MDGs), as the foundation.

Plainly speaking, the old goals, MDGs, were development goals targeting "developing countries" and adopted eight goals for poverty countermeasures for the period up to 2015.

The new goals, SDGs, are development goals that are set in 17 fields under "sustainable development" as cross-cutting themes, including developed countries as well as developing countries. In particular, the following goals are closely related to the energy and power fields.



Goal 7 "Clean energy for everyone": Secure access to affordable, reliable, sustainable and modern energy for everyone



Goal 9 "Industrial and technological innovation and social infrastructure": By developing robust infrastructure, promote inclusive and sustainable industrialization and also expand technological innovation.



Goal 13 "Urgent handling of climate change": Take urgent countermeasures for climate change and its impact.

To become one of the advanced countries, proper recognition of contribution to the international society and its accompanying responsibilities are necessary. To establish this master plan, further agreement with the major direction of the international society is required. The relationships between these SDGs and this master plan are shown below.

Table 1-1 Link between PSMP2016 and the SDGs

Sustainable Development Goals: SDGs			
	Affordable and clean energy	Industry, innovation, infrastructure	Climate action
	Ensure access to affordable, reliable, sustainable and modern energy for all	Build resilient infrastructure, promote sustainable industrialization and foster innovation	Take urgent action to combat climate change and its impacts
Concept	Energy for everyone and clean energy	Infrastructure for industries and technological innovation	Specific actions for climate change
Specific contents	Secure access to affordable, reliable, sustainable and modern energy for everyone.	By developing robust infrastructure, promote inclusive and sustainable industrialization and also expand technological innovation.	Take urgent countermeasures for climate change and its impact.
Five key viewpoints			
Viewpoint 1 Robust Energy Import Infrastructure and Flexible Operation		◎	
Viewpoint 2 Domestic Resources' Efficient Development and Use (Natural Gas and Coal)		◎	
Viewpoint 3 Quality and Robust Power System Development	◎	◎	○
Viewpoint 4 Advanced Use of Green Energy	◎	○	◎
Viewpoint 5 Human Resource and System Development for Stable Energy Supply	○	◎	○

Source: UNDP Website and JICA Survey Team

Practical Vision

1.5 Practical Vision

1.5.1 Relationships between the Five Key Viewpoints and the Master Plan Investigation Items

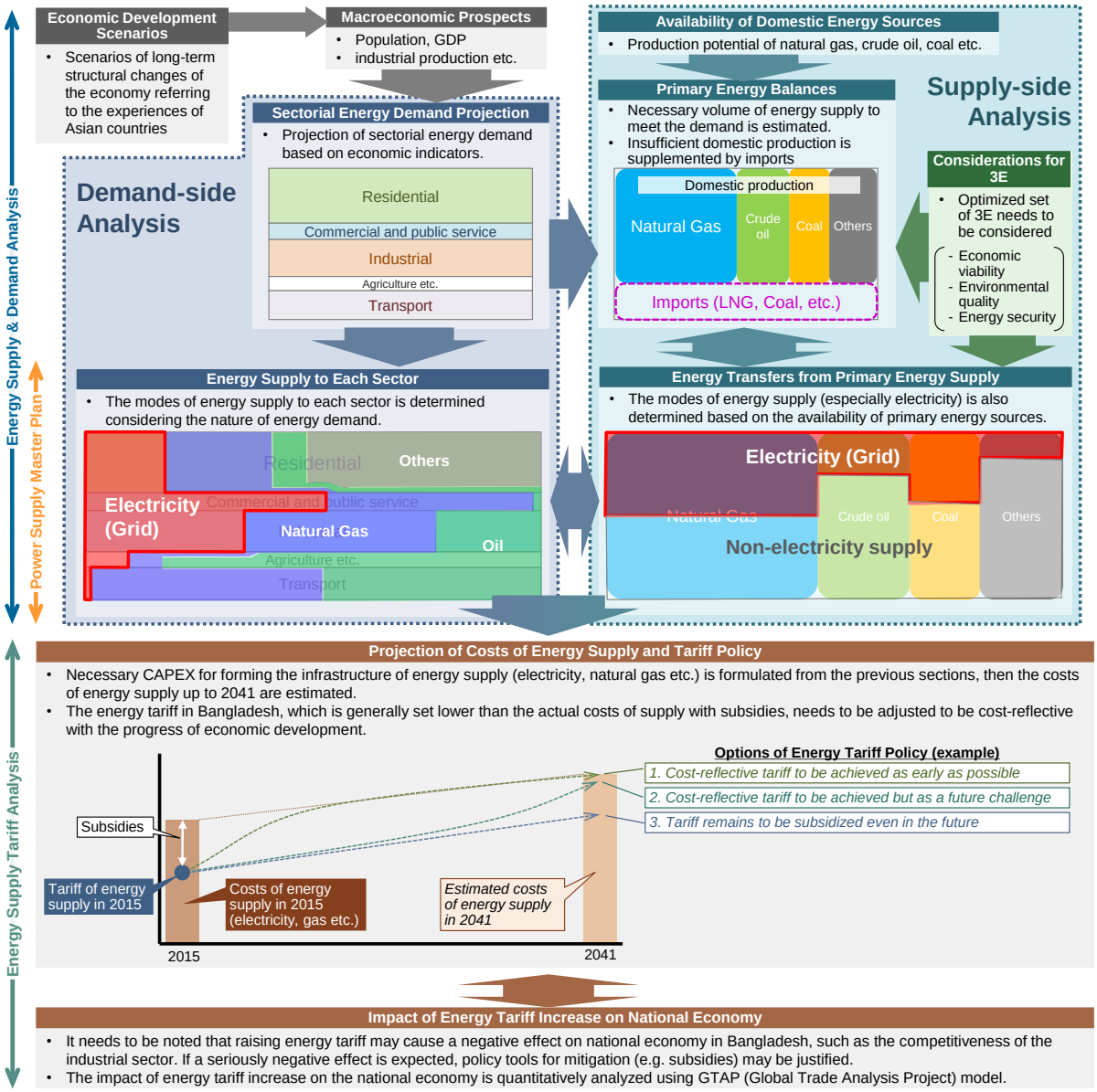
The table below shows the relationship between "the five key policy viewpoints" mentioned above and the components of the master plan. The master plan is composed of a policy for the economic growth, a plan on the primary energy balance, a plan on the power balance mainly based on the power development plan and a policy on energy prices. The components of the master plan are closely related to the five key viewpoints required for achieving the vision mentioned in the previous section as shown in the table below.

	PSMP Composition		Political Vision				
			Five Key Viewpoints				
			Viewpoint 1 Robust Energy Import Infrastructure and Flexible Operation	Viewpoint 2 Domestic Resources' Efficient Development and Use (Natural Gas and Coal)	Viewpoint 3 Quality and Robust Power System Development	Viewpoint 4 Advanced Use of Green Energy	Viewpoint 5 Human Resource and System Development for Stable Energy Supply
Practical Vision	Economy	Economic Development	◎				
	Energy Balance	2. Energy Demand and Supply	◎				
		3. Gas	◎	◎			◎
		4. Coal	◎	◎			◎
		5. Oil	◎				
	Power Balance	6. Power Development Plan			◎		◎
		7. Hydropower			◎		◎
		8. Renewable Energy				◎	
		9. power Import			◎	◎	
		10. Nuclear Power			◎		
		11. Power System Plan					◎
		12. Powr Quality					◎
		13. Thermal O&M					◎
	Tariff	14. Energy Tariff					◎

1.5.2 Methodologies for this Study

(1) Implementation flow

The overall methodologies and tasks for this study are summarized in the following flow chart.



Source: JICA Survey Team

Figure 1-1 Overall Workflow for This Study

(2) Study on the Future Scenarios of Economic Development

To begin with, this Study considers the future scenarios of economic development in Bangladesh as the baseline data for energy supply and demand projections.

Taking into account that this study is targeting the period up to 2041, which is considerably long,

structural changes to the Bangladesh economy are expected to occur during its course. That is, macroeconomic parameters for energy demand forecasts such as GDP and industrial production need to be projected on the condition that non-linear structural changes to the national economy will take place along with the development of Bangladesh economy.
Though it is hardly possible to determine such structural changes quantitatively, this study considers the future scenarios of economic development that are likely to occur in Bangladesh, as ascertained through discussion with local stakeholders. The Government of Bangladesh (GoB) has set an ambitious target for the country to become a member of the "High-income Countries" by 2041, though the details to support this have not been provided. This Study also evaluates the feasibility of this target through the economic development projections and provides policy recommendations for achieving the economic development target.

(3) Energy Demand Forecast and Projection of Necessary Volume of Primary Energy Supply

Referring to the projection of economic development, this Study formulates the energy demand forecast and then estimates the necessary supply that meets the energy demand in the future.
It also needs to be noted that the optimized set of energy supply varies among countries depending on their geographical and geopolitical conditions. Especially for a country like Bangladesh, where the domestic energy production such as natural gas has mainly satisfied the domestic demand but the depletion of energy production and increased dependence on imported energy sources are expected in the future, it is appropriate to develop the energy supply plan by prioritizing the optimized utilization of domestic energy production and then by incorporating the imported energy sources in the energy supply system to fill the insufficiency.
Therefore, this study first estimates the total volume of primary energy supply necessary for Bangladesh based on the energy demand forecast and then estimates the requirement for each energy source as the combination of domestic energy production and imports.

(4) Power Supply Master Plan

For the meanwhile, this Study also formulates the energy supply and demand balance in terms of the modes of energy supply to end consumption of energy. Among the various modes of energy supply, the electricity supply needs more specific considerations for infrastructure development, thus this study segregates the sections related to power supply and presents the "Power Supply Master Plan".
In order to determine the optimized set of supply modes, this study takes approaches from both the demand-side and supply-side. From the demand-side, each mode of energy supply (electricity, natural gas, oil products etc.) is projected as a part of the aforementioned energy demand projection and the electricity demand is determined. In Bangladesh, the electrification of unelectrified villages is still in progress and even in the already electrified villages a shift of energy supply to electricity from other modes will continue to occur. These transitions need to be considered in an appropriate timeline.
From the supply-side, how to match the primary energy supply sources with the modes of energy supply is analyzed. Because forming energy supply infrastructure requires a considerably long lead-time, drastic change of energy supply modes in a short time is not possible. Hence, an appropriate timeline for infrastructure development also needs to be considered so that the existing energy infrastructure will be gradually strengthened and modified. For example, the industrial sector, which is supposed to increase energy demand rapidly in Bangladesh, may consume more electricity from the grid if sufficient volume of electricity supply from the grid exists. However, because of the limitation with grid power supply and the considerable capacity of existing captive power generation that has been installed in the past, it may take time to phase out the use of electricity from captive power generation, which is generally less efficient than the power supply from the grid.
Then, the analyses from both the demand-side and supply-side are harmonized to determine how to establish the energy supply to end consumption. The future requirements of the primary energy supply will be finalized by calculating back from the energy supply to end consumption, considering that the

energy loss from transfer (e.g. power generation), transport and consumption differs among different modes of energy supply.

(5) Quantitative Evaluation of 3E

For identifying the best energy mix scenario for "Power Supply Master Plan", 3E (economic viability, environmental quality, and energy security) evaluation is employed.
Needless to say, for a country like Bangladesh where energy demand is expected to increase rapidly to sustain the economic development, economic viability, i.e. "assuring that energy supply meets the energy demand in an economically reasonable way", needs to be considered as a priority.
However, as the country's economic development is expected to reach a certain level of maturity by 2041, which coincides with GoB's national target of the country becoming a member of the "High-income Countries", this Study expects that the energy policy will need to assume responsibility beyond "low-cost supply" and that it will affect the structure of energy supply in Bangladesh. The country is expected to raise its domestic and international commitments to reduce environmental burdens such as greenhouse gas emissions. Considering that these environmental commitments can affect the plan for future energy supply, this study discusses with the stakeholders the policy options that the country will need to prepare.
In addition, as the Bangladesh economy will continue to be enhanced and modernized, the necessity for stability of energy supply is expected to gain importance. In order to achieve stability of the energy supply, not only improving the energy supply infrastructure itself but also improving stability in the upstream of the supply chain, i.e. stability of quantity and prices to secure primary energy supply, will gain more importance. There is some literature both in Japan and overseas that has attempted a quantitative evaluation of energy security, but standardized methodologies have not been established. It also needs to be noted that the main concerns about energy security may differ among countries. Therefore, in evaluating the energy security of Bangladesh, these past studies are reviewed but their methodologies are not strictly followed. An appropriate set of performance indicators is introduced through discussion with stakeholders in Bangladesh.
This study proposes a future energy supply that is appropriate for Bangladesh as a "responsible" developed country, taking also into account quantitative evaluations not only from the aspect of economic viability but also from the aspects of environmental commitments and energy security.

(6) Analysis of the Financial Conditions of the Power Sector and the Costs of Power Supply

Following the results of supply and demand projections for energy and power conducted in the previous sections, this study analyzes the financial conditions of the power sector in Bangladesh and the costs of the power supply.
In order to achieve self-contained and sustainable management of the power supply, the power supply tariff should be set at a level so that these supply costs can be appropriately recovered from end-consumers. The current status in Bangladesh, however, is that the tariff is set at a low level that can hardly recover the costs appropriately. This study discusses the direction of power tariff reforms while ascertaining the overall picture of the power sector's financial conditions and the costs of power supply.

(7) Estimation of the Impact of Energy Tariff on National Economy

On the other hand, it is common worldwide that raising energy tariffs is a politically sensitive issue and that tariff reforms may need to be made gradually. In addition, drastically raising the energy tariff at the time when the manufacturing sector of a country starts to develop and to be exposed to international competition may affect the sector's international competitiveness.
Therefore, the study on the energy supply tariff in Bangladesh up to 2041 needs to analyze how the "cost-reflective tariff will affect the national economy depending on the timeline to achieve this",

taking into consideration the level of economic development.
In order to evaluate the effects of raising energy supply tariffs on the national economy quantitatively, this study runs the simulation model called GTAP (Global Trade Analysis Project). Referring to the results of this simulation, this study makes a policy recommendation on the future energy supply tariff.

1.5.3 Scope of work

The Survey had been carried out according to the minutes between JICA and the Bangladesh government. The JICA Survey Team conducted the following items and make reports on the basis of the survey policy and considerations. The Survey started at the end of October 2014, be carried out as per following Table, and the Final Report had submitted in September 2016.

Table 1-2 Contents of the Study

	Contents of the Study
1	**Confirmation of the background**
2	**Review of PSMP2010 and develop PSMP2016** • Primary energy demand and supply scenario • O&M policy • Best Mix of generation power sources • Study of issues related to generation plant and transmission line system development plan • Study of consistency of off-grid renewable energy development and power development plan • Study of economic impact on energy price hike and its countermeasures • Study of JICA's potential projects in power and energy sector
3	**Collect information on O&M** • Current O&M situation in national thermal power plants • Collection of basic data for upgrading national power plants to combined cycle • Selection of model thermal power plant among existing plants to consider O&M and upgrading to combined cycle • Cost-benefit analysis, risk analysis and assistant approach for model power plant • Study of legal framework for sustainable O&M implementation • Concept level plan of the combined cycle to model plant • Arrangement of risks and issues in the application of combined cycle; examination of JICA approach • Report on the study from legal system examination
4	**Collect information on domestic hydropower potential** • Review of existing documents about micro hydropower plant and interviews with related agencies • Site survey, analysis and selection of potential hydropower plant, such as Kaptai Lake • Preparation of the TOR for the required F/S or pre-F/S in the next stage • Preliminary Social and environmental evaluation for the proposed project sites
5	**Primary Energy（Fuel）** • Study and collect basic information for primary energy demand forecast and making supply plan • Study of development regarding Seventh five-year plan • Preparation of prospects for economic development and energy demand forecast by 2041 • Consideration of exploration of undiscovered domestic natural gas and development plan • Preparation of primary energy supply plan • Calculation of cost required for developing infrastructure for energy supply • Review of price in terms of domestic energy supply

	Contents of the Study
	• Making financial plan (Future scenario considering price hike for energy supply) • Technical issues related to reviewing introduction of LNG receiving terminal • Confirmation of status of LNG receiving terminal plan in progress
6	**Improvement Measures for Power Quality** (1) Proposal for Preparation of a Legal Framework, rules and improvement of work procedures • Propose and support the preparation or amendment of various rules with reference to the rules in Japan (or Europe/America, if necessary) and TEPCO. • Check progress of amendment of the Grid code by BPDB and suggest reinforcement of NLDC's orders and generator participation in frequency control. (2) Draft plan for frequency quality improvement • Evaluate the frequency quality improvement by introducing generators with frequency control functions. • Propose the development of a future plan for securement of spinning reserve (free governor mode, LFC) and roadmap for frequency quality improvement for PGCB (NLDC) and BPDB, and regulating authorities (Energy division and BERC). (3) SCADA system renewal plan for NLDC • Confirming needs for introducing new functions or adding data to NLDC's SCADA system, in order to realize online output instruction orders for power stations. • Possibility study for introducing Japanese SCADA system
7	**Holding of the seminars** • 1st Seminar (November 2014, Dhaka) Agenda: Explanation of and discussion on the survey plan • 2nd Seminar (June 2015, Dhaka) Agenda: Explanation of and discussion on the interim report • 3rd Seminar (December 2015, Dhaka) Agenda: Explanation of and discussion on the interim report (reflecting survey results after 2nd Seminar) • 4th Seminar (June 2016, Dhaka) Agenda: Explanation of and discussion on the survey results in the draft final report
8	**Reports to be submitted** • Inception Report (October 2014) • Interim Report (December 2015) • Draft Final Report (June 2016) • Final Report (September 2016)

Source: JICA Survey Team

1.5.4 Survey Implementation Feamework

Five years have already passed since the latest PSMP2010 was prepared, so the Survey targeted not only a review of PSMP2010 but also studied the plan up to 2041. The review of the Survey was discussed and confirmed with the government and relevant agencies in Bangladesh, and also with JICA.

The Survey was conducted with one steering committee and four subordinate working groups to facilitate consensus building over a wide area of the relevant organizations. The committee and all technical discussion meeting were set up on the initiative of the Power Division (PD) of the Ministry of Power, Energy and Mineral Resources (MPEMR).

(1) PSMP2010 Review Steering Committee

The Steering Committee members include PD of MPEMR, Energy and Mineral Resources Division (EMRD) of MPEMR, Power Cell (PC) of MPEMR, Bangladesh Power Development Board (BPDB), Power Grid Company of Bangladesh (PGCB), Secretary, Economic Relations Division (ERD) of Ministry of Finance (MF), Financial Division (FD) of MF, Ministry of Law, Justice, & Parliamentary Affairs (MLJPA), Ministry of Water Resources (MWR), and the Prime Minister's Office. The Steering Committee is the organization that makes the highest decisions based on the discussions with the 5 subordinate technical discussion meeting.

(2) PSMP2010 Review Technical discussion meeting

The PSMP2010 Review Working Group members include PD of MPEMR, EMRD of MPEMR, PC of MPEMR, Sustainable and Renewable Energy Development Authority (SREDA), BPDB, generation corporation, PGCB including National Load Dispatch Centre (NLDC), Infrastructure Development Company Limited (IDCOL), Petrobangla and its subordinate companies, ERD of MF, and FD of MF. Technical discussion meeting will discuss the reduction of subsidiaries for energy utilities, the impact on the amount of LNG imports and the prices of electricity and gas, the coexistence of off-grid renewable energy and on-grid equipment, and issues across the executing agencies.

(3) Thermal Power Plant O&M Technical discussion meeting

The O&M Working Group members include PD of MPEMR, PC of MPEMR, BPDB, generation corporation, PGCB including NLDC, Petrobangla and its subordinate companies, and MLJPA. Technical discussion meeting will discuss the amendment of the Electricity Act, and related laws and regulations.

(4) Hydropower Development Technical discussion meeting

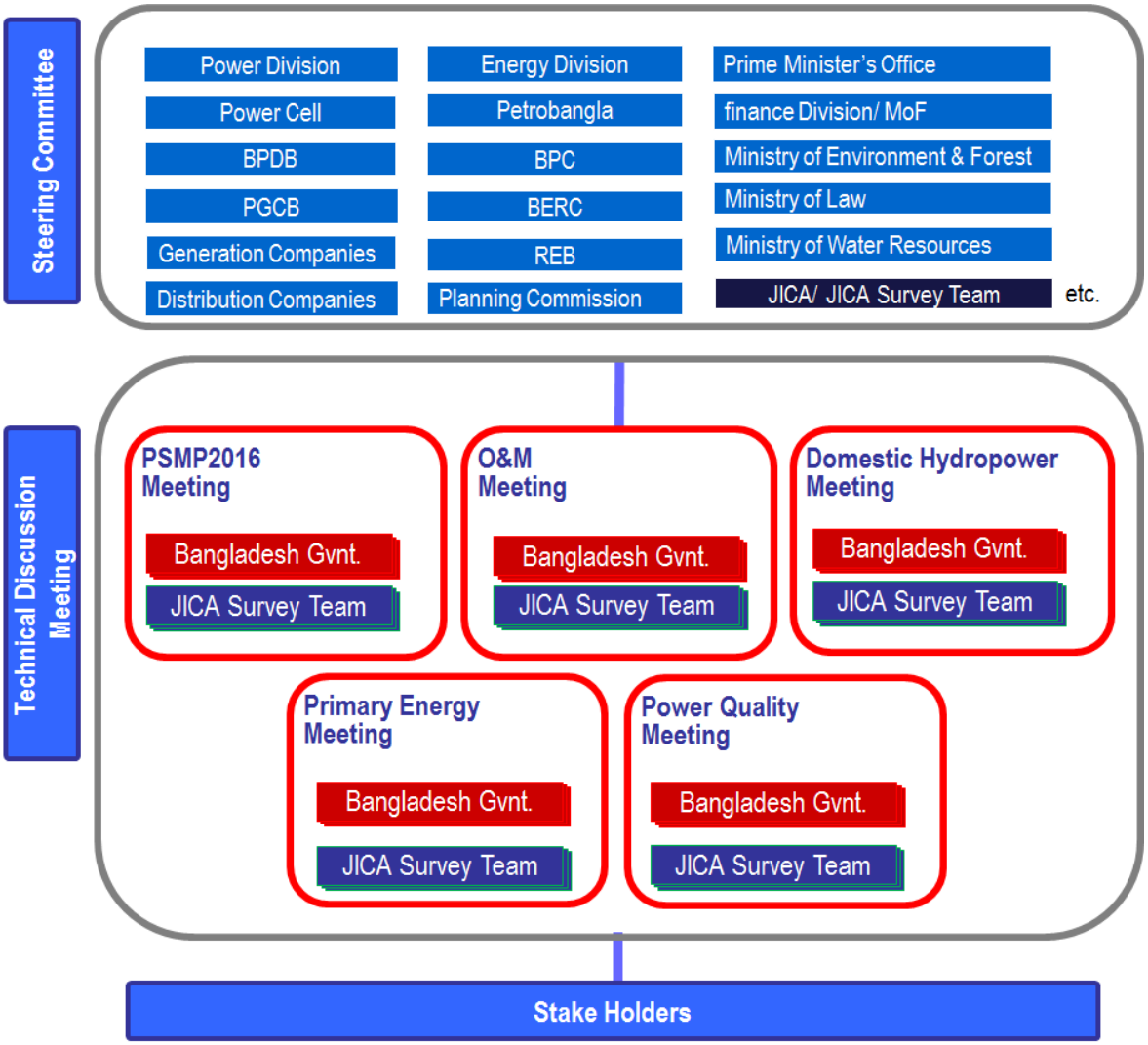
The Hydropower Development Working Group members include PD of MPEMR, MWR, and BPDB. Technical discussion meeting will discuss the impacts and countermeasures downstream due to the planned dam construction, and issues related to the executing agencies.

(5) Primary Energy Technical discussion meeting

The Primary Energy technical discussion meeting was composed as a counterpart agency to PD of MPEMR, and as a new counterpart agency to the Energy Division (ED).

(6) Improvement Measures for Power Quality Technical discussion meeting

Improvement Measures for Power Quality technical discussion meeting cooperates with the Master Plan technical discussion meeting and Thermal Power technical discussion meeting. Technical discussion meeting examines proposals for Preparation of a Legal Framework, rules and improvements for work procedures, and a draft plan for frequency quality improvement.



Source: JICA Survey Team

Figure 1-2 Implementation framework

1.5.5 JICA Study Team

The JICA Study Team is composed of the following members.

Assignment	Name
Team Leader/Power Development Plan (A)	Toshiyuki Kobayashi
Adviser to PM/Power Development Plan (B)	Kunio Hatanaka
Power System Planning A	Masaharu Yogo
Power System Planning B	Shinichi Funabashi
Primary Energy Analysis 1A (Coal)	Hajime Endo
Primary Energy Analysis 1B (Gas and Oil)	Kazuo Koide
Primary Energy Analysis 2A (Energy Balance)	Tomoyuki Inoue
Primary Energy Analysis 2B (Energy Balance)	Takeshi Aoki
Economic and Financial Analysis A	Shigefumi Okumura (Kei Owada)
Economic and Financial Analysis B	Dinh Minh Hung
Energy Supply Cost Analysis	Satoko Horie
Environmental & Social Considerations A	Shigeki Wada
Environmental & Social Considerations B	Akiko Urago
Renewable Energy	Masaki Kuroiwa
Rural Electrification	Toshifumi Watahiki
Transmission and Substation Equipment	Osamu Matsuzaki
Sub-team Leader/Thermal Power Plant O&M A	Genshiro Kano
Thermal Power Plant O&M B	Ken Shimizu
Thermal Fired Power Plant Ability Analysis A	Masahiro Ose (Sho Tai)
Thermal Fired Power Plant Ability Analysis B	Hiroyuki Sako (Eiji Naraoka)
Thermal Fired Power Plant Ability Analysis C	Yusuke Irisawa
Legal Framework Design	Katsuhiro Komura
Hydropower Planning	Jun Tamagawa
Sub-team leader (Primary energy)/ Energy economic analysis	Yasushi Iida
Economic growth strategy	Masaya Nakano
Environmental Policy	Shunsuke Kawagishi
Energy supply and demand analysis (Commercial)	Mari Iwata (Sayaka Okumura)
Energy supply and demand analysis (Industrial)	Hideshige Matsumoto
Energy supply and demand analysis (Transportation)	Hidenao Tanaka
Energy supply and demand analysis (Energy Model)	Yumiko Watanabe
Macroeconomic Analysis	Akiko Higashi

Assignment	Name
Energy supply and demand analysis (Electric Power)	Daichi Saito
Energy development analysis (LNG gas development A)	Hideo Matsushita
Energy development analysis (LNG gas development B)	Uichiro Machida
Energy development analysis (LNG gas development C)	Daihachi Okai
Energy development analysis (Interior Natural gas development)	Masaaki Ebina
Sub-team leader/Power system operation A	Shinichi Suganuma
Power system operation B	Masafumi Shinozaki
Power system operation C	Keisuke Ueda (Hideaki Kuraishi)
Power system facilities A	Kazuki Kito
Power system facilities B	Hisanori Masuda (Naoto Tokoda)
Power system facilities C	Keisuke Kusuhara
Sub-team leader (Energy strategy)/Energy policy	Minako Matsukawa (Mochida)
Payment structure (Electric power and Gas) A	Masato Muto
Payment structure (Electric power and Gas) B	Junji Ueda

1.5.6 Past Activities

(1) 1st Seminar (1st Steering Committee)

- Date: 29 October 2014
- Venue: Board Room of BPDB at Buddyut Bhaban, Dhaka
- Discussion Point: Explain for Inception Report
  - ✓ Establishment of Steering Committee (SC) and the Working Group (WG) for the Survey.
  - ✓ Explained the survey objectives, methodologies, member, and implementation schedule





(2) 2nd Seminar (2nd Steering Committee)

- Date: 4 Jun 2015
- Venue: Board Room of BPDB at Buddyut Bhaban, Dhaka
- Discussion Point:
  - ✓ Primary Energy Balance for Power Sector
  - ✓ Power Demand Forecast
  - ✓ Power Development Plan





(3) 3rd Seminar (3rd Steering Committee)

- Date: 15 December 2015
- Venue: Board Room of BPDB at Buddyut Bhaban, Dhaka
- Discussion Point:
  - ✓ Project Outline
  - ✓ Primary Energy
  - ✓ Power Demand Forecast and Power Development Plan
  - ✓ Power Quality
  - ✓ Operation and Maintenance (O&M)





(4) Pre- High Level Discussion Meeting (Tokyo)

- Date: 5 Apr 2016
- Venue: TEPCO Headquarter (Tokyo)
- Discussion Point:
  - ✓ Economic Development
  - ✓ Primary Energy Balance
  - ✓ Power Balance
  - ✓ Cost and Tariff Balance



(5) High Level Discussion (Dhaka)

- Date: 7 April 2016
- Venue: Bijoy Hall, Bidyut Bhaban, Power Division, MoPEMR
- Discussion Point:
  - ✓ PSMP 2010/2016 comparison

- ✓ Macroeconomic Projection & Industrial Policy
- ✓ Energy Balance Strategy
- ✓ Energy Efficiency Target Setting & Supply-Demand Balance
- ✓ Power Balance Strategy
- ✓ A Project Outline and Road Map





(6) 4th Seminar (4th Steering Committee)

- Date: 18 June 2016
- Venue: Bijoy Hall, Bidyut Bhaban, Power Division, MoPEMR
- Discussion Point: Explain for Draft Final Report
  - ✓ Economic Development
  - ✓ Primary Energy Balance
  - ✓ Power Balance
  - ✓ Cost and Tariff Balance

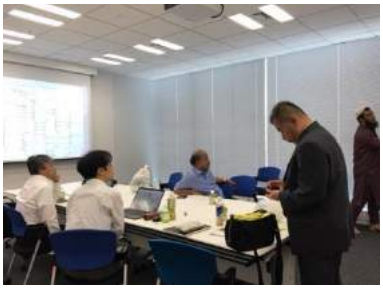




(7) Official comments meeting for Final Report (FR)

- Date: 1,2,4 August 2016
- Venue: TEPSCO Headquarter (Tokyo)
- Discussion Point:
  - ✓ Economic Development
  - ✓ Primary Energy Balance
  - ✓ Power Balance
  - ✓ Cost and Tariff Balance





(8) Official comments meeting for Final Report (FR)

- Date: 7 September 2016
- Venue: TEPCO Headquarter (Tokyo)
- Discussion Point:
  - ✓ Continuous Technical Support for Post-PSMP2016





Technical Focal Poits

1.6 Focal points

1.6.1 PSMP 2010 Review

(1) Economic Development

Table 1-3 and Figure 1-3 compares the actual performance of GDP growth rate with the projected growth rate in PSMP 2010 and the target of GDP growth rate in the Sixth Five-Year Plan that was set forth by the GOB in 2011. During the period of the Sixth Five-Year Plan, Bangladesh achieved annual average of 6.3% growth rate. This was higher than the actual growth rate in each of the past five-year plans (1st-5th) and the result implies that the country started taking a path of rapid economic growth.

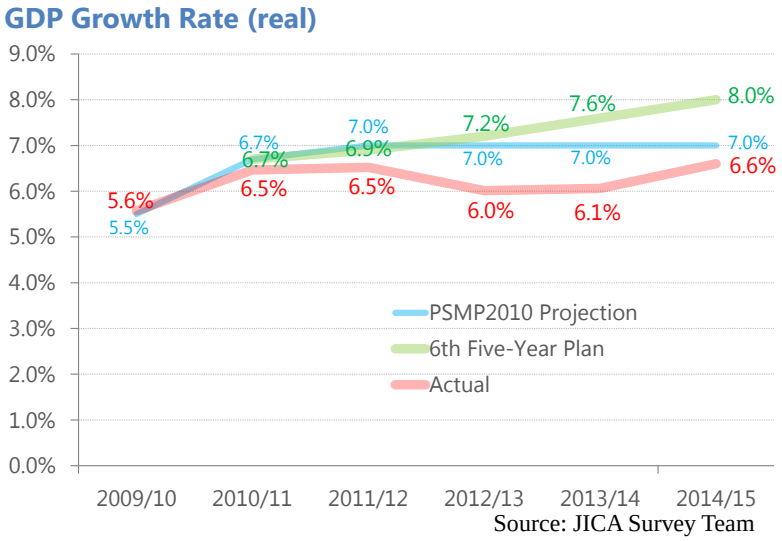
However, the economic growth rate still underperformed the target of the Sixth Five-Year Plan (average 7.3% growth) every year and the gap was widened in the later years. The actual growth rate was also lower than the projection of PSMP2010 that expected the Bangladesh economy to attain 7% growth. The main factor of this gap is supposed to be the delay of economic reforms for inducing further economic growth. The country may not be able to fully reap the opportunity of economic development and the growth rate may continue underperforming the government's expectation unless economic policies to promote the development are not in place as planned.

Table 1-3 PSMP2010 Review (Economic Development)

FY	GDP Growth Rate (real price)		
	PSMP2010 Projection	6th Five-Year Plan	Actual
	[%]	[%]	[%]
2009/10	*5.5%*	-	*5.6%*
2010/11	6.7%	6.7%	6.5%
2011/12	7.0%	6.9%	6.5%
2012/13	7.0%	7.2%	6.0%
2013/14	7.0%	7.6%	6.1%
2014/15	7.0%	8.0%	6.6%
Average	6.9%	7.3%	6.3%

Source: JICA Survey Team

Note: the average in the table is the five-year average from FY2010-2011 to FY2011-2012



Source: JICA Survey Team

Figure 1-3 PSMP2010 Review (Economic Development)

(2) Domestic Coal Production

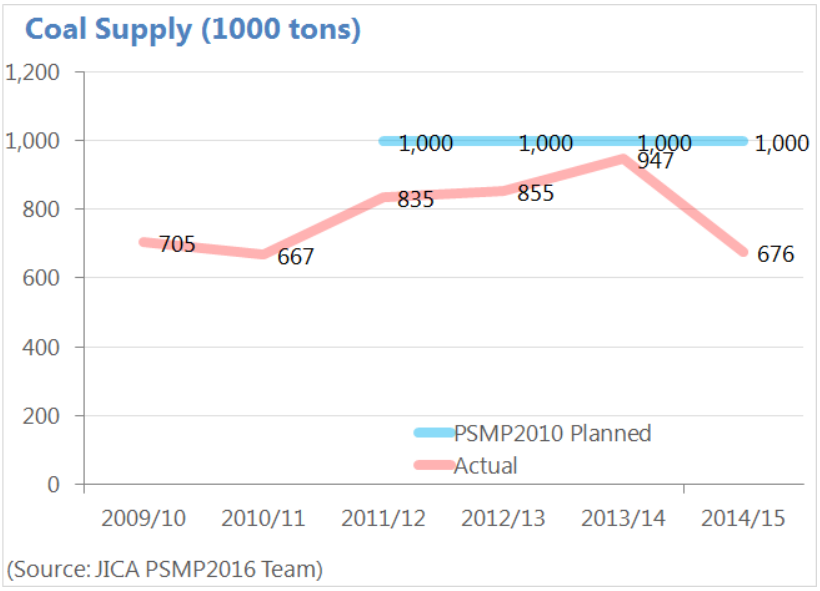
Table 1-4 shows the performance and the forecast of coal production in PSMP2010 and Figure 1-4 shows them by chart. Annual production of 1 million tones will be possible using existing facilities.

New longwall mining equipment called LTCC (Longwall Top Coal Caving) for thick coal seams was introduced in May 2013 from China and the mining height was increased from 3 meters to about twice this. Actual mining height is not clear, but mining efficiency was obviously improved. The coal production in 2013/14 achieved 0.947 million tons. However, in 2014/15, the figure decreased to 0.676 million tons. The main reason for this was a delay in the withdrawal and installation of the new equipment on-site. It is normal for people to take time to become skilled in the use of new equipment. If they can master the operation technology of the new facilities, it is surmised that 1,000,000t is quite possible.

Table 1-4 PSMP2010 Review (Coal Supply)

FY	Coal Supply		
	PSMP2010 Planned	Actual	Gap
	[1000tons]	[1000tons]	[%]
2009/10		705	
2010/11		667	
2011/12	1,000	835	84%
2012/13	1,000	855	86%
2013/14	1,000	947	95%
2014/15	1,000	676	68%
Average	1,000	781	83%

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-4 PSMP2010 Review (Coal Supply)

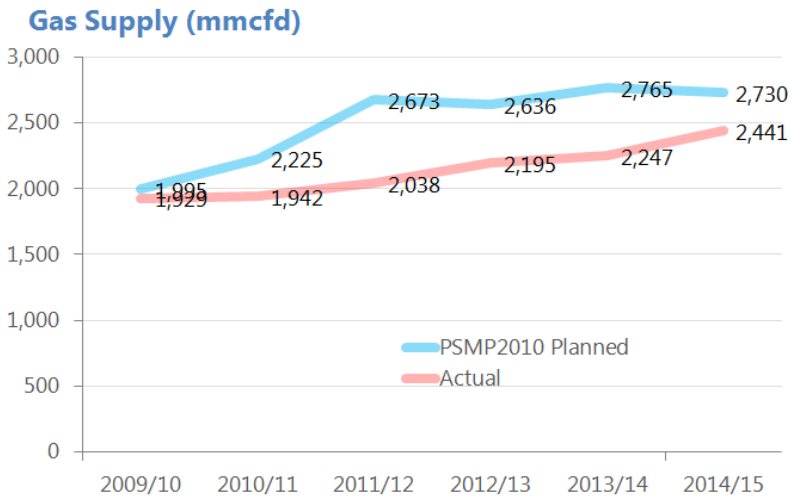
(3) Gas Supply

Five year gas supply projection in the PSMP2010 was reviewed against the actual supply records from 2009/10 through to 2014/15. The results show that the actual supply figure is 15 points lower than that of the projected figures. The projection was made based on the gas reserve data by Hydrocarbon Unit (HCU) (2011); however, the projection did not reflect the gas field development plan or investment plan for new and/or existing gas fields after 2010/11. There are also differences in gas reserve data between Hydrocarbon Unit (HCU) (2011) and USGD/Petrobangla. Hydrocarbon Unit (HCU) (2011) uses P90/P50/P10 while USGD/Petrobangla uses P95/Mean/P05 for gas reserve assessment, hence the USGD/Petrobangla gas reserve appears smaller. The difference between the projection and actual is considered as a combination of all these factors.

Table 1-5 PSMP2010 Review (Gas Supply)

FY	Gas Supply		
	PSMP2010 Planned	Actual	Gap
	[mmsfd]	[mmsfd]	[%]
2009/10	1,995	1,929	97%
2010/11	2,225	1,942	87%
2011/12	2,673	2,038	76%
2012/13	2,636	2,195	83%
2013/14	2,765	2,247	81%
2014/15	2,730	2,441	89%
Average	2,504	2,132	86%

Source: JICA Survey Team, based on the HCU and Petrobangla data



Source: JICA Survey Team, based on the HCU and Petrobangla data

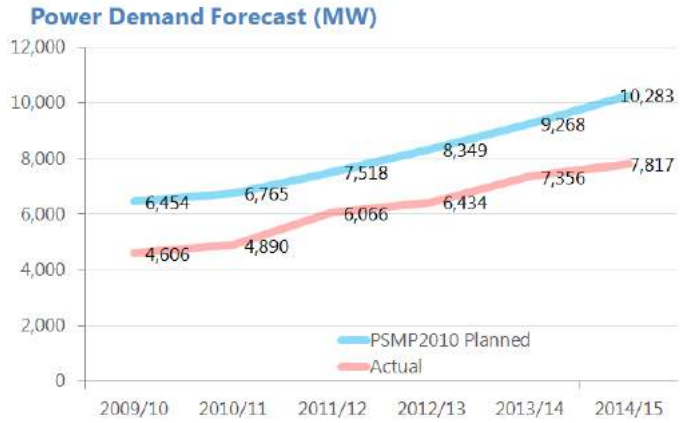
Figure 1-5 PSMP2010 Review (Gas Supply)

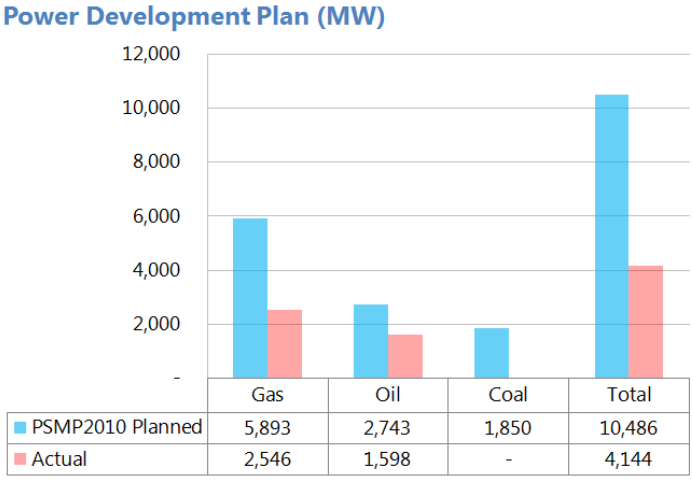
(4) Power Demand and Power Development Plan

The figure below shows the five-year power demand forecast in PSMP 2010 and the actual power demand. When PSMP 2010 was formulated five years ago, the demand was estimated to increase to around 10,000 MW by 2015. However, the actual demand in 2015 was approx. 80% of the estimate, around 8,000 MW.

The increase in the power demand including potential demand driven by the rapid economic development in recent years is expected to continue. The shortage of supply is considered to be the main cause of the continuation of this imbalance between the supply and demand. The figure below shows that the actual outputs of the gas and coal thermal power generation were only at 40% and 60% of the outputs described in PSMP 2010, respectively. In the case of the coal thermal power generation, a very important base load power source in the energy mix, while the output in 2015 was forecast at 1,850 MW in PSMP 2010, even the construction of coal power plants has not been commenced five years after the formulation of the plan. The lack of integrated planning and implementation of the construction of large-scale port facilities indispensable for the stable import of fuel and the construction of the power plants and the increased difficulty in fundraising for such a large-scale infrastructure development are considered to be major factors for the failure to develop power generating facilities as planned.

Therefore, it is considered necessary for the Energy Division and the Power Division to develop an organizational structure and operating system more integrated than before and take concerted measures to formulate a joint infrastructure development plan, to raise fund in the public-private partnership and to develop infrastructure systematically for the achievement of the stable energy supply, a source of the future economic development.





	Gas	Oil	Coal	Total
PSMP2010 Planned	5,893	2,743	1,850	10,486
Actual	2,546	1,598	-	4,144

Source: JICA Survey Team

Figure 1-6 PSMP2010 Review (Power Development Plan)

1.6.2 Economic Development Policy

(1) Current Status and Issues

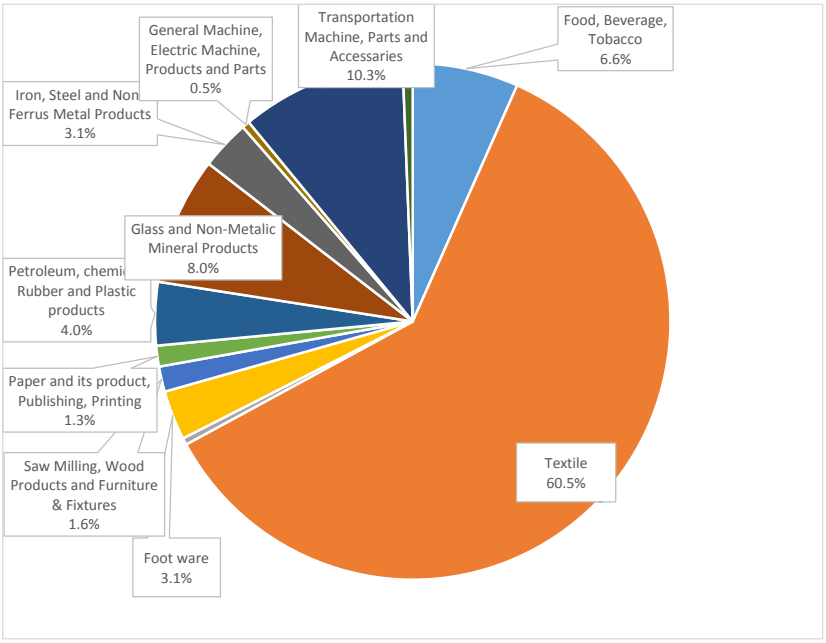
Bangladesh's economy has seen steady growth since independence was declared in 1971. GDP per capita has been steadily expanding since the 1990s, when the ready-made garments (RMG) sector emerged as a major export industry for the country. GDP annual growth rate during the Sixth Five-Year Plan from 2011 to 2015 averaged 6.3%. According to the Seventh Five-Year Plan formulated by the Government of Bangladesh, the average GDP growth rate from 2016 to 2020 is expected to reach 7.4%.
Based on this, the JICA Survey Team conducted Bangladesh's economic forecasting up to the year 2041 and the result is summarized in the following table. This projection assumes that Bangladesh's economy continues to grow as projected in the Seventh Five-Year Plan during the first half of the 2020s, and GDP growth rate is expected to become moderate after the mid-2020s, when the country's economic development reaches a certain level of maturity. Bangladesh's economy will continue to grow steadily so that its GDP per capita (nominal base) is expected to reach 10,993 US$ in 2041.
According to the income classification by the World Bank, Bangladesh will become a member of the upper-middle-income economies in the 2020s and will get close to the high-income economies by 2041 if the economic development is achieved as projected.

Table 1-6 Projection of GDP and GDP per capita up to 2041

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD) *1	93,236	126,630	181,282	258,598	351,109	453,642	587,665
GDP Growth Rate (p.a.) *1	6.1%	6.3%	7.4%	7.4%	6.3%	5.3%	4.4%
GDP per capita (USD) *1	615	787	1,063	1,444	1,883	2,357	2,970
GDP per capita (USD) *2	760	1,207	1,998	3,270	5,060	7,396	10,993

Note: Average growth rate is a five-year average except in the column for 2041, which is a six-year average.
*1: Real Basis at 2005 price
*2: Nominal Basis
Source: JICA Survey Team

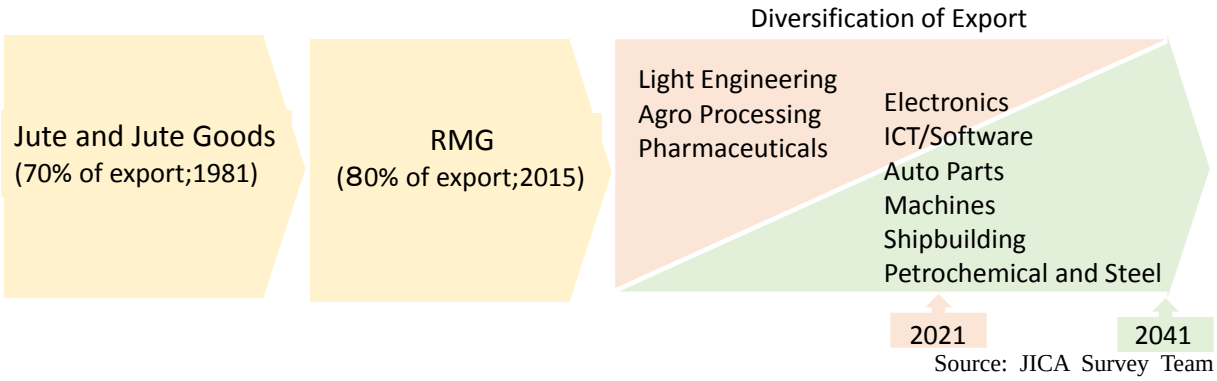
Until now, Bangladesh's economic growth has been maintained by labor-intensive industries such as the garment industry. However, heavy dependence on these industries is not sufficient to sustain further economic growth on a long-term basis. It is necessary to achieve industrial structural changes in Bangladesh by diversifying industries and to foster high value added industries by implementing proactive industrial policies.
Present value added by sub-sectors in the manufacturing sector of Bangladesh is shown in the figure below. The textile industry is the largest in the manufacturing sector and accounts for approximately 60% of the total value added in the sector. In addition, there exist other industries such as "machinery and parts", "processed foods", "plastic products" and "metal products" in the manufacturing sector, but these industries' share in value added is still limited. These industries may possibly change the industrial structure of Bangladesh's economy.



Note: (p) indicates "provisional".
Source: Prepared by JICA Survey Team referring to BBS "Bangladesh National Account Statistics: Sources and Methods 2013-14"

Figure 1-7 Value Added by Large and Middle Scale Manufacturing Industries

The following figure is a conceptual illustration of Bangladesh's future industrial development up to 2041. While Bangladesh's economy will continue to depend greatly on traditional industries, namely the RMG, jute and leather industries, until the beginning of the 2020s, new industries will grow gradually. Export items are expected to become diversified, such as light engineering products, processed foods and pharmaceutical products. From then on, i.e. toward 2041, this diversification will expand to higher value added new industries and products such as electronics, information and technology/software, automobile parts, machinery and shipbuilding.
To achieve such industrial development, it is necessary to implement various industrial policies including incentives for foreign direct investment, infrastructure development and industrial human resource development.



Source: JICA Survey Team

Figure 1-8 Illustration of Industrial Development in Bangladesh Toward 2041

(2) Targets to Achieve

- Achieve high economic growth rates with an average annual growth rate of 7.4% until 2025 and become a member of upper-middle-income economies (at a GNI (Gross National Income) per capita of 4,126 US$ or more) in mid-2020s.
- Maintain high economic growth from 2025 onward and achieve GDP per capita equal to that of

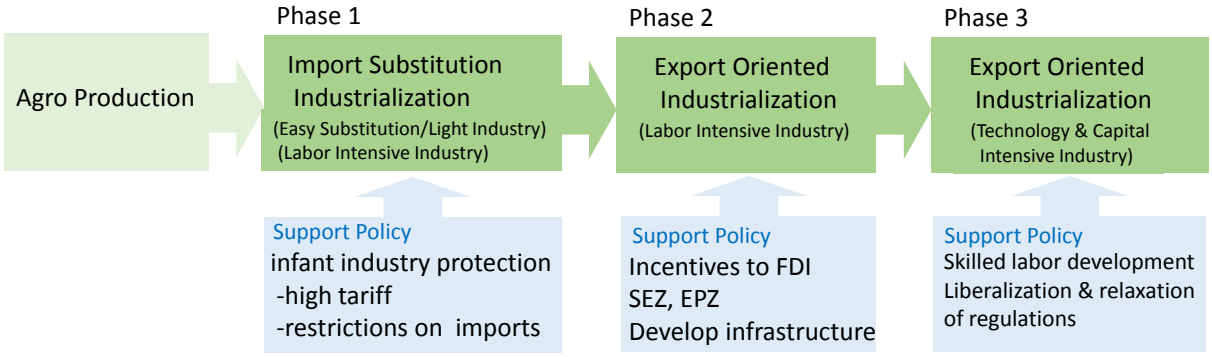
high-income economies (at a GNI per capita of 12,736 US$ or more) by 2041.

- Foster high value-added industries and facilitate export-oriented industrialization so as to achieve high economic growth rates. Toward this end, implement appropriate industrial policies according to the stage of industrial development.

(3) Roadmap

It is estimated that Bangladesh is currently on the way to Phase 2 of the following industrialization process and is likely to move toward Phase 3. To maintain long term economic growth without stalling current favorable economic conditions, it is necessary to implement the following measures for further advancement of domestic industries.

- Short and medium term: incentives for foreign direct investment; various infrastructure developments such as construction of industrial parks like SEZ, ports, roads, railways and power plants.
- Medium and long term: construction of industrial parks; facilitation of infrastructure development; industrial human resource development such as development of skilled labor force; promotion of deregulation and economic liberalization.



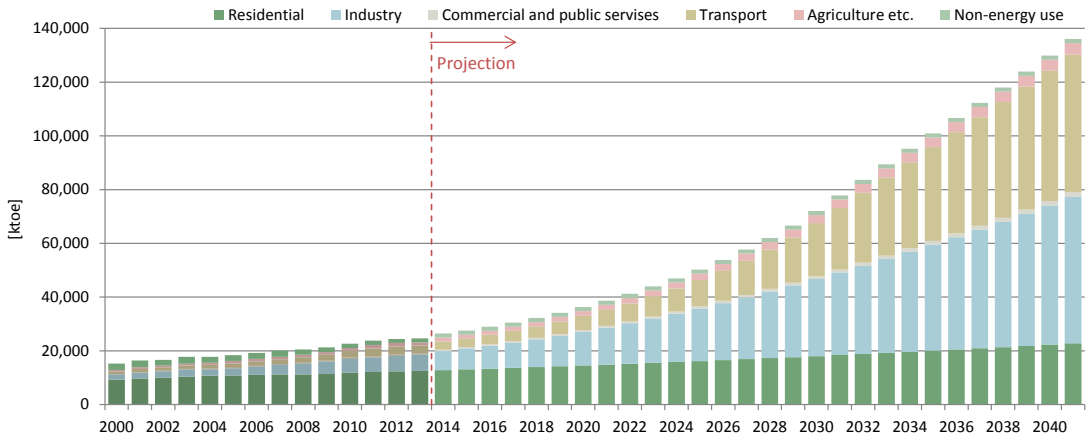
Source: JICA Survey Team

Figure 1-9 Stages of Industrial Development and Necessary Policy Measures to Support This

1.6.3 Primary Energy

(1) Current Status and Issues

Based on the aforementioned economic growth outlook, energy consumption outlook by sector until 2041 was studied. Final energy consumption outlook and the sectoral breakdown in the BAU scenario without considering the effects of energy-saving measures are indicated in the figure below.



Source: JICA Survey Team

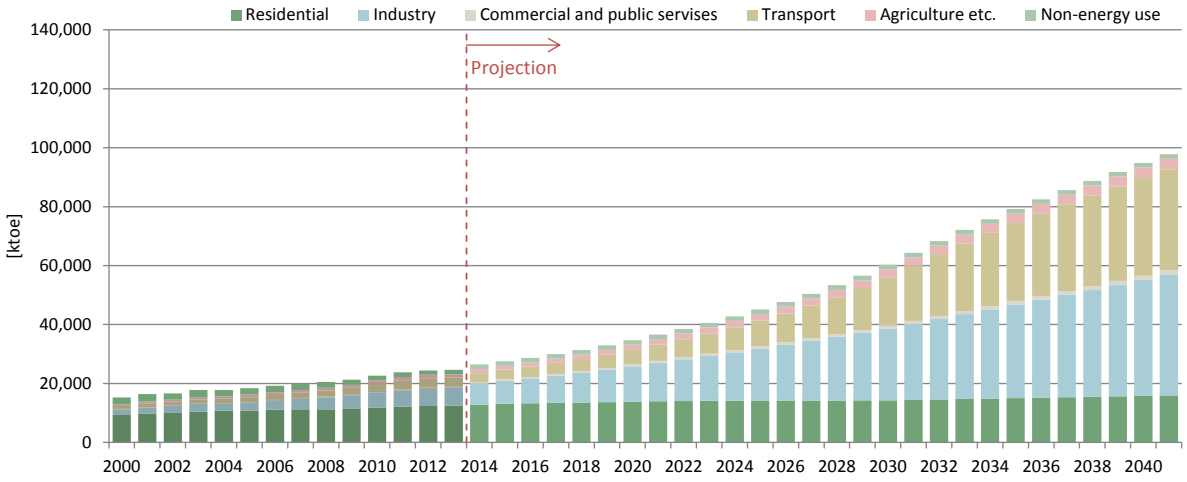
Figure 1-10 Projection of Final energy Consumption (BAU Scenario)

With the rapid advancement of industrialization in Bangladesh, it is expected that there will be a shift in the industrial sector from labor-intensive industries like RMG to energy-intensive industries. As a result, energy consumption in the industrial sector is expected to increase rapidly. In addition, in the transport sector, as growth in GDP per capita is expected to facilitate vehicle ownership from the middle of the 2020s onward, it is estimated that energy consumption in the transport sector will significantly exceed that of the residential sector in the future.

It is estimated that the average annual growth rate of total final energy consumption including the aforementioned two sectors will be 6.3% between 2014 and 2041. According to this BAU scenario, the growth in energy consumption will slightly exceed the GDP growth rate (annual average real GDP growth rate is 6.1%). Though total energy consumption per GDP tends to decrease until the middle of the 2020s, it is expected to turn upward and, in 2041, reach the same level as the actual figure in 2014 (3.42 toe/million BDT).

For the purpose of relieving rapid growth in energy consumption in Bangladesh in the future, "Energy Efficiency and Conservation Master Plan up to 2030" (EECMP) was formulated in March 2015, supported by JICA. In light of the survey results from EECMP and based on the assumption that measures proposed in the Master Plan will be properly implemented, it is estimated that total energy consumption per GDP will decrease as follows in the Energy Efficiency Scenario. The difference between the figure in this Scenario and the target set in the EECMP (energy consumption per GDP in 2030 is -20% compared to 2014) was due to the difference in definition. For example, calculation in this Scenario considered the transport sector, which was not included in the EECMP's calculation. If calculation is carried out on the basis of the same definition, energy consumption per GDP in 2030 is -20% and that in 2041 is -23% compared to 2014.

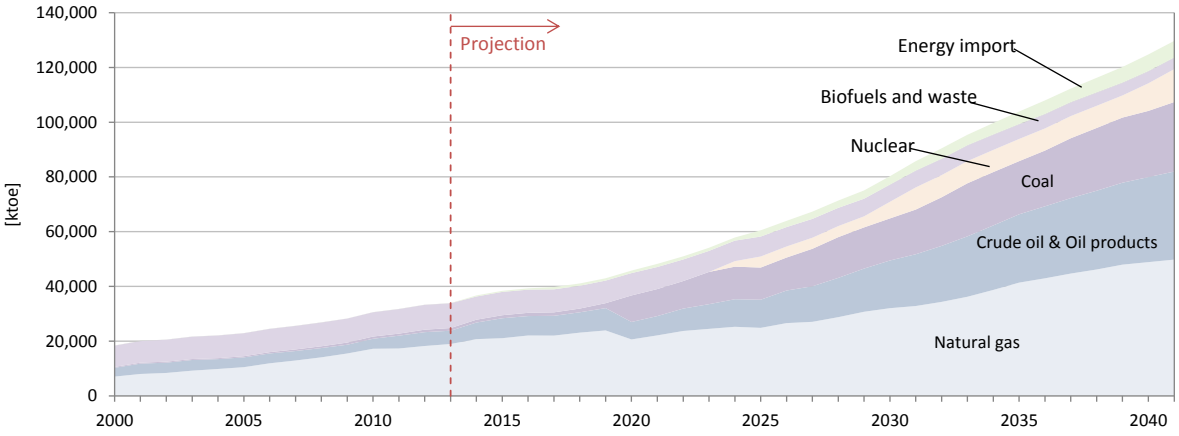
- 2.65 toe/million BDT as of 2030 (decrease of 23% compared to 2014)
- 2.56 toe/million BDT as of 2041 (decrease of 25% compared to 2014)



Source: JICA Survey Team

Figure 1-11 Projection of Final Energy Consumption (Energy Efficiency Scenario)

The projection of primary energy supply calculated based on this is shown in the following figure and table (in the case of Scenario 3 among the five scenarios that are discussed in Chapter 12). Average annual primary energy supply will grow at a moderate rate of 4.8% up to 2041. However, in addition to significant growth in energy supply from coal and renewable energy, which is mainly used for power generation, energy supply from oil slightly exceeds the average figure due to increasing demand in the transport sector.



Source: JICA Survey Team

Figure 1-12 Projection of Primary Energy Supply – Scenario 3

Table 1-7 Projection of Primary Energy Supply – Scenario 3

Primary Energy Sources	2014		2041		Annual growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**50,149**	**(38%)**	**3.3% p.a.**
Oil (Crude oil + refined products)	6,263	(17%)	**32,153**	**(25%)**	**6.2% p.a.**
Coal	1,361	(4%)	**26,273**	**(20%)**	**12.7% p.a.**
Nuclear power	-	-	**11,942**	**(9%)**	**-**
Hydro, solar, wind power and others	36	(0%)	**197**	**(0%)**	**6.5% p.a.**
Biofuel and waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Power (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**130,827**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

(2) Targets to Achieve

- Based on the assumption of introducing energy-saving measures proposed in EECMP, GDP intensity of total energy consumption will decrease by 23% in 2030 compared to 2014 (-20% if calculated based on the same definition as EECMP) and will decrease by 25% in 2041 compared to 2014 (-23% if calculated based on the same definition as EECMP).
- To attain the above goal, the aim is to achieve reductions in energy consumption of 16% in 2030 and of 28% in 2041 compared to the BAU scenario.
- Though energy saving in the transport sector was not taken into consideration in EECMP, it needs to be noted that motorization will be accelerated significantly due to income growth. As a result, energy consumption in this sector is expected to expand dramatically. To achieve the above goal, the aim is to realize a reduction in energy consumption in the transportation sector of 33% compared to the BAU scenario.

(3) Roadmap

To implement the Action Plans proposed in the EECMP.

- Energy management system (targeted for demand in the large-scale industrial sector and the commercial sector)
- Performance labeling and minimum performance standards for electrical appliances (mainly targeting energy demand in the residential sector)
- Implementation of energy-saving construction standards (i.e. revised BNBC)
- Low-interest loan programs for the installation of EEC equipment

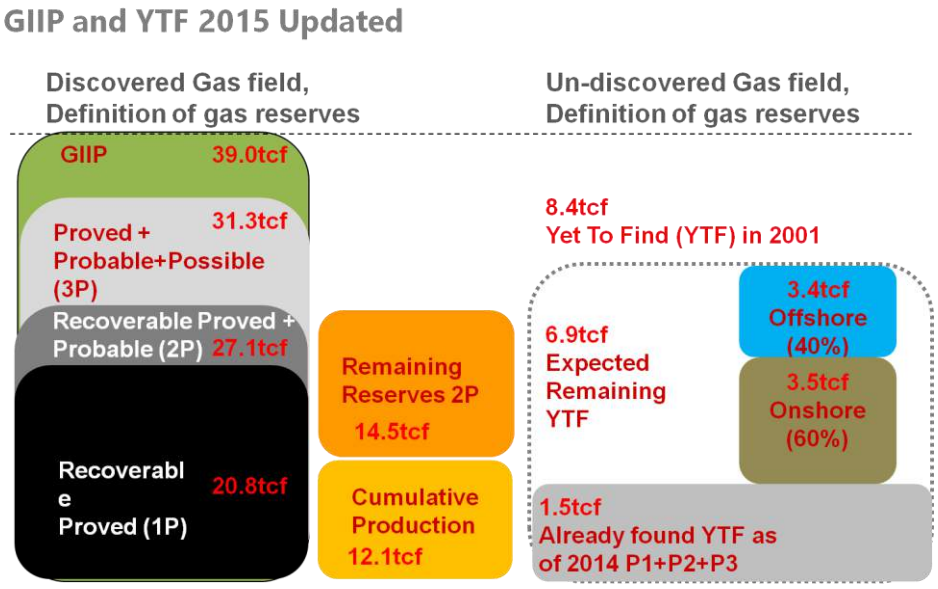
In the transport sector, not only the improvement of fuel consumption efficiency for passenger vehicles but also the improvement of traffic conditions in urban areas (within Dhaka city), which are affected by chronic heavy traffic congestion, needs to be considered.

- Policy measures for improvement of passenger vehicles' combustion efficiency (e.g. eco car program)
- Improvement of road network development in urban areas (e.g. road widening, construction of flyovers)
- Development of railway network (e.g. MRT development within Dhaka city, Dhaka-Chittagong railway network development)

1.6.4 Natural Gas (Domestic)

(1) Current Status and Issues

Natural resources, if used, will run out someday. This also applies to natural gas in Bangladesh. Recoverable Proven reserve of natural gas in Bangladesh is 20.8 TCF. 12.1 TCF had been produced and consumed by 2014, and therefore the remaining gas reserve will be 8.7 TCF, corresponding to a Reserve Production Ratio of 9.5 years.



Source: Field-wise natural gas reserve estimates (Petrobangla, Nov. 2014), and Draft Five Year Gas Supply Strategy 2015-2019)

Figure 1-13 Gas Resource Balance

From an international economic point of view, the people of Bangladesh should recognize the true value of domestic natural gas. They need to maximize its recovery and use it efficiently.

In the area of oil and gas field development, significant technological advancement has been made since 1990, and oil and gas recovery has improved significantly. Gas development in Bangladesh needs to benefit from such advancement and to introduce some mechanism to take advantage of it.

Bangladesh has invited IOCs (International Oil Companies) for offshore development; however, it has not been particularly interested in working with technologically advanced and financially sound IOCs for onshore gas field development.

In order to maximize the recovery of gas from onshore fields and develop them more efficiently, it is important to invite these IOCs for onshore gas development. Existing PSC should be amended to attract such IOCs. International tenders to be carried out under the revised PSC, and partnerships between domestic production companies (BAPEX, BGFCL, and SGFL) and IOCs should be encouraged.

Natural gas will run out someday. The role of BAPEX should be changed to allow it to acquire energy asset overseas in order to contribute to energy security in future, in a similar manner to that of ONGC in India.

Gas Use Efficiency is one of the critical issues that needs to be introduced. "Cheap gas" will not be available in the future and gas users need to enhance their efficiency to save the country's indigenous gas resources. Both the Urea Manufacturing Sector and Power Sector are major gas users and have a significant impact on the overall gas consumption.

Urea is manufactured from natural gas. The world benchmark efficiency for Urea Manufacturing is 25mcf/ton, while average efficiency in Bangladesh was 44 mcf/ton as of 2014 FY, much higher than that of the international benchmark. Provided that the international benchmark is used in the country, 130 mmscfd of gas would be saved in manufacturing 2,375,000 tons in 2014 and this figure would translate into the power plant equivalent of 1000 MW.

Gas Consumption for the Power Sector (under BPDB) was 337.4 BCF in FY 2014 while Power Generation Capacity was 8,340 MW and Generated Power was 42,200 GWh. From these figures, it is assumed that current power generation efficiency is around 38%. Provided that efficiency can be raised to 45%, which is considered the international benchmark for a gas based power plant, Energy gas consumption will be reduced to 285 BCF, and the difference of 52 BCF can be said to be wasted. This is equivalent to 1,300 MW in power plant annual operation.
In addition, it appears that power generation efficiency of Captive Power is not necessarily high enough. Further investigation is necessary but low gas efficiency is a waste of resources and some penalty should be imposed.

It is necessary to enhance the efficiency to the international level and a supporting legal framework and regulations need to be put in place.

(2) Targets to Achieve

1) In order to attain efficient and economical development of domestic gas resources, introduction of technologically advanced and financially sound IOCs is considered very important. Policy and legal framework should be reviewed and changed. A new legal/regulation scheme should be developed by 2019.

2) Acquisition of energy resources from overseas is necessary in order to maintain and/or increase the national energy assets belonging to Bangladesh. (Mid/Long Term)

3) Gas Use Efficiency to be enhanced to the international level with the use of the best commercially available technology (Short/Mid Term).

(3) Roadmap

- Amendment of PSC by 2019 to attract IOCs and encourage them to make investments in Bangladesh
  - International Tender based on new PSC
  - Encourage forming of partnerships between IOCs and domestic gas production companies, i.e., BAPEX、BGFCL (Bangladesh Gas Field Company Limited), SGFL (Sylhet Gas Field Limited)

- Role of BAPEX and associated legal framework to be changed by 2019
  - Acquisition of Energy resources overseas by 2028

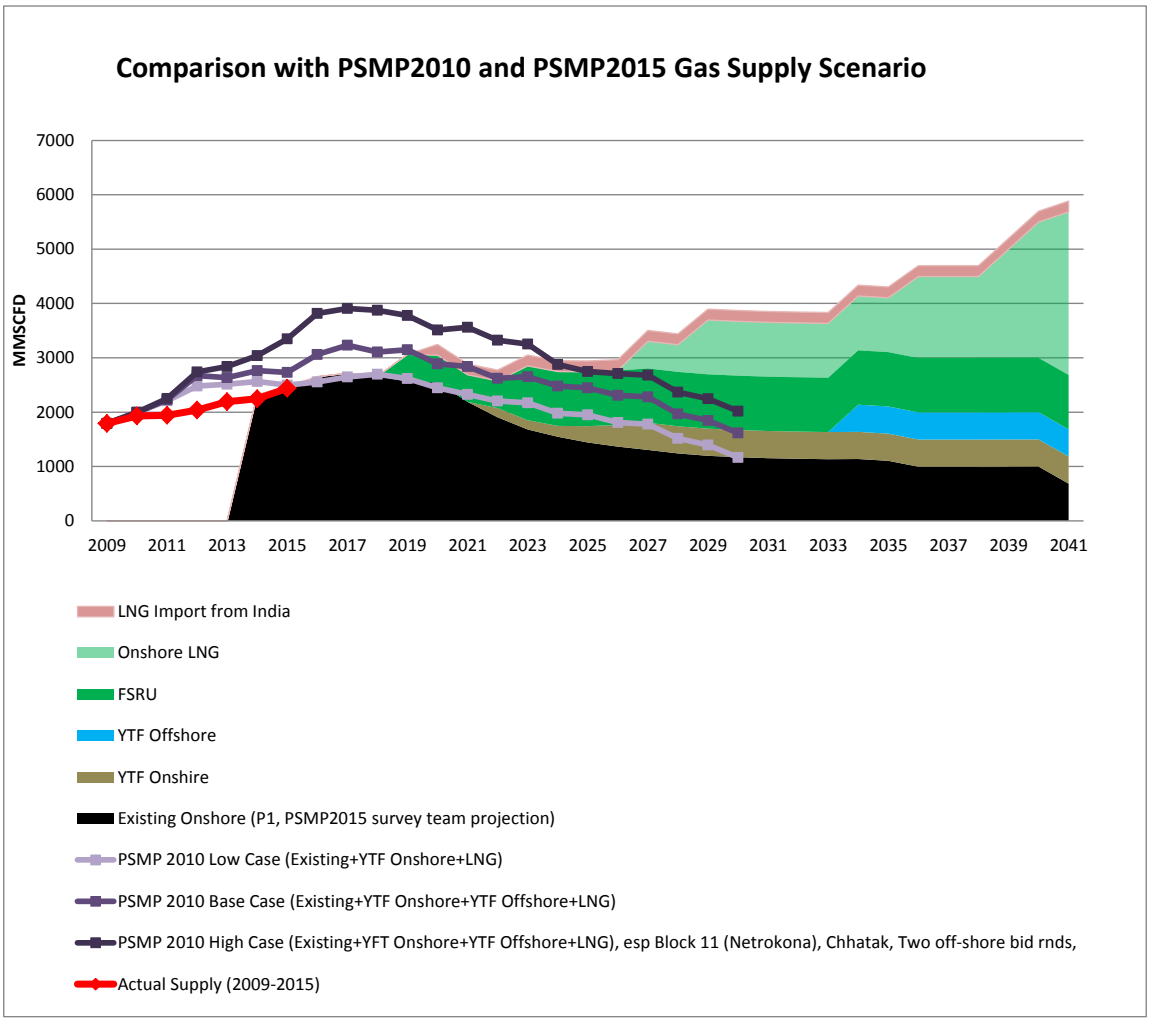
- Legal framework to enhance gas efficiency to be in place by 2019
  - Efficiency to be enhanced to the international level and discourage the use of substandard facilities.

- Gas Transmission and Distribution infrastructure to be modernized by 2019
  - Transmission and Distribution gas Infrastructure should be electronically mapped and able to introduce advanced monitoring and control systems to support the efficient use of gas.

1.6.5 Natural Gas (LNG Imports)

(1) Current Status and Issues

Gas Production from the current domestic gas fields in 2015 was 2,500 mmcfd and will reach a peak production of 2,700 mmscfd in 2017, then start to decline. However, Gas demand in Bangladesh forecasts a significant increase in future. The demand and supply gap must be filled by gas (LNG) imports. The first LNG will be introduced in 2019 at the rate of 500 mmscfd, which corresponds to 17% of gas demand. This percentage is forecast to increase to 40% in 2023, 50% in 2028, and 70% in 2041.



Source: JICA Survey Team

Figure 1-14 Gas Supply Forecast 2016~2041

Under these circumstances, gas (LNG) import infrastructure, including an LNG Import and re-gasification terminal, and connecting pipeline to the existing transmission and distribution infrastructure, needs to be constructed urgently to fill the supply and demand gap.
Currently, introduction of LNG via FSRU, initiated by Petrobangla, is underway, and concurrently, construction of a land LNG terminal by Power Cell is also under discussion. It is important to understand the difference in these systems in view of economics, construction schedule and operational risk, and it is advisable to prepare in the Master Plan the introduction of LNG to Bangladesh.
The economics of a land LNG Terminal require large upfront investment for land acquisition and

infrastructure construction; however, gas handling capacity can be increased with the increase in demand with minimum cost and schedule. Unit operation cost will be lower with the increase of handling volume. It is also important to note that larger size tankers can be used for LNG delivery and this will benefit the land LNG Terminal by reducing the unit transportation cost.
In view of the construction schedule, a Land LNG terminal requires 10 years including land acquisition and the associated re-settlement plan. FSRU requires less than 3 years for commercial operation.
It should be noted, however, that the current FSRU project in Bangladesh would require more than 60 times' the LNG delivery using Ship to Ship Transfer, and would be vulnerable to weather conditions.
LNG Terminal Capacity will be expanding and transmission capacity of the pipeline infrastructure from LNG terminals to the existing distribution infrastructure may need to be studied in advance. Sending out gas pressure at the terminal should be studied to allow the use of higher pressure for gas transportation, eliminating booster compressors downstream. Higher pressure in the system will impact existing gas systems and well head separation performances. The LNG Master Plan should be prepared to optimize and solve potential operational issues.
Fluidization of LNG supply has started already and the inflexible Take or Pay Contract has been an old legacy in US and Europe. On the other hand, Asia has suffered from an expensive gas pricing system known as the Asian Premium. It is important to tie up with other LNG importing Asian nations and consider the introduction of spot procurement, and discuss product exchange (trading) among the LNG importing nations. It is advisable to own a slightly larger storage capacity and loading facility for re-export. Terms of sales/purchase agreements for LNG are not simple. It is important to set up a strategy taking the above into consideration.
It should be noted that the current LNG price is about ten times higher than that for Bangladesh's domestically produced and marketed gas, where the current gas price for the electric power sector is 1.02 USD/Mcf and that for the fertilizer sector is 0.94 USD/Mcf. In the near future the dependence on LNG over the total gas supply will sharply increase, and the dependency on LNG is projected to exceed 70% of the total gas supply in the year 2041. Domestic Gas prices need to accommodate the LNG price. Under these circumstances, existing fertilizer manufacturing facilities will not be able to produce economically competitive product and the power price from old existing facilities will not be able to compete economically with higher efficiency facilities. Similarly, more attention should be given to gas leaks and system loss from gas transmission and distribution infrastructure to prevent economic loss, i.e., "the lost opportunity cost".
It is very important to review the integrity of the existing infrastructure, and swiftly introduce an electronic mapping system with object orientated features as a first step.

(2) Targets to Achieve

1) Land LNG Terminal: Commence 500mmscfd of gas supply in 2027, expanded to 2,000mmscfd in 2041
2) FSRU Phase 1: Commence gas supply of 500 mmscfd in 2019, and additional 500 mmscfd as Phase 2 in 2023

(3) Roadmap

- Master Plan for LNG Introduction to be prepared and completed by end of 2017, covering economic analysis, construction schedule, operational risks, energy security, and international cooperation (including joint LNG infrastructure operation)
- Initial land-based LNG terminal commences operation in 2027, supplying 500mmscfd of natural gas. The terminal is expanded to supply 3,000 mmscfd gas in 2041.
- FSRU Phase 1 and connecting pipeline to be completed and start supplying 500 mmscfd of gas in 2019
- Impact of LNG introduction on existing gas infrastructure and gas field facilities to be investigated and reinforcement plan to be prepared by 2019
- LNG Procurement Strategy to be prepared by 2018.

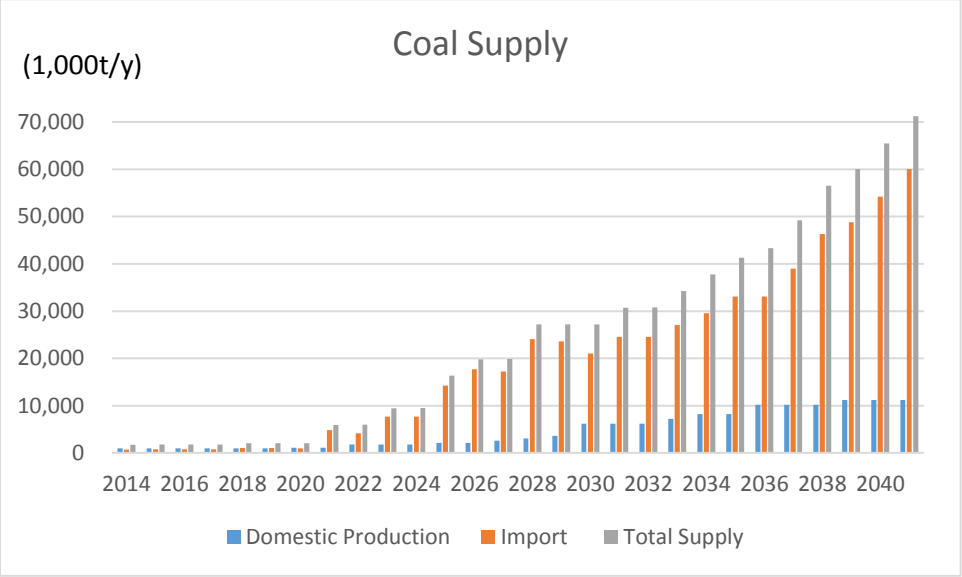
1.6.6 Coal

In this section, the infrastructure for import coal and domestic coal development is considered.

(1) Current Situation and Issues

(a) Infrastructure for import coal

1) As for the quantity of import coal in 2041, 60 million tons is expected.
2) Because the infrastructure for import coal is closely related to handling cost, it is left to the consideration of each power station plan at present. There are some options such as Coal Center + Barge Transport, Coal Center + Belt Conveyor Transport and Offshore Unloader + Barge Transport etc.
3) On the other hand, a Coal Center will be a major solution playing a key role in the future because a steady coal supply is the most critical issue for a power station.



Source: JICA Survey Team

Figure 1-15 Forecast of Coal Demand and Supply

(b) Domestic coal development

1) Coal will be the cheapest primary energy now and in the future and coal-fired power stations will increase in Bangladesh.
2) On the other hand, the coal-fired power stations in Southern Asia surrounding Bangladesh are increasing rapidly. As a result, the supply, the quality and the price of import coal will become very unstable in the future.
3) From the situation mentioned above, domestic coal development will become more important than at present in future, because high quality coal is abundant in Bangladesh.
4) The understanding of inhabitants is necessary for domestic coal development, and the government needs to perform awareness activities in order to gain the understanding of the nation.
5) Despite the high price paid for the coal mined by the Chinese contractor, the technology transfer from the contractor to Bangladeshi engineers has been limited. If this system of the mining continues, the increase in coal production with the development of new underground coal mines will not lead to the reduction in the production cost and, therefore, the stable supply of domestically produced coal will not be realized.

(2) Targets to Achieve

(a) Infrastructure for import coal

1) Enforcement of F/S for the import coal infrastructure
2) Construction based on the F/S

(b) Domestic coal development

1) Technology acquisition in coal mines for Bangladesh
2) Carrying out pilot operation of open cut mining technology in the Barapukuria coal mine.
3) Development permission for Digipara coal mine and Karaspir coal mine
4) Approval of small scale open cut mining at Phulbari after the pilot operation at Barapukuria coal mine

(3) Roadmap

(a) Infrastructure of import coal

1) Implementation of import coal infrastructure in the F/S.
- The F/S for the CTT (Coal Transshipment Terminal) planned in the Matarbari area has already been completed (Source: Preparatory Survey for the Construction and Operation of Imported Coal Transshipment Terminal Project in Matarbari Area in People's Republic of Bangladesh as a PPP infrastructure project).
- In this plan, phased development for CTT was recommended to provide sufficient flexibility, i.e., to expand the CTT when the power generation program development and realistic commission operation date (COD) become certain.
- The first phase of the CTT will commence operation in 2025 (planned amount of coal: 10.4 million t/year); the object of the second phase will include those power stations that commence operation by 2029 (amount of coal: 25.6 million t/year) and use the CTT.
- For the future, with an increase in the development of new coal-thermal power plants there is a need to implement the F/S for the infrastructure and plan for efficient coal transportation.
- It will be important to conduct a F/S on the possibilities of the construction of CTT in near future and offshore loading and unloading including an analysis of the actual record of the offshore loading and unloading in the Bay of Bengal.

2) Based on the F/S Construction
- For CTT (Coal Transshipment Terminal), efficient coal supply operation while ensuring long-term stability is desired. When planning in Bangladesh, it is important to take into account the natural characteristics such as the broad expanses of sand, cyclones and high rainfall, and the protection of precious animals and plants.
- When importing coal over a long period of time, facility planning that can respond to changes in the type of coal is desirable as, depending on the coal mine reserves, future coal mines and countries may change.
- The promotion of mechanization and securing of stable supply for offshore loading and unloading by floating crane; the implementation of early construction of the CTT.

(b) Domestic coal development

1) Because it will take about 10 years to develop a new coal mine and start production, production will begin in 2025 at the earliest even if it is prepared now. Therefore, it is necessary to carry out the

required preparation from a position of being able to do this now due to as much utilization of the excellent domestic resources as possible.

2) Unfortunately, the production of Barapukuria coal mines in 2015 was 0.68 million tons and did not reach 1 million tons as planned, but 1.1 million tons from U/G in 2020 and a total of 3.2 million tons (1.2 million tons from U/G and 2 million tons from O/C) from 2030 to 2041 are assumed.

3) In addition, it is assumed that total production will be 1.1 million tons by 2020, 5.7 million tons by 2030 and 11.2 million tons by 2041, considering the production scenario in which Dighipara and Kalaspir coalfields have high development possibility, including the Phulbari coalfield.

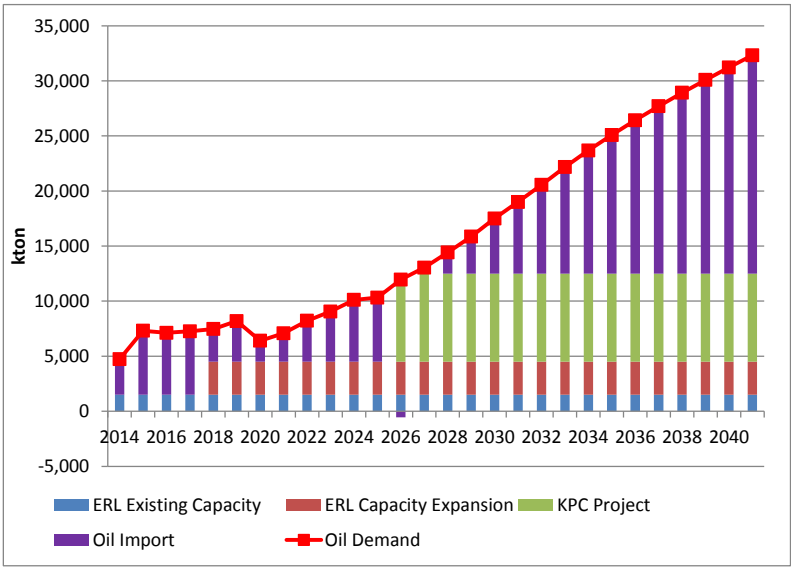
4) The acquisition of coal mine technology by Bangladesh
It should be the case that by 2020 systems have been established through which Bangladesh can learn in technologies such as mining, ventilation and mine safety technology for stable production in the Barapukuria coal mine, and that Bangladesh can play a key role in developing a new coal mine.
It is considered necessary to establish an institution for training mining engineers and a third-party organization for technology transfer, *e.g.* a mining college, in order to enable Bangladeshi workers to implement and evaluate the outputs of the programs and extend of the use of transferred technologies to other mines later in the medium- to long-term.

1.6.7 Oil and LPG

(1) Current Status and Issues

Bangladesh's current oil annual demand is around 5 million tons, and the self-sufficiency rate is only 5%. However, Bangladesh expects continuous economic development, and the industry sector and transport sector demand will lead drastic oil demand growth: 6 times higher in 2041 than in 2016 (average growth rate 7.4% p.a.), even under the "Energy Efficient and Conservation Scenario".

Bangladesh has several plans to extend or newly develop oil refineries; however, if the oil demand grows as projected, oil imports will be mandatory to meet the demand and keep increasing.



Source: JICA "Southern Chittagong" Survey Team and PSMP2016 Survey Team

Figure 1-16 Oil Demand and Supply Balance, 2014 to 2041

Furthermore, Bangladesh's LPG demand is only 2% of total oil demand, and less than 0.01% of the total energy demand. However, LPG consumption is expected to grow drastically as an alternative for households' cooking fuel (currently domestic natural gas) and transportation fuel.

The current price of LPG is two to three times higher than that of the pipelined gas, and may not be affordable for average households in Bangladesh. While Bangladesh rural households spend 4-7 % of their monthly income on traditional solid biomass, LPG at the market price would be 25%. If the government seriously intends to pursue universal access to modern energy, LPG may not be a good solution or may need some policy countermeasures. Subsidy of LPG may work to some degree to increase affordability; however, without sound consideration of the side effects and an exit strategy, LPG subsidy would create huge pressure on the national coffers, given the projected future demand.

In terms of affordability, biogas could be an alternative to promote universal access to modern energy, especially in rural areas.

(2) Targets to Achieve

- The government should define a strategic position for oil products in its holistic energy policy, and economic development policy.
- The government should develop an exit strategy for oil product subsidy.

(3) Roadmap

- A clear strategic positioning for oil products in the energy policy by 2017.
- Exit strategy for oil product subsidy by 2017.

1.6.8 Power Development Plan

(1) Current Status and Issues

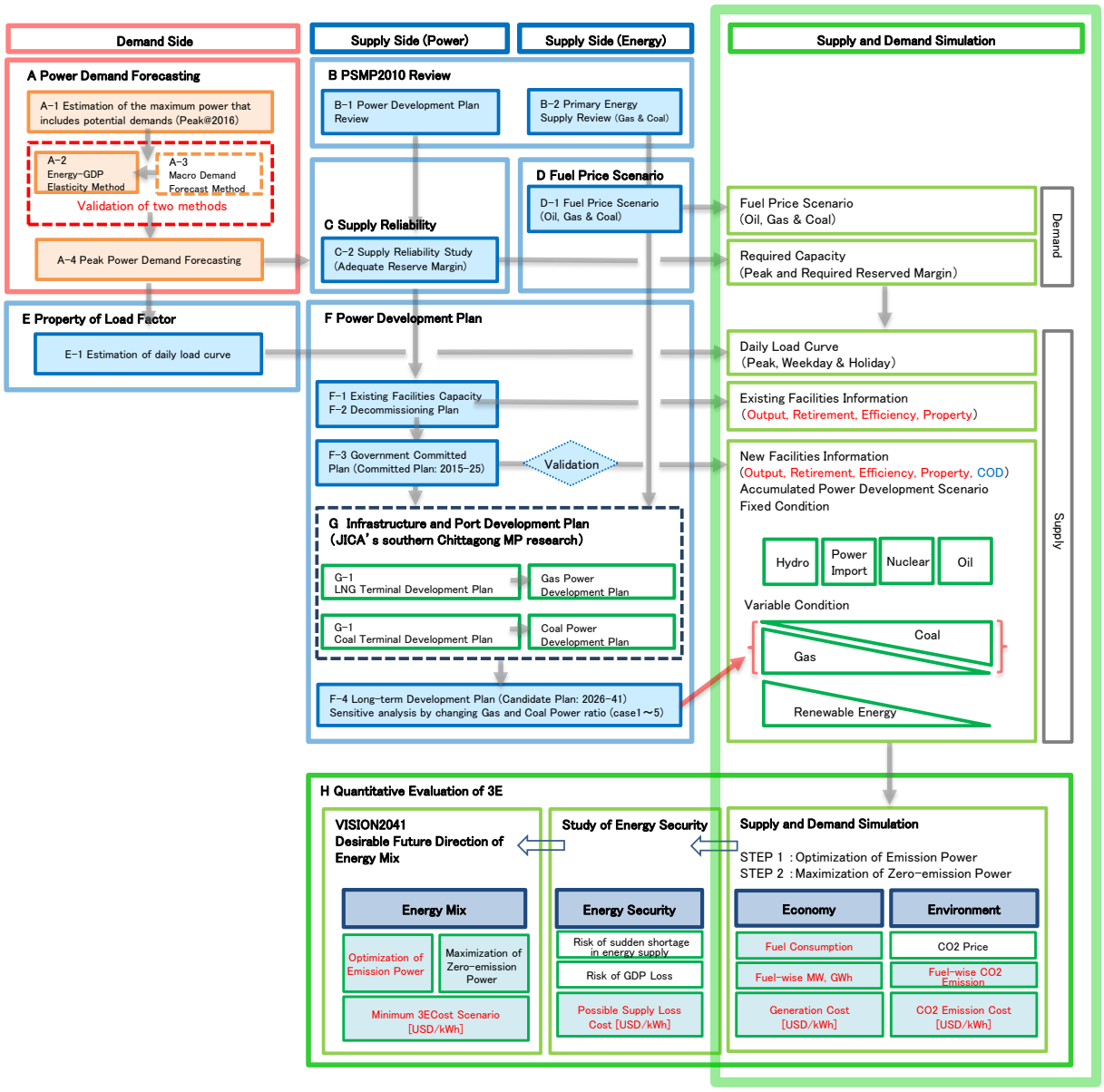
As mentioned in Chapter PSMP2010 review, five-year power demand by PSMP2010 and its actual performance had remained in about 8,000MW which is about 80% level of the plan, because it was delayed power plant construction which had been planned and necessary infrastructure such as port which is essential to stable fuel imports has not been established.

Therefore, it is considered necessary for the Energy Division and the Power Division to develop an organizational structure and operating system more integrated than before. They must also make concerted efforts to formulate a joint infrastructure development plan, to raise funds in the public-private partnership and to develop infrastructure systematically in order to achieve a stable energy supply, a source of future economic development.

(2) Targets to Achieve

The power demand forecast is an important factor in the formulation of a future power development plan (PDP). However, the accuracy of the actual demand forecast is at such a level that it is difficult to forecast even the demand for the next day accurately and, in fact, it is almost impossible to accurately forecast the power demand for several years or longer. Because of this unreliability of the demand forecast, it is not advisable to formulate a PDP optimal for a certain condition in future and promote actual power development in accordance with this PDP. In other words, it is very important in formulating a future PDP to consider all the elements, including the demand variables in the estimation, conduct a sensitivity analysis while changing these variables within their respective reasonable ranges for a certain system, and analyze the relationship between power generating facilities in the system and the economic, environmental and energy security values of the system.

Therefore, a long-term vision for the power source composition created by making a rough estimation of the future demand based on a scenario of the macro economic growth, simulating a demand/supply operation somewhat simply using the estimated demand scenario as a variable and formulating the optimal PDP is presented as a recommendation. The planning flow is as follows.



Source: JICA Survey Team

Figure 1-17 Power Development Planning Flow

1) Peak Power Demand Projection

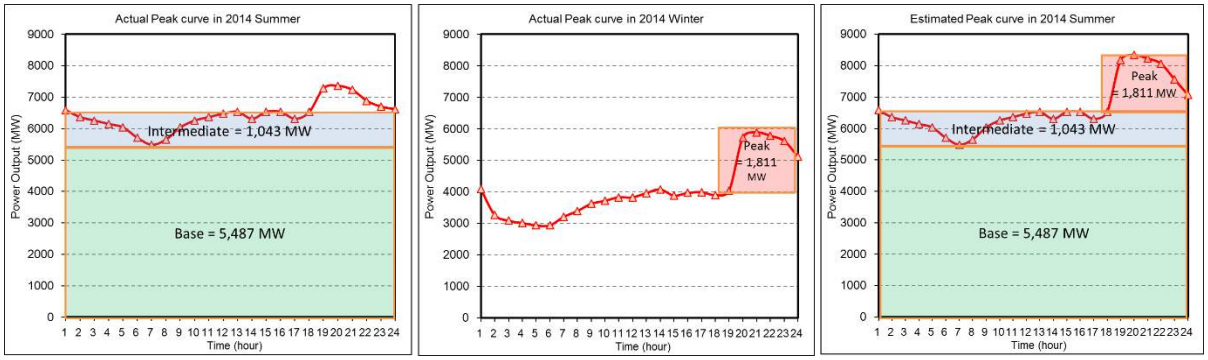
As for the methodology of peak demand projection for PSMP2016, this study adopted the "GDP elasticity method", which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan. However, it has to be noted that this methodology disregards various factors that may also affect the power demand; hence, the results may differ significantly from other methodologies. This study therefore also tried the peak demand projection based on the "Sectorial analysis method" to confirm the appropriateness of the "GDP elasticity method".

(a) Estimation of the maximum power that includes potential demands

Because of the particular situation in Bangladesh whereby rolling blackouts have been used as a measure to circumvent power shortages at the peak hours, the recorded maximum power consumption does not include such potential power demand. Therefore, an accurate forecast of the maximum demand including the potential demand requires a theoretical estimation of load curves from the daily operational data with particular attention on the characteristics of the seasonal changes in the daily load curve and the frequency and durations of rolling blackouts.

Because rolling blackouts have been relatively rare on weekends and holidays in the winter (between November and January), a daily load curve gives an actual peak load (at the hours of the peak power consumption for lighting) that is quite accurate. A daily load curve in the summer gives estimates of the base and intermediate loads close to the recorded values.

Therefore, a composite daily load curve representing the peak power demand was created from the daily load curve in the summer with part of the peak hours replaced by the same part of the daily load curve in the winter as shown in the figure below. The peak power demand in FY 2014, which was used as the baseline for the peak demand forecast, was set at 8,039 MW by adding the base and intermediate load in the summer (5,487 MW and 1,043 MW, respectively) and the peak load in the winter (1,811 MW) recorded in FY 2015. The peak power demand in FY 2016 was estimated at 8,921 MW in the same way and this value was used as the reference value in the peak power demand forecast.

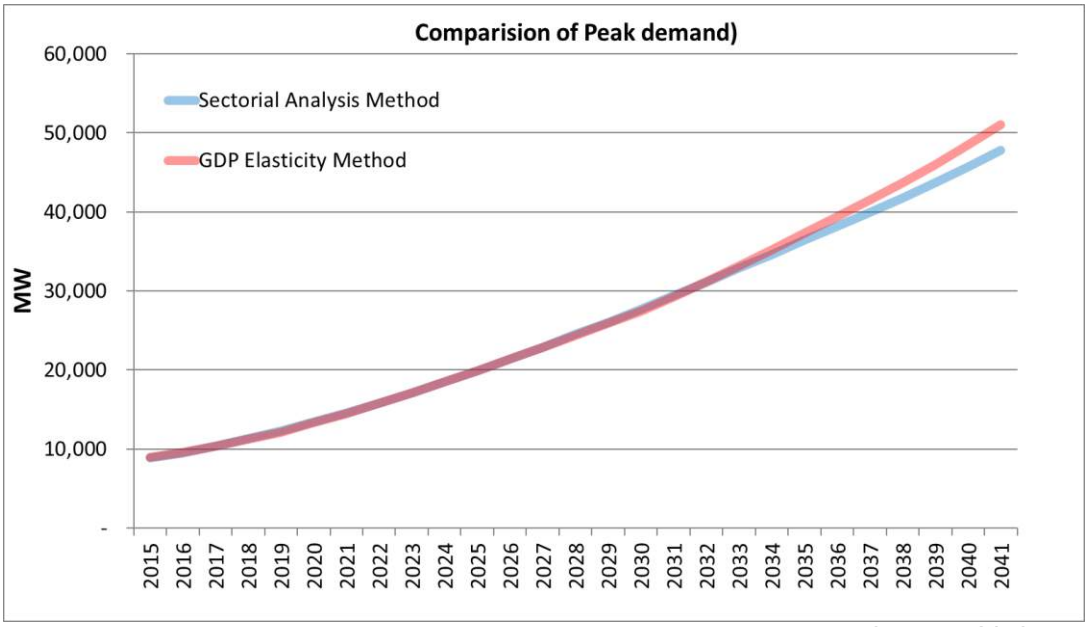


Source : JICA Survey Team

Figure 1-18 Estimated Composite Daily Load Curve in the Summer in Bangladesh

(c) Verification of GDP elasticity method by using Sectorial analysis method

In comparing the power demand projection between the “GDP elasticity method” and the “Sectorial analysis method”, this study concluded that the results are almost identical, though the latter exceeded the former by about 5%. Therefore, this study adopted a peak demand projection using the "GDP elasticity method”, which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan.



Source: JICA Survey Team

Figure 1-19 Comparision of peak power demand in both models

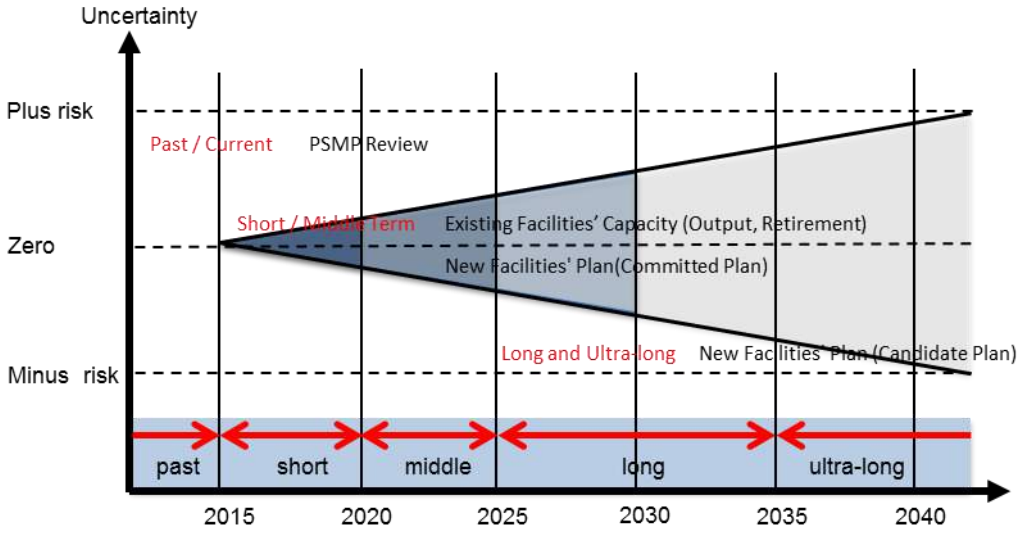
(d) Integration of Peak Power Demand Projection and Energy Supply-Demand Projection

Following the projection of peak power demand as formulated above, this study calculated the available electricity supply from the power grid by multiplying the annual load factor, and then compared this with the projection of total electricity consumption that was discussed in the previous section in the projection of primary energy supply and demand.

2) Power DevelopmentPlan

Short-term and medium-term power development plans are to be formulated after verifying the appropriateness of matters with a little short-term uncertainty (the state and retirement plans of the existing facilities and the plans approved by the Government) in the formulation of a long-term power development plan. The basic CODs of the gas and coal power plants in the long-term and candidate plans are to be determined in conformity with the port and fuel depot infrastructure development plan to be formulated separately in the "Data Collection Survey on Integrated Development for Southern Chittagong Region (Southern Chittagong MP Survey)."

The optimum power source composition is to be determined in the preparation of the future vision of the power source composition by conducting a quantitative evaluation of the economic, environmental and energy security (3E) values of scenarios with different composition ratios for the gas and coal power generation. Different composition ratios for the gas and coal power generation within ranges that are consistent with the infrastructure development plan in the Southern Chittagong MP Survey are to be used in the scenarios, particularly for the highly unpredictable periods for the long-term and candidate plans.



Source：JICA Survey Team

Figure 1-20 Relationship between the Time Scale and the Change in PDP

(a) Existing plants

The installed capacity of existing plants was determined as described below after discussions with the organizations concerned in Bangladesh. The installed capacity of existing plants is 10,895MW as of 2015.

(b) Retirement Plan

The lists of the existing power generation facilities above show their outputs, CODs, retirement years and operation periods. Analysis of these data has revealed that the average operation period for these power plants is approximately 20 years. It is difficult to improve the efficiency of the existing inefficient plants significantly because of the large cost required for such improvements. For these reasons, it has been concluded that the retirement plans prepared by the government are appropriate. The adoption of a strategy aiming at improving the efficiency of the entire power supply network by retiring the existing inefficient power plants gradually and replacing them with new, efficient facilities is considered essential for realizing the maximum use of the limited resources.

(c) Evaluation of the Plans Approved by the Government (Committed Plan)

Power plants with a total output capacity of approximately 14,000 MW are to be constructed in the next ten years. The current status of each thermal power development plan was confirmed based on the discussion with related companies, such as BPDB, BIFPCL, CPGCBL, NWPGCL, Orion Group, etc.

(d) Consideration of Consistency with the Southern Chittagong MP Survey

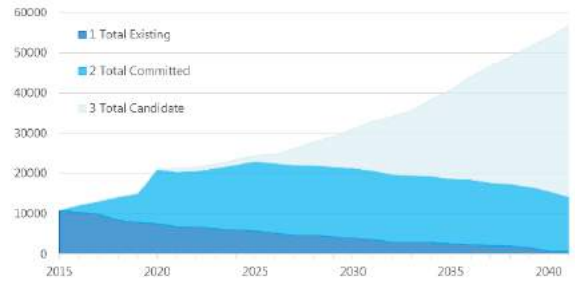
Guarantee of the long-term stability of the fuel supply is a very important factor in the formulation of a power development plan. The existence of a port infrastructure required for the importing of fuels including gas and coal during operation has to be a precondition for the decision on the CODs of new power plants, in particular. Therefore, the infrastructure and port development plan formulated with the consent of the Government of Bangladesh in the Southern Chittagong MP Survey, implemented by JICA, was used as reference in this analysis and the CODs of the power supply facilities were set in a way consistent with the plan.

(e) Evaluationb of the Ultra-long term Power Development Plan (Candidate Plan)

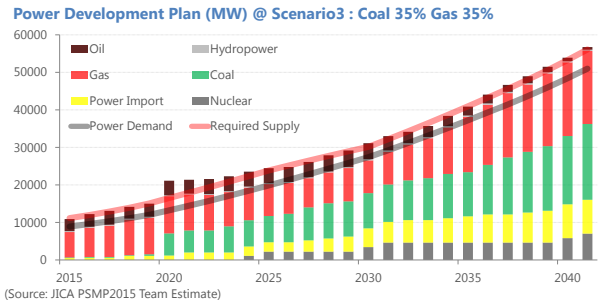
A study on increasing the power sources by changing the ratios of the gas and coal power generation in accordance with the progress in the infrastructure and port development planned in JICA's Southern Chittagong MP Survey is to be conducted for the formulation of the candidate plan. In this section, a scenario that sets the composition ratios of the gas and coal power generation in 2041 at 35% is to be used as the basic power development plan.

(f) Summary of Power Development Plan

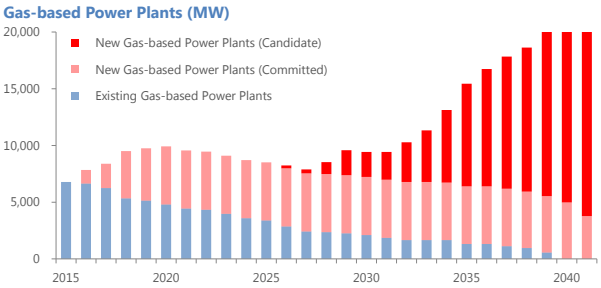
The figure below shows the power supply plan formulated by adding the capacity of the existing plants estimated with the retirement plan in the plan for the existing facilities taken into consideration (existing capacity), the capacity of the plants mentioned in the Committed Plan to be constructed by 2025, the capacity of the plants to be constructed later in the Candidate Plan that is subject to changes and the capacity required to ensure supply reliability during peak demand.



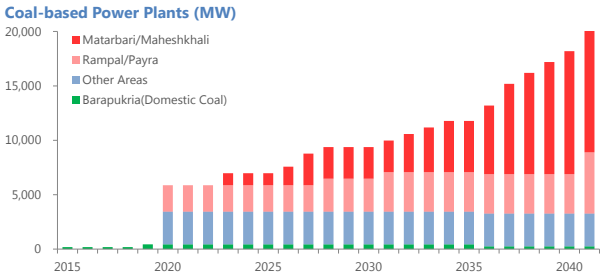
PowerDevelopment Plan (Base case)



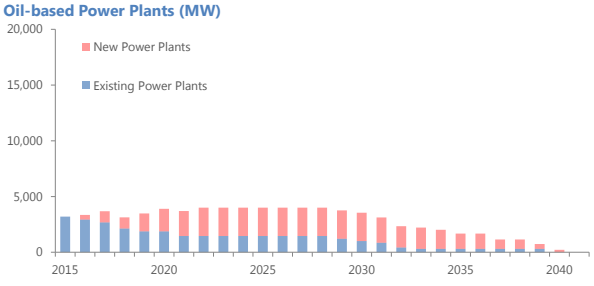
Power Development Plan (Base case)



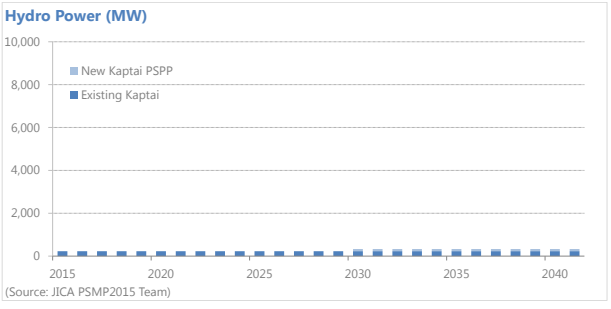
Gas



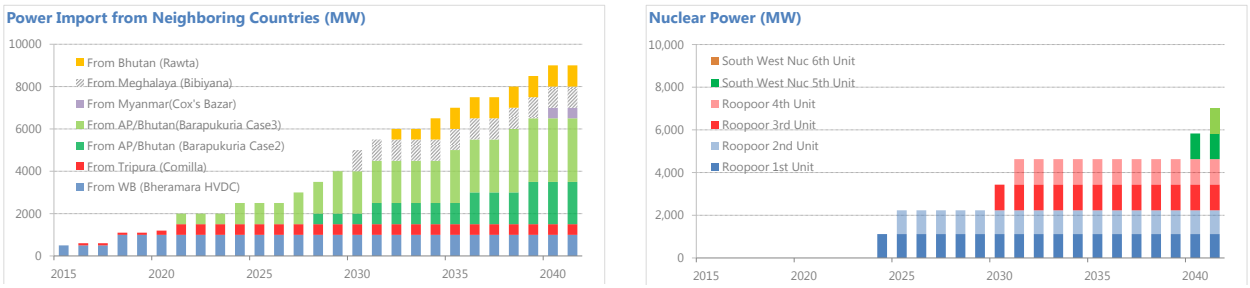
Coal



Oil



Hydro



Power Import　　Nuclear

Source：JICA Survey Team

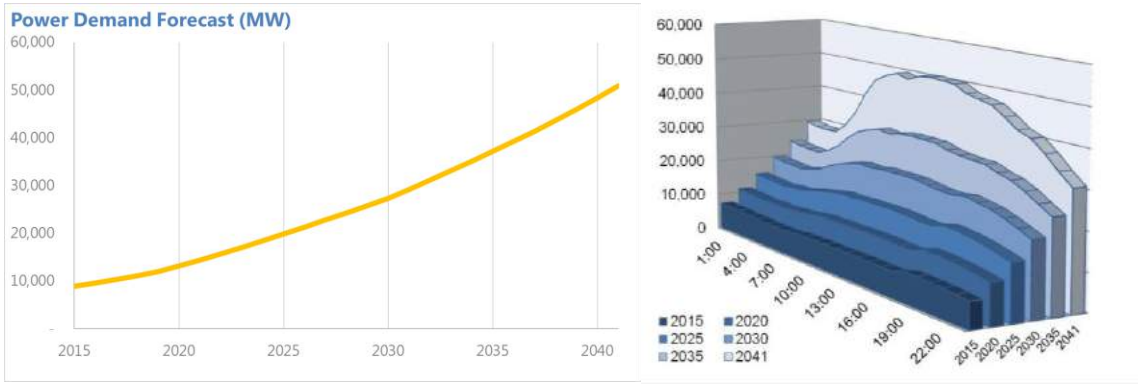
Figure 1-21 Annual Trend of Each Power Plants（MW）

3) Simulation of Supply/Demand Operation

(a) Preconditions for the Estimation of the Economic and Environmental Values

(a-1) Daily load curve

The following estimates the daily load curve in Bangladesh during the 2015-2041 period. The performance records of the daily load curve in Bangladesh in 2015 are represented by a curve having a power demand peak in the evening, as illustrated below. In the meantime, by 2041, the economic growth rate in Bangladesh is estimated to reach the daily load curve of advanced countries, where the peak is found in the daytime and evening, if the growth of the electrification rate is taken into account.

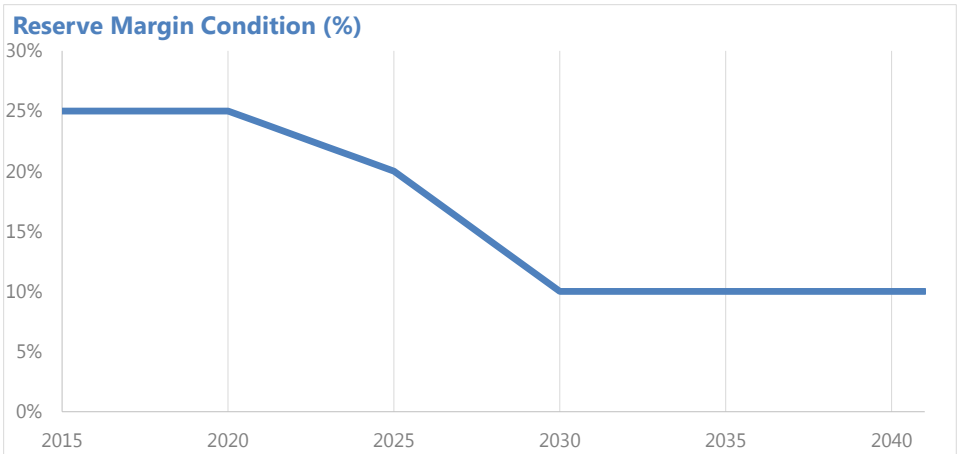


Source: JICA Survey Team

Figure 1-22 Transition of estimated power demand during 2015-2041 (Unit: MW)

(a-2) Power supply reliability

An analysis was conducted on the relationship between the reliability of power supply and the required capacity based on the power demand forecast (Base Case) and PDP. The relationship between the reserve margin and LOLE changes from year to year. If the value of LOLE is set at the standard value for developing countries of 1.0 to 1.5%, the reserve margin theoretically appropriate for the current state is approximately 25%. If international linkage and nuclear power generation are to be introduced *ca.* 2025, the reliability of the power supply shall have to be improved, as mentioned in detail in the chapter on power quality. A margin of between 8% and 15% will be required in order to achieve the target of LOLE = 0.3%, which is acknowledged to be a very challenging target. Therefore, it was assumed that the reserve margin shall be reduced from 25% in 2020 to the target of 10% by 2030 and shall be maintained at this level thereafter.



Source：JICA Survey Team

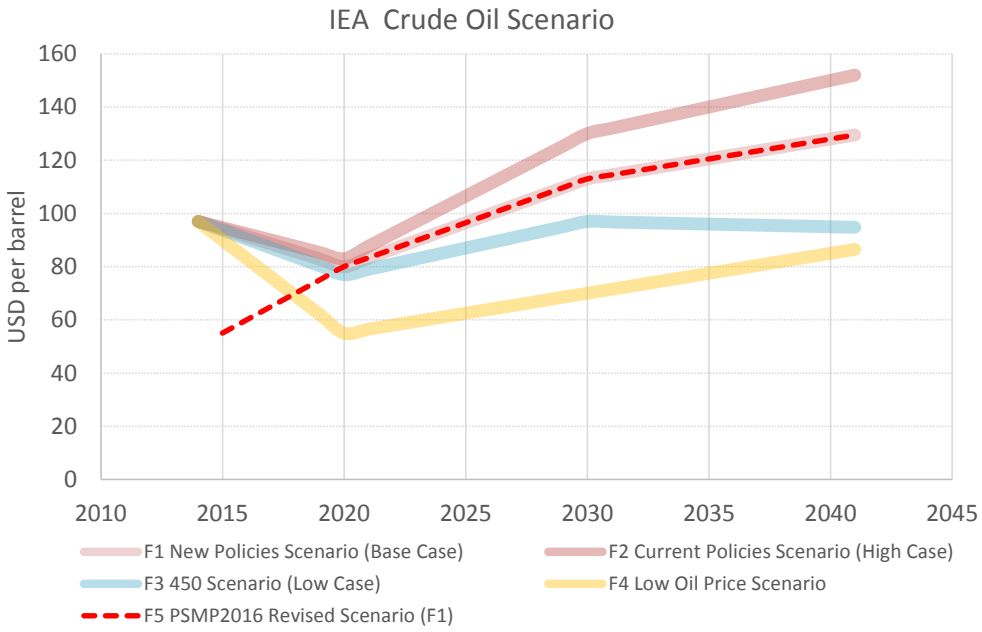
Figure 1-23 Reserve Margin

(a-3) Fuel Price Scenarios

The differences between the prices of fuels in Bangladesh, including the price of domestically produced gas in particular, and the prices in the international market are large and fuel in Bangladesh is provided at prices significantly lower than those in the international market. As the future economic growth will inevitably make it impossible to satisfy the power demand with domestically produced resources, the proportion of imported fuel in the fuel supply is expected to increase rapidly and the prices of fuel are expected to increase to close to those in the international market.

In the discussion with the Government of Bangladesh and the IEA, the international organization on energy, it was decided to use the IEA Scenario for the price of crude oil that projected the price on the basis of a very long-term projection of the supply/demand balance in this analysis.

However, there is a difference between the market price of crude oil in the IEA scenario and the actual price in the market in Bangladesh at present. Therefore, an original scenario for this analysis (F5) has been formulated as the basic scenario for the price of crude oil. In this scenario, the reference price is set at the average price of crude oil in the domestic market in 2015 and the price is projected to follow the New Policies Scenario of the IEA (F1) from 2020 onward.



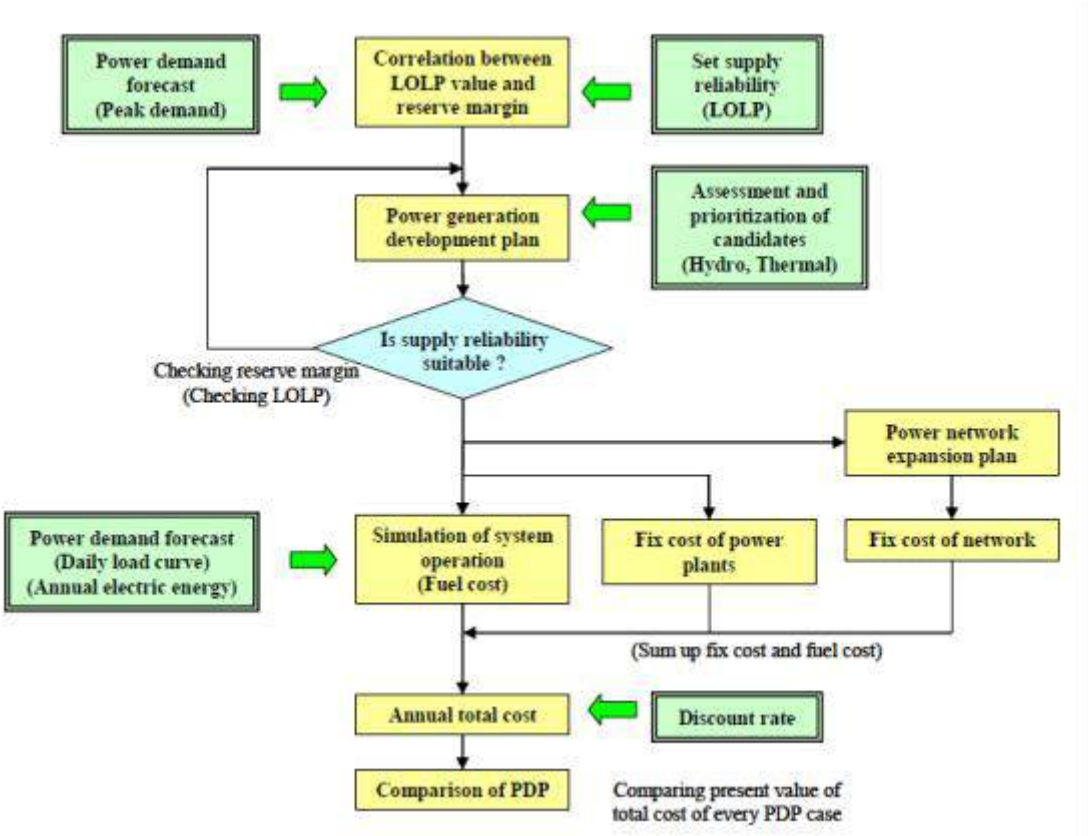
Source: JICA Survey Team

Figure 1-24 IEACrude Oil Scenario

(b) General description of Supply/Demand Operation Simulation

The estimation with the least cost method was used in the quantitative evaluation of the optimum power development plan. A good balance of the economic, environmental and energy security values based on the primary energy supply/demand balance, PDP, power system analysis and power system operation was taken into account in the evaluation. The results of the evaluation were reflected in PDP. PDPAT II and WASP IV were used as the tools for the simulation of supply/demand operation in the formulation of PDP, which was implemented in accordance with the flowchart shown in the figure below.

The annual fuel cost for a certain year was estimated by finding the most cost-effective operation of the given power generation facilities to satisfy a given demand of the year concerned in the simulation of the supply/demand operation. At the same time, a comparison of the fuel cost was conducted, the annual expenses were estimated as a total of the fixed cost, fuel cost and inter-connected cost, the least cost operation, the most cost-effective operation of the total power system, was identified in the simulation and the economic value of the power development plan was evaluated. The optimum development plan was selected by comparing the estimated annual expenses with those of other development plans.

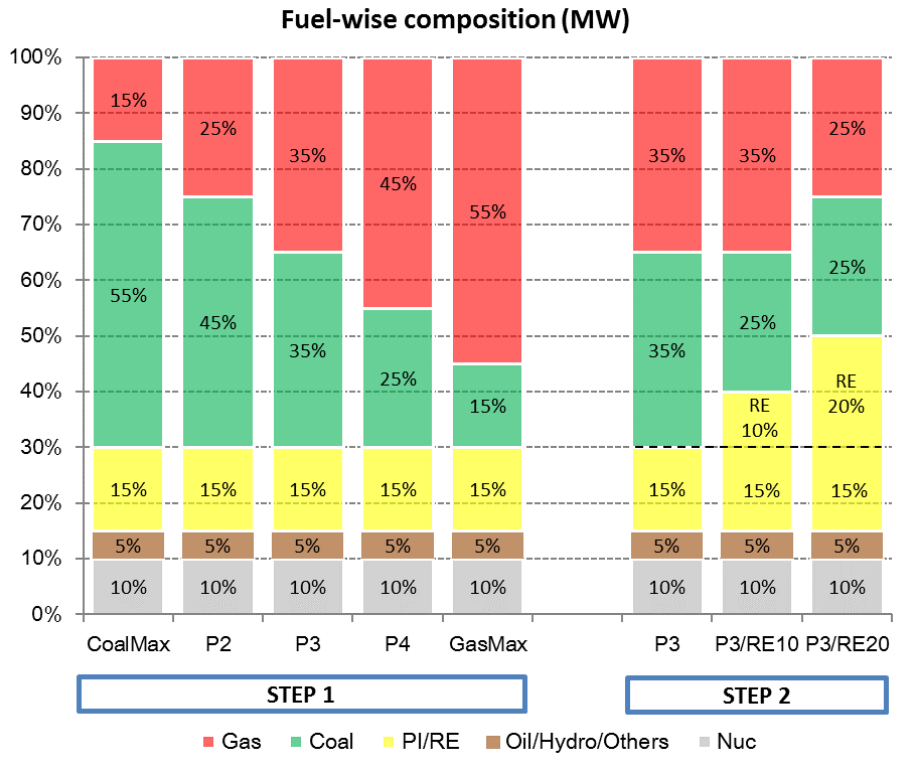


Source: JICA Survey Team

Figure 1-25 Simulation schem of the supply/demand operation

The energy mix should be examined based on the fixed factor and the variable factor as shown in the figure below. For the fixed factor, nuclear power plants, power imports, hydropower plants, existing coal-fired power plants, existing oil-fired power plants, and candidate coal, gas and oil-fired plants that the plan is already in progress should be taken into consideration. For the variable factor, assuming that 70% of the total energy source that is considered appropriate for the power generation plan will be covered by coal and gas, in order to study the optimum energy source composition, five scenarios of energy mix with the share of coal and gas in the energy mix as of 2041 changed from P1 to P5 in the figure below are studied.

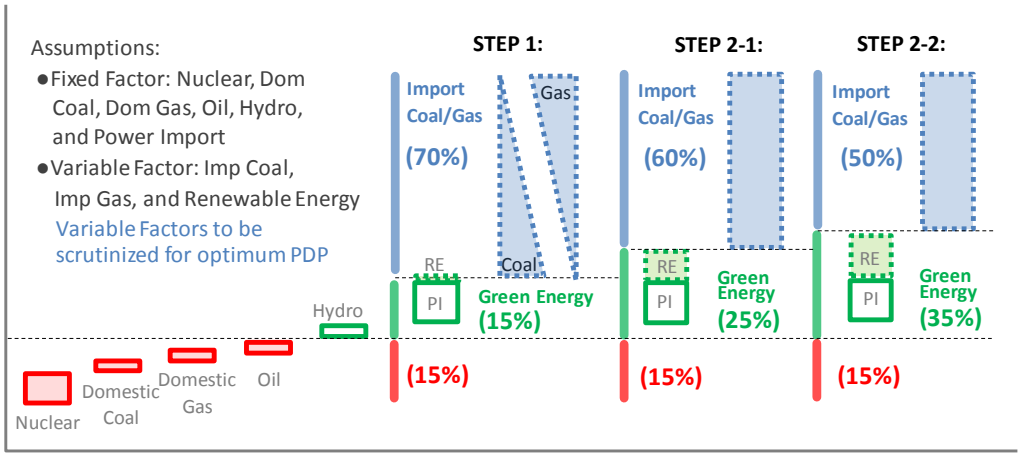
In this case, the share of oil and other fuels in the energy mix should not change in each scenario. The energy mix by fuel type from 2015 to 2041 in each scenario is as shown in the following figure.



Source: JICA Survey Team

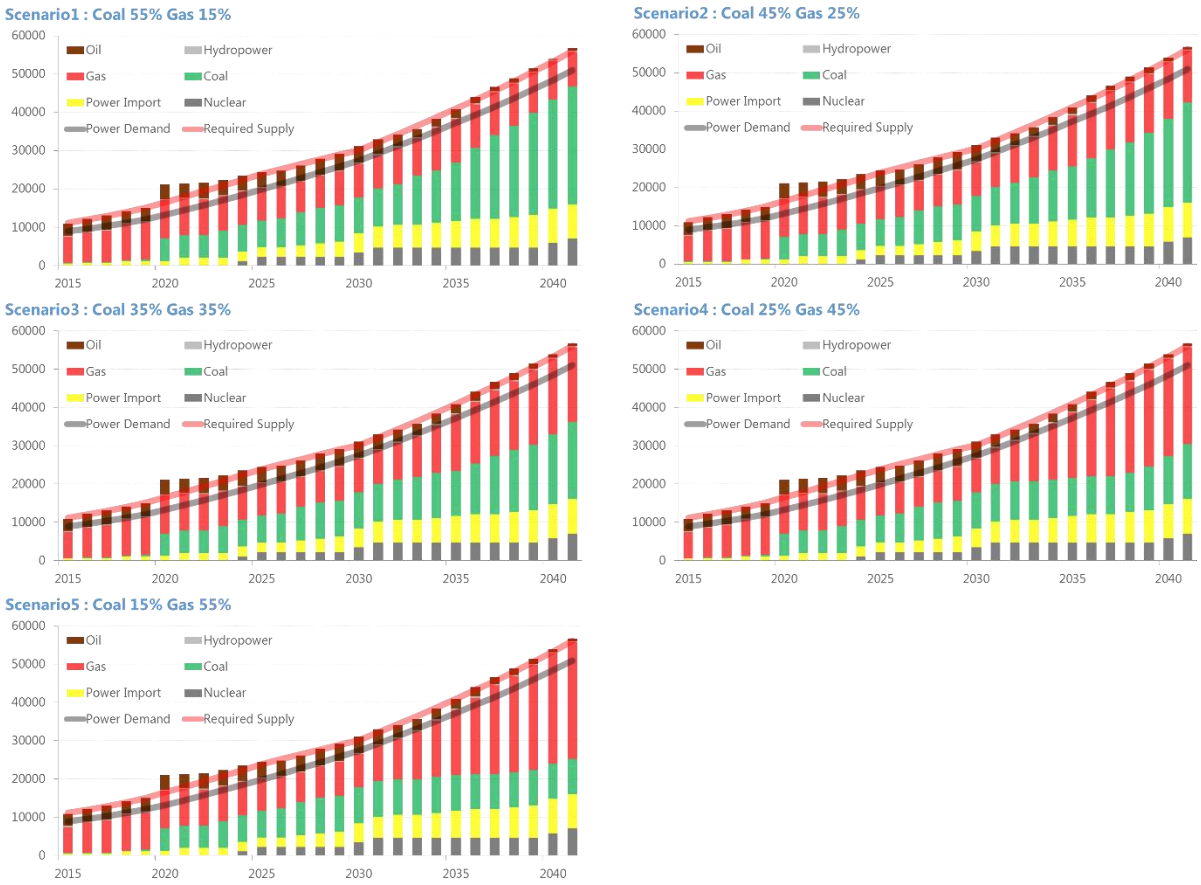
Figure 1-26 Generation pattern in 2041

After determining the optimum share of gas and coal in the energy mix, for Step 2, changing the share of fuels other than thermal power and nuclear power in the energy mix should be considered.



Source: JICA Survey Team

Figure 1-27 Image for demand and supply simulation

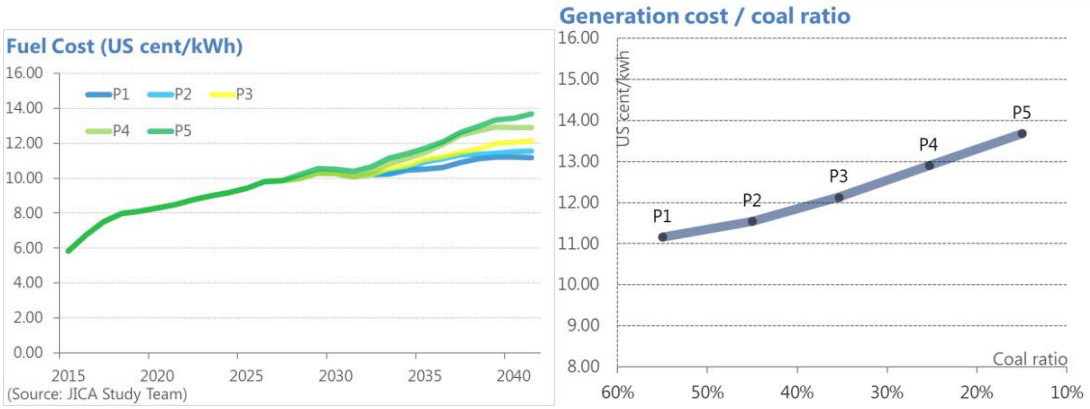


Source: JICA Survey Team

Figure 1-28 Annual Trend of Energy Mix in Different Scenarios

(c) Estimation of Economic Value

The following figure shows the trends of five scenarios for generation cost. As the use of coal spreads in stages, the fuel expense will be slashed, helping curve increases in power generation costs. Thus, the power generation cost is estimated at 9 to 12 US cents/kWh for 2040. In addition, comparison of the power generation cost between the five scenarios for energy source ratio (P1 to P5) shows that the power generation cost becomes higher as the ratio of coal to all the energy sources becomes smaller.

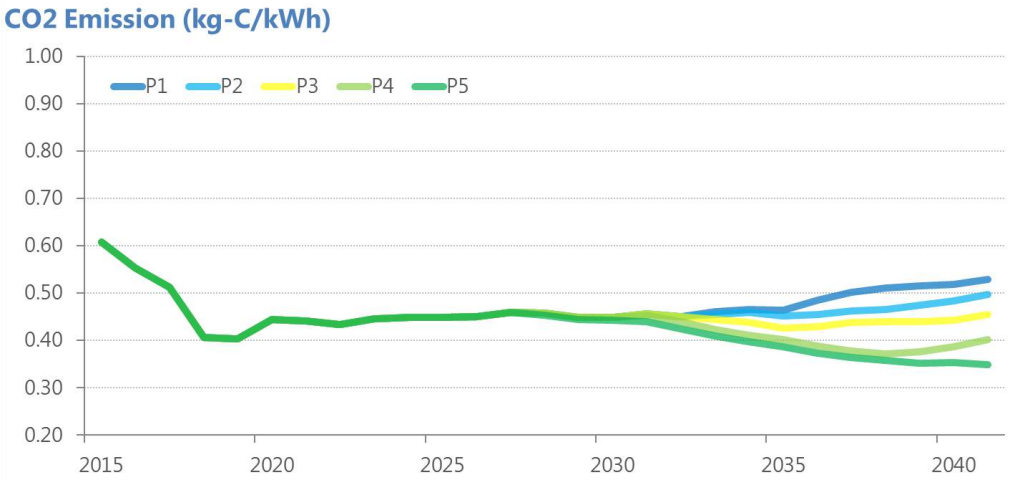


Source: JICA Survey Team

Figure 1-29 Power generation cost under each scenario and Ratio of coal （US cent/kWh）

(d) Estimation of Environmental Value

CO2 emissions in different scenarios are shown in the figure below. The CO2 emissions in 2041 are the highest (0.82 CO2 kg-C/kWh) in Scenario P1, with a high share of coal in the energy mix, and the lowest (0.55 CO2 kg-C/kWh) in Scenario P5, with a low share of coal in the energy mix.



Source: JICASurevy Team

Figure 1-30 Scenario-Wise CO2 Emissions（CO2 kg-C/kWh）

As discussed in Chapter 5, which analyzes the environmental policy, climate change is one of the most critical issues among the environmental impacts of power supply. Bangladesh also submitted INDC to UNFCCC in 2015 and projected greenhouse gas emission reductions in the power sector by 2030.

Thus, the environmental value of each power development scenario should be evaluated focusing on CO2 emissions. This study employed CO2 cost per unit of electricity generated to evaluate the environmental value of each power development scenario. CO2 cost is calculated by multiplying CO2 emissions and CO2 price. In this study, 125 USD/tCO2 is used for the CO2 price, referring to the assumption in the 450 scenario of IEA World Energy Outlook 2015.

(e) Estimation of Energy Security Value

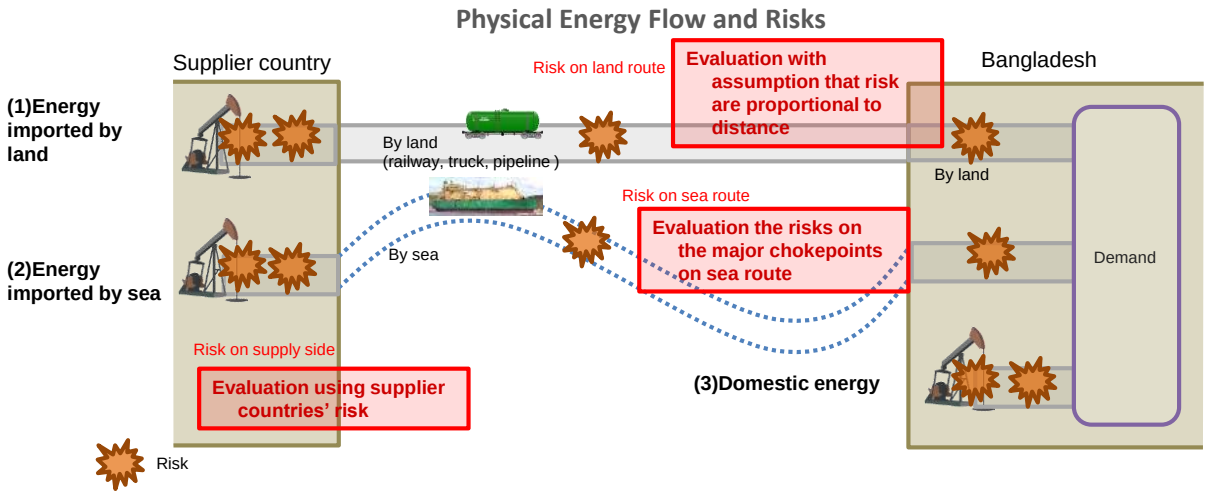
Energy security covers many concepts and there are no common approaches to evaluate it unlike previous two values. Here, we focused on risk of sudden shortage in energy supply quantity, which would directly damage Bangladesh economic activities. The difference ratio of coal and gas among power development scenarios brings different dependence on supplier countries and delivery routes, and thus different shortage risks. This energy shortage risk can be quantified in monetary value as potential loss value of economic production.

Proposed index is calculated using the formula below.

Energy Security Index [USD / kWh] = GDP [USD] x Possible non-delivery rate [%] / Primary Energy Supply [toe] / Generation Efficiency [kWh/toe]

To calculate “possible non-delivery rate”, we modeled physical energy delivery routes to Bangladesh and assumed the blockage probability of each point on the routes. The following figure illustrates the model concept. Among many kinds of risk on the energy delivery routes, we focused on three risks:

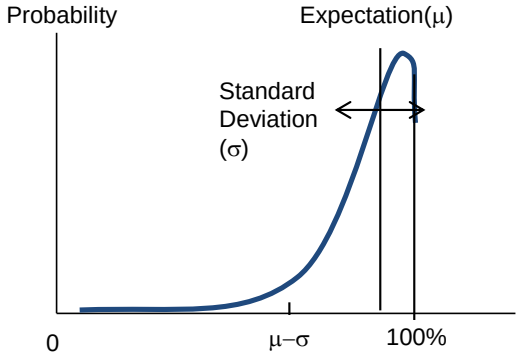
export suspension risk, blockage risk on land route, and blockage risk on sea route. We ignored the risks to deliver domestic energy.



Source: JICA Survey Team

Figure 1-31 Physical Energy Delivery Routes and Risks

With the model, energy delivery rate to Bangladesh can be expressed in the form of probability density function as shown in Figure 1-31, considering many different combinations of risk realization. This curve itself reflects the risk situation of the physical energy delivery of the country. Using the parameter of the expectation (μ) and the standard deviation (σ) of this distribution curve, we can calculate a value of (μ– σ) which shows minimum delivery rate with 84% confident interval mathematically. In the other word, 1– (μ– σ) shows maximum non-delivery rate. This number is that we call "Possible non-delivery rate" here.



Source: JICA Survey Team

Figure 1-32 An Example of Probability Density of Energy Delivery

3) 3E Evaluation Results in Bangladesh

Power supply is closely related with economic activities and environmental issues. For a certain pattern of energy supply to be sustainable, it has to satisfy the conditions called "3E," consisting of the economic value, environmental value and energy security value. The Basic Energy Plan of Japan states that the energy policy of Japan shall satisfy the "3E" conditions.

A quantitative evaluation of the 3E values in 2041 of each of the power development scenarios proposed in the previous section conducted for the selection of the most recommendable scenario is

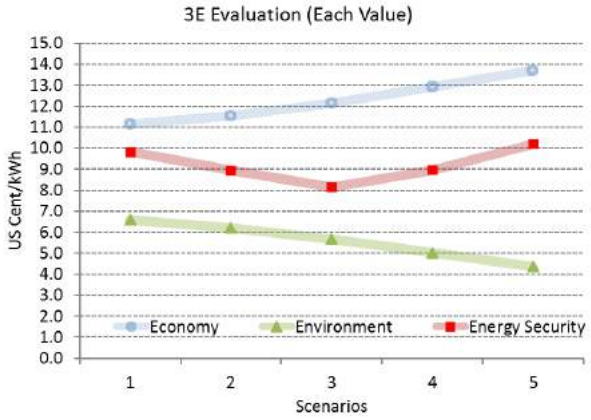
described in this chapter.

Based on the aforementioned methodologies, five scenarios of power development were evaluated using 3E indicators, as shown in the following table. All indicators are expressed in monetary values and they indicate better performance when the number is small. The sum of these three indicators is the total score for the 3E evaluation.

Table 1-8 3E Evaluation Results of Each Power Development Scenario

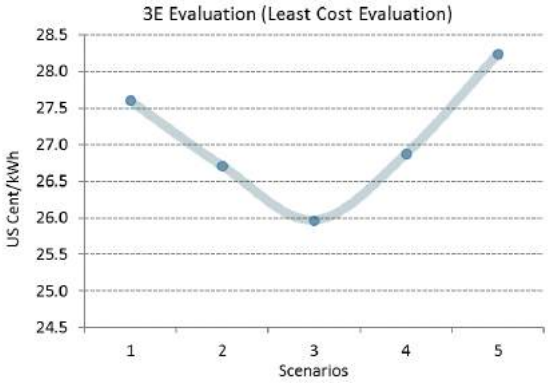
	Composition (MW base)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	11.2	6.6	9.8	27.6
Scenario 2	Gas 25%, Coal 45%	11.6	6.2	8.9	26.7
Scenario 3	Gas 35%, Coal 35%	12.1	5.7	8.2	26.0
Scenario 4	Gas 45%, Coal 25%	12.9	5.0	9.0	26.9
Scenario 5	Gas 55%, Coal 15%	13.7	4.4	10.2	28.2

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-33 3E Evaluation Results (Each Value)



Source: JICA Survey Team

Figure 1-34 3E Evaluation Results (Total)

(g) 3E Evaluation including the Possibility of the Use of Renewable Energy

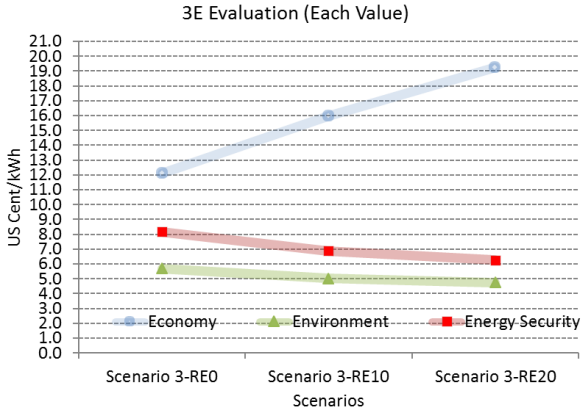
As mentioned above, after determining the optimum share of gas and coal in the enrgy mix, as Step2, changing the share of renewable energy in the energy mix should be considered. In this study, RE10 scenario increasing 10% Renewable energy and RE20 scenario increasing 20% reneawable energy is considered.

Figs. 1-33 and -34 show the 3E values of the scenarios estimated with the "3E" Evaluation Indicator Estimation Method mentioned above. The introduction of power generation with renewable energy in RE Scenarios 10 and 20 will lead to a significant increase in the unit power generation cost because of the increase in the cost for its introduction.

Table 1-9 3E Evaluation Results of Each Power Development Scenario

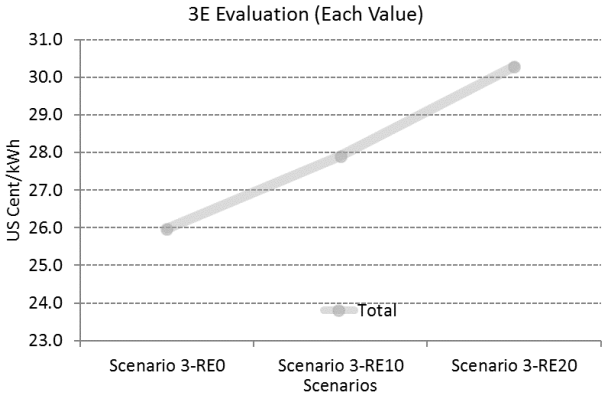
Composition (MW base)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]	Composition (MW base)
Scenario 3	Gas 35%, Coal 35%	12.1	5.7	8.2	26.0
Scenario 3 RE10	Gas 35%, Coal 25%	16.0	5.0	6.9	27.9
Scenario 3 RE20	Gas 25%, Coal 25%	19.2	4.7	6.2	30.2

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-35 3E Evaluation Results (Each Value)

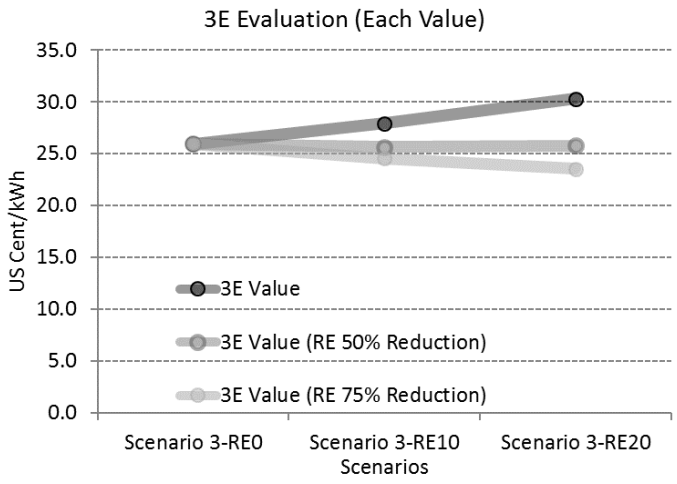


Source: JICA Survey Team

Figure 1-36 3E Evaluation Results (Total)

Because the power generation cost is an economic indicator that has a great impact on the 3E evaluation, a sensitivity analysis was conducted with different costs for the introduction of renewable energy power generation. Fig. 1-36 shows the result of the comparison of cases in which the introduction cost is assumed to have been reduced by 50% and 75% with the case of introduction at the current price.

The 3E evaluation values of the scenarios with the introduction of renewable energy power generation are lower than those of the scenario without the introduction when the cost of the introduction has been reduced by at least 5%. Therefore, it is advisable to decide the proportion of the power supply generated with renewable energy in the total supply with the reduction in the cost of the introduction to be realized by technical innovation taken into account.



Source: JICA Survey Team

Figure 1-37 3E Evaluation Results (Total)

(3) Roadmap

i) Short term (up to 2020)

- Capacity building for MP revision
  - ✓ Collaboration between organizations for power and energy master plan
  - ✓ Periodic rolling revisions for milestone mater plan
  - ✓ Comprehensive statistical work function
  - ✓ Introduction of KPI management
- Improvement in the investment climate
  - ✓ Improvement of PPA
  - ✓ Reinforcing tax exemption for FDI
  - ✓ Prompt procedure
  - ✓ Financial credit approval by international organization
- Eliminating rolling blackouts
- Reform of O&M of power plants and revision of electricity charges

ii) Short- to medium-term (up to 2025)

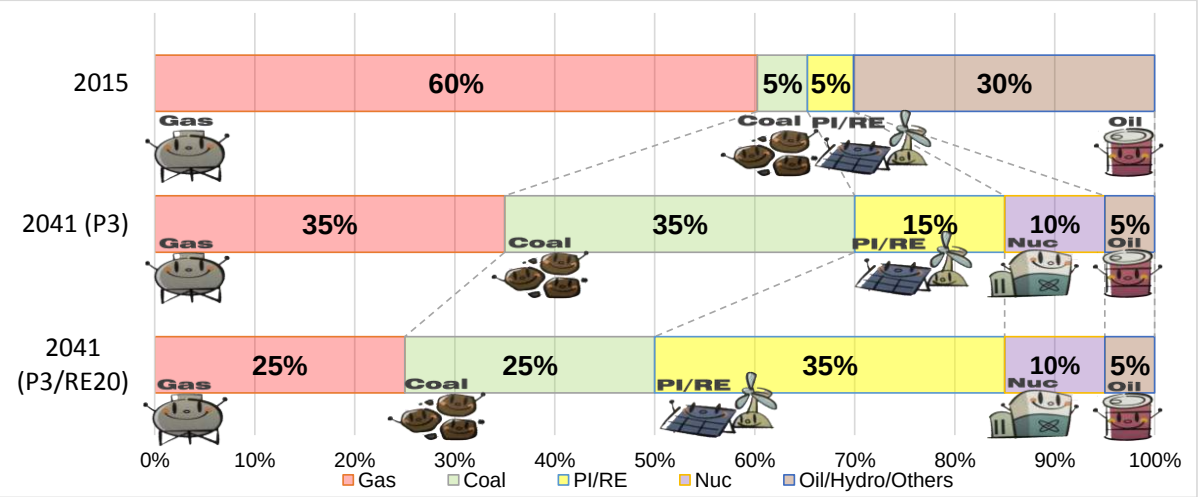
- Breaking away from the dependence on costly petroleum and rental power generation
- Promotion of PPP investment in power generation projects
- Reform of O&M of power plants and revision of electricity rates

iii) Medium- to very long-term (up to 2041)

- Establishment of reliable large-scale base power sources
- Promotion of PPP investment in power generation projects
- Reform of O&M of power plants and revision of electricity rates
- Realization of the best mix of power sources with high 3E values

Regarding acchieve to best energy mix, in order to maximize the 3E value (the total of the economic, environmental and energy security values) of the power source composition of the energy mix, a portfolio consisting of well-balanced proportions of gas, coal and other power sources shall be realized. This shall be done by halving the proportion of gas power generation to depart from the current heavy reliance on gas, and with the systematic expansion of relatively inexpensive large-scale coal power generation and international connection with the neighboring countries as an exit strategy from the reliance on expensive oil-based rental power.
In addition, the investment cost for the use of renewable energy, which is larger than that for the use of

conventional energy sources, is expected to reduce in future with technological advancements and the extension of its use in society. When this condition has been met, a shift to the active use of renewable energy and a reduction in the consumption of fossil fuel shall have to be realized, following the global trend, with the aim of increasing the use of zero-emission power sources.



Source: JICA Survey Team

Figure 1-38 Best mix including expansion of renewable enegy

1.6.9 Hydropower development

(1) Current status and issues

1) Current Situation of hydropower development

Bangladesh's climate is categorized as a subtropical zone monsoonal climate, and its characteristic is abundant rainfall. As for the topography of Bangladesh, most of the national land is spread over the delta area along the Bay of Bengal on the Indian subcontinent. Most areas are lower than 9 m above sea level. In this regard, Bangladesh has relatively limited hydropower potential even though it has abundant water resources. Only in the Chittagong hilly terrain area are there some potential hydropower resources.
The existing Karnafuli Hydropower Plant is in the Chittagong area and uses the water of Kaptai Lake. It is the only hydropower plant in Bangladesh and its total installed capacity is 230 MW. Its No. 1 and 2 units (2 units of 40 MW) and No. 3 unit (50MW) were installed with assistance from the United States, and operation started in 1962 and 1982 respectively. No. 4 and 5 units were installed with assistance from Japan, and operation started in 1987. Further, No. 6 and 7 units were planned as a Japanese Yen Loan Project in order to strengthen the power supply for peak demand. However, since an Environmental Impact Assessment was not carried out and local consensus was not attained, a Japanese ODA loan was not provided for the project. The problem was caused by conflicts between indigenous people and immigrant Bengali people who were living around Kaptai Lake. Compensation issues during the construction of Kaptai Dam were also one of the causes. Even now, entry to the area is restricted because of law-and-order problems.

Despite such a situation, the Government of Bangladesh expects further hydropower development for reduction of CO2 emissions and power system stability.

2) Results and issues

Under this Study, potential hydropower sites for Pumped Storage Power Plants (PSPP) and Ordinary Hydropower Plants (Ordinary HP) or Small Scale Hydropower Plants (SSHP) were surveyed. The results of the survey and identified issues are shown as follows:

(a) Potential PSPP Sites

The potential PSPP sites identified in the preliminary map study are shown in Figure 1-39. Comparison of the potential sites was conducted based on the results of the literature survey and site reconnaissance. PSPP No. 17 was selected as the most preferable potential site for the first PSPP project in Bangladesh, and PSPP No. 13 was evaluated as the second potential site. However, it is judged that realization of the projects will be difficult at this stage because of limited map data, restrictions on survey activities and difficulties in the acquisition of and compensation for land due to local sentiments against hydropower development.

In the future, however, it is expected that the selected potential PSPP sites will be developed when the need for PSPP development increases for stability of the power system, and the above mentioned limitations regarding the project implementation are solved.

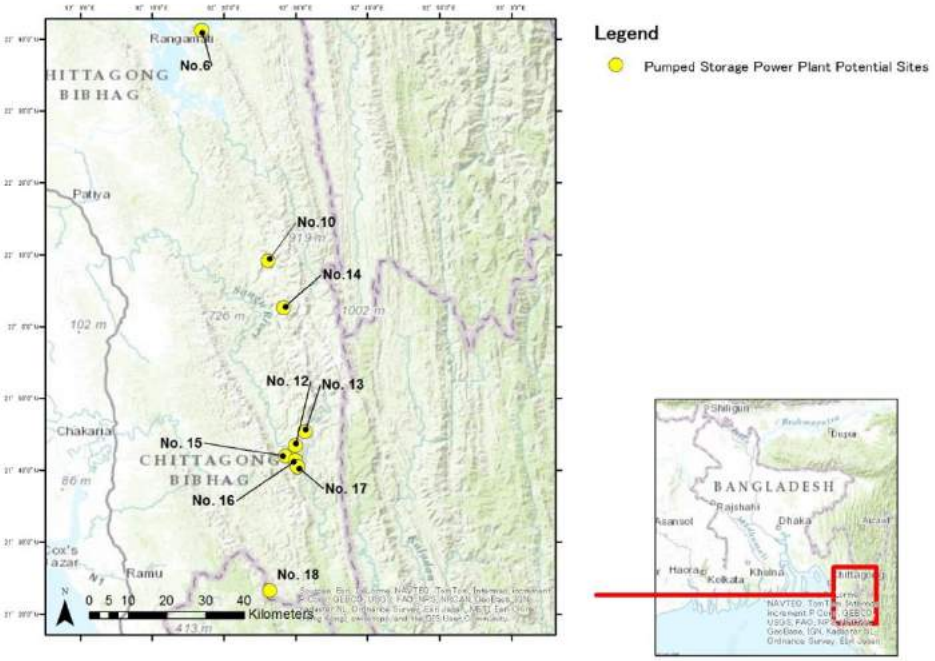


Figure 1-39 Location Map of Potential PSPP Sites

(b) Ordinary HP/SSHP Potential Sites

The locations of the potential sites for ordinary HP and SSHP in this study are shown in Figure 1-40.

Although the number of site visits was limited the JICA Survey Team came to the assumption that most of the potential sites along the Sangu main river may cause large scale resettlements due to the relatively gentle slope of the river. Though there are some prospective sites in terms of technical and economic viability, those sites may not be suitable sites for development in consideration of the environmental and social impact aspects.

On the other hand, the potential sites on the tributaries of the Sangu River are anticipated to have limited water flow, particularly in the dry season. Thus, those sites do not seem financially viable.

In this regard, these potential sites seem unattractive for development of hydropower projects.

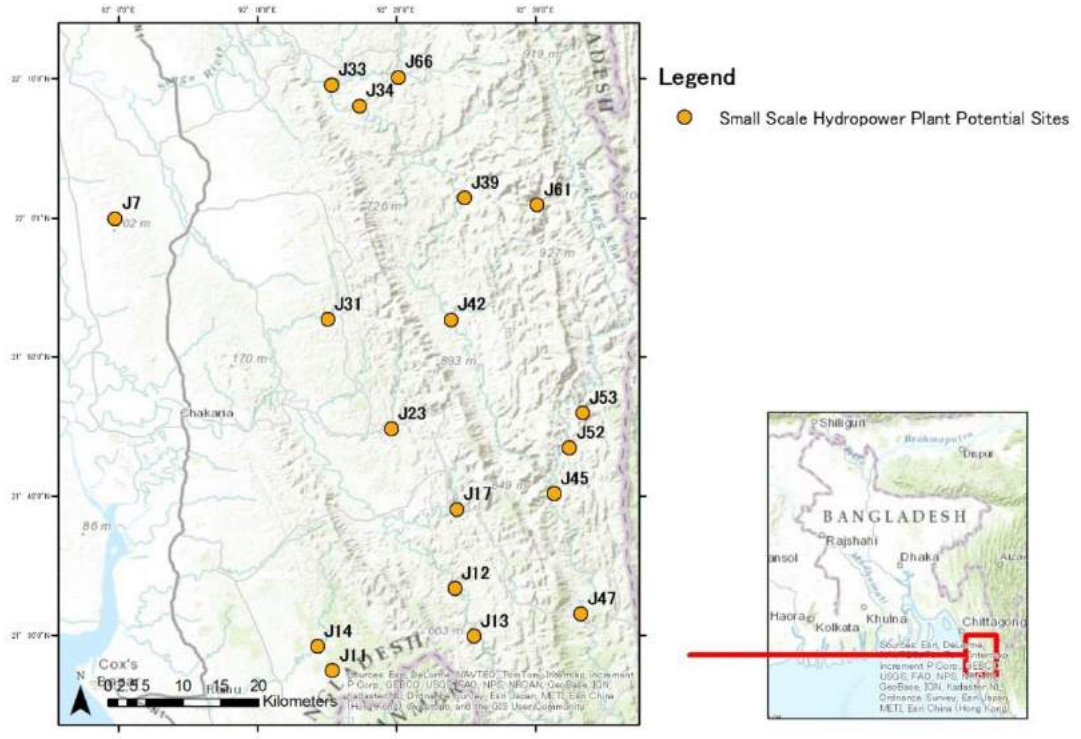


Figure 1-40 Location Map of Potential Sites for Ordinary and Small Scale Hydropower

(2) Targets to Achieve

Targets to be achieved for realization of hydropower development in the Chittagong hilly area are as follows:

- Topographic maps are required for the initial survey and planning for the development of infrastructure including hydropower generation facilities. However, the topographic maps of the Chittagong Hill Tracts that can be used in such a survey and planning are not available.
  The government should develop and arrange more detailed (1/25,000 scale) maps required for further planning and conceptual design.
- The implementing agency needs to find a solution to ease the sentiments of local people and to gain understanding as to the necessity of hydropower plants.
- The government should reduce concerns over security in the area.

(3) Roadmap

The road map for development of a PSPP by 2030 is as follows:

- Preparation of maps by 2018.
  The topographic maps of the Chittagong Hill Tracts shall have to be made available by 2018.
- Completion of FS and establishment and capacity building of organizations engaged in the pumped-storage power generation (PSPG).by 2020.
  It is necessary to conduct a pre-FS or FS for the construction of a pumped-storage power plant (PSPP) at the candidate sites identified in this survey when the topographic maps of the areas concerned have been created and the residents in the areas have given consent to the construction.
  Human resource development will also be required for the development of PSPG. An organization engaged in PSPG shall have to acquire the basic knowledge on the functions, roles and economic characteristics of a PSPP. Persons who are to make decision on the feasibility of a

project for the construction of a PSPP, in particular, must have sufficient knowledge of PSPG. Therefore, training on PSPG shall have to be provided to not only the staff of an implementing organization responsible for PSPG but also the decision makers while the above-mentioned pre-FS or FS is being conducted.

- Completion of Detailed Design by 2023.
  The training of the power system operators shall also have to be conducted. Stabilization of the power system is a significant function of PSPPs. Therefore, the training of the system operators will be required for the effective use of PSPPs.
  It is also necessary to establish ancillary services in the electric power market. When the proportions of coal and renewable energy as the sources of power generation in the power system in Bangladesh increase, the necessity for not only the power load-leveling but also ancillary services will increase and the significance of PSPG will increase. The improvement of the power market including ancillary services will be required for the realization of the optimum power source balance with proper evaluation of PSPG.
- Commencement of Construction of a PSPP by 2024.
  A PSPP is a facility contributing to the stabilization of a power system. However, it is not easy to evaluate its value accurately. It is difficult for a private company to construct a PSPP because the profitability of operating such a plant is low unless there exists a special market such as an ancillary service market or a special rate system for PSPG. As the PSPP concerned is the first PSPP to be constructed in Bangladesh, it is expected to be constructed by a parastatal company. Therefore, it is recommended that the PSPP be constructed in accordance with the conclusion of a F/S in an ODA project.
- Commissioning of the first unit of a PSPP by 2030.

1.6.10 Renewable Energy

(1) Current Status and Issues

Regardless of the economic status, developing or developed, it is the international trend to promote renewable energy, as part of energy security as well as greenhouse gas emission reduction. Many countries have adopted renewable energy promotion policies, such as feed-in-tariffs (FIT) and various incentives. India in particular has an aggressive plan, where renewable energy shares half of the new generation capacity to be built by 2040 (while India will also increase coal-fired power plants).

Bangladesh is not an exception to this trend. Its Vision2021 and COP-INDC promise that Bangladesh's renewable generation capacity share will become 5% by 2015 and 10% by 2021. Bangladesh is currently preparing the competitive bidding by IPPs, drafting FIT and providing other incentives (mainly financial ones) for renewable energy businesses. However, Bangladesh has major constraints for renewable energy expansion – namely land availability and meteorological conditions – and the maximum renewable energy (power generation) potential is up to 3,700MW (see the below Table). Even if the Variable Renewable Energy (VRE), such as solar PV or wind potential, is developed to the maximum potential and connected to the grid, Bangladesh will gain about 4,200GWh per year. This amount is quite limited in comparison with the total grid generation energy (estimated at 82,000GWh in 2020, 307,000GWh in 2040), and the IEA points out that the 5-10% of VRE in the network does not require a major transformation of network development or operation, as such output variation can occur as a result of load change or unplanned power plant outage.[1] Still, as far as Bangladesh increases the grid-connected renewable generation capacity, network and operation capacity needs to be improved. In addition, Bangladesh needs to develop technical rules and regulations for grid-connected renewable energy generation, as they do not exist at this moment.

Table 1-10 Renewable Energy Potential in Bangladesh

Technology	Resource	Capacity (MW)	Annual Generation (GWh)
Solar Park	Solar	1400*	2,000
Solar Rooftop	Solar	635	860
Solar Home Systems, (SHS)	Solar	100	115
Solar Irrigation	Solar	545	735
Wind Park	Wind	637**	1250
Biomass Generation	Rice husk	275	1800
Biogas Generation	Animal waste	10	40
Waste to Energy	Municipal waste	1	6
Small hydro power plants	Hydropower	60	200
Mini-grid, Micro-grid	Hybrid	3***	4
Total		3,666	7,010

* Case 1 (agricultural land excluded) estimate
** Case 1 (flood-prone land excluded) estimate
*** Based on planned projects only, not a theoretical maximum potential, because there is potential overlap with off-grid solar systems. Either could be used to serve off-grid demand.

Source: SREDA-World Bank Scaling Up Renewable Energy in Low Income Countries (SREP) Investment Plan for Bangladesh, October 2015

Biogas in Bangladesh, while it has limited potential as a power generation source or for meeting major

[1] According to the IEA, these variable renewable energies would not create a major technical problem if the share of the generated renewable energy (GWh) is 5~10% of the total grid generated energy.

gas demand, has great potential as home cooking fuel. Considering LPG's expensive price, biogas could play an important role especially in rural areas in order to realize SDG 7's "affordable and clean energy" goal. However, some lead time is required for substantial roll-out of a new type (glass fiber) of biogas digester by removing duties and developing domestic manufacturers, and addressing the biogas issue is a mid-term target.

In addition to the "within-the-boundary" renewable energy potential, Bangladesh is in a good position to exploit the ample regional hydropower potential and import it through the cross-border transmission network. Another JICA Survey shows the cross-border hydropower potential available to Bangladesh is 3,500-8,500MW in 2030, mainly from Nepal and north-west India. Details of the cross border status, issues and countermeasures are discussed in 1.6.11 .

(2) Targets to Achieve

1) Domestic renewable energy power generation (cumulative): 2,470MW (by 2021), and 3,864MW (by 2041)
2) Domestic biogas production: 790,000m3/day (including additional 600,000m3/day by 2031, 3 million m3/day by 2041)
3) Cross-border Energy Imports: 3,500~8,500MW (by 2031), 9,000MW (by 2041)
4) Cross-border energy import rules and regulations' set-up, associated with capacity building in this area (mid to long term)

(3) Roadmap

1) Domestic renewable energy power generation (cumulative): 2,470MW (by 2021), and 3,864MW (by 2041)

- One project utility-scale solar park IPP project on competitive bidding basis, contracted and operation start (short term)
- Wind Resource Assessment completion (short term)
- Grid connection technical rules and regulations for renewable energy generation (short term)
- Grid connection approval process for utility-scale renewable energy generation (short term)
- Grid enhancement planning and implementation for utility-scale renewable energy generation (short term)
- FIT and reverse auction setup (short term)
- Network operation to manage renewable energy's variable output (short term)
- FIT revision and application to new projects (mid term)
- Utility-scale solar project roll out (short to mid term)

2) Domestic biogas production: 790,000m3/day (including additional 600,000m3/day by 2031, 3 million m3/day by 2041)

- Import duty/levy on glass-fiber biogas digester/material removal (short term)
- Glass-fiber biogas digester domestic manufacturer development (mid term)
- Glass-fiber biogas digester roll-out through IDCOL loan scheme (mid to long term)

3) Cross-border Energy Imports: 3,500~8,500 MW (by 2031), 9,000MW (by 2041)
See 1.6.11

4) Cross-border energy import rules and regulations' set-up, associated with capacity building in this area (mid to long term)
See 1.6.11 .

1.6.11 Power Imports

(1) Current Status and Issues

Industrial diversification and advancement are essential in order to achieve further economic development in Bangladesh. To this end, improvement of the quality of the power supply, such as stabilization of network voltage and frequency, is a prerequisite. In addition, in anticipation of the growing share of coal-fired thermal power generation in the medium and long term, the exploitation of renewable energy resources with low environmental burden under the climate change perspective is envisaged.

On-grid large-scale hydropower development seems to be an effective measure to overcome the aforementioned issues. However, due to its flat geographical features, Bangladesh lacks prospective hydropower potential over 1 MW apart from the existing Kaptai hydro power plant (230MW). In contrast, there is abundant water power resource potential in the countries surrounding Bangladesh, namely Bhutan, Nepal, Myanmar, and the Indian States of the North East and West Bengal (collectively "neighboring countries"). Thus, it is expected that Bangladesh imports electricity out of such hydropower generation via power interconnections with such neighboring countries for stable base load supply, energy fuel diversification, and climate change mitigation.

The challenges arising from importing power and their countermeasures are as follows.

(i) Energy Security

In the case of importing power from other countries, the risk of supply interruption caused by adverse relationships between the two countries needs to be considered. Electric power, which is different from other types of supply, is technically easy to shut down even in minutes. So it is necessary to avoid excessive reliance on other countries in order not to place oneself in a serious situation. Specifically, the capacity of imported power from one country should be within the limit of generating reserve margin and also 10% of all supply capacity in order to continue the supply in the event of supply interruption. In the case of Bangladesh, imported power from Bhutan and Nepal has to be transmitted through India. Therefore, imported power from Bhutan and Nepal should be within 10% of all supply capacity.

(ii) Compliance with Commissioning Timing of the Transmission Lines in India

The power import plan through India hinges on commercial operation of the Case 2 HVDC (±800kV) interconnection line or the Case 3 HVAC (765kV) interconnection line. These interconnection lines shall be constructed in close cooperation with India after fully understanding and confirming India's needs.

When hydropower capacity exceeds 3,000MW in Arunachal Pradesh, the ±800kV inter-state transmission line currently under construction reaches its full transmission capacity, giving rise to a need for the construction of the Case 2 interconnection line. On the other hand, there seems to be no reason for India to realize the need for the Case 3 line for the time being. However, need for the Case 3 line's construction will arise if construction of the Case 2 line is delayed due to a delay in the hydro power development in Arunachal state, or high construction costs etc.

(iii) Massive blackout due to large scale power loss of supply

It is desirable to import as much power as possible through one connecting point from the viewpoint of economic efficiency. However, if a huge amount of power is transmitted through one connecting point, it can lead to the risk of massive blackout, such as blackout across the entire country during the shutdown of the connecting line. Massive blackout occurred on 1st November 2014, triggered by 500MW power loss of the BTB break down on the inter-connection line from India. In order to avoid

this risk, the limit of the power loss level needs to be worked out, by checking sufficiently continuous power generators' operation during frequency drop and the load shedding scheme during large scale power supply loss. Based on this result, the maximum level of import capacity in one inter-connection point has to be decided. In concrete terms, it is preferable that the amount of imported power through one connecting point is within 10% of the demand.

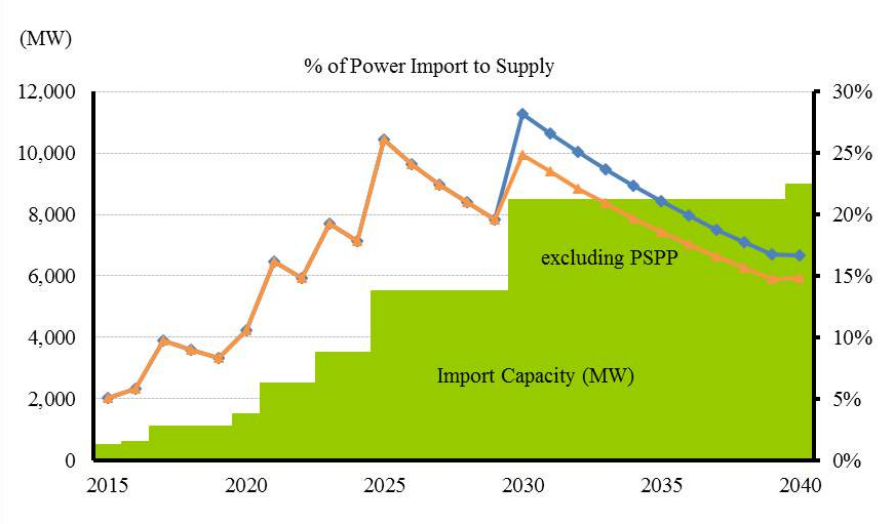
(iv) Mutual Interference due to Grid Accidents

Conducting power trading means transmission lines are connected between two neighboring countries, which will lead to the threat of mutual interference due to grid accidents. But it is possible to minimize the influence by connecting DC lines. Current inter-connection lines between India and Bangladesh apply DC lines or non-connected lines by switching the load. There will be a few mutual interferences due to grid accidents in these two cases.

(2) Targets to Achieve

(i) High Case Scenario

The High Case Scenario, in which more electric power can be expected due to operation of the Case 2 line and Case 3 line starting on schedule, is shown below.



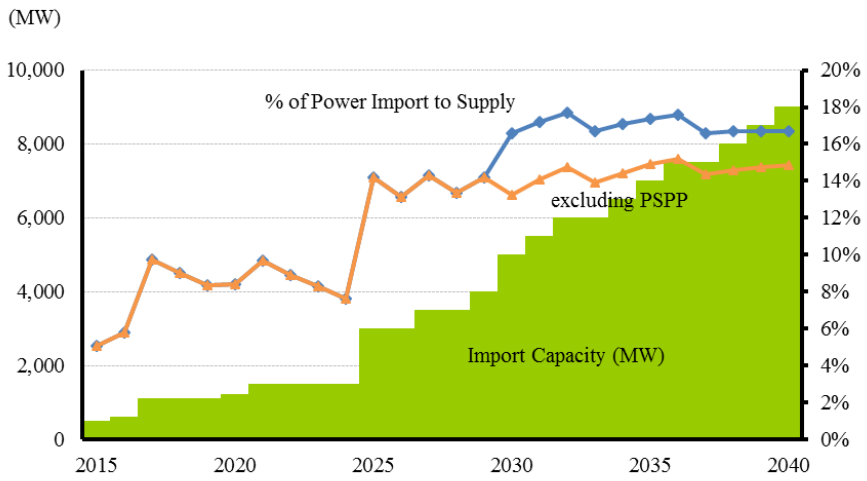
Source: JICA Survey Team

Figure 1-41 Future Power Import Volume and its Share (High Case Scenario)

The share of power imports against the total supply capacity will be between 20% and 25% within the permissible range, albeit a little bit large.

(ii) Low Case Scenario

The Low Case Scenario, in which excessive import of electric power from neighboring countries is not expected, is shown below.



Source: JICA Survey Team

Figure 1-42 Future Power Import Volume and its Share (Low Case Scenario)

The share of power imports against the total supply capacity will be approximately 15% within the appropriate range after 2025.

(3) Road Map

Agreement acquisition with India is indispensable in order to achieve the plan for power imports from the neighboring countries that are mentioned above. In particular, it is important to negotiate tenaciously on the following items.

- Advanced development of the Case 3 line
  The Case 3 line is more flexible than the Case 2 line, and more effective for Bangladesh. Because Bangladesh can import electric power from various regions by using the Case 3 line it is important that it aims to advance development of this line.
- Securing power transmission capacity in India
  Bhutan and Nepal are positively in favor of electric power exports to Bangladesh. However, when Bangladesh imports electric power from the two countries, it must pass through the Indian system. It is especially important to match the system development plan in India and to advance the plan if necessary in order to secure the power transmission capacity in India.
- Direct connection of PSPP in Meghalaya state to Bangladesh system
  The PSPP is a very effective tool for stabilizing the system and improving the power quality. It is necessary to connect the generator directly to the Bangladesh system to enjoy such an effect. As for the PSPP in Meghalaya state, large-scale development of 1,000MW or more is possible at each site. Therefore, it is possible to secure economy even if the system is divided into two parts at the power plant and half of the generators connect with the Bangladesh system directly.

The existing communication channel suffices for discussions over bilateral power trades between Bangladesh and India. However, if power trades with Bhutan and Nepal are involved, the use of the Indian network is inevitable. Bilateral discussions between a seller (Bhutan or Nepal) and a buyer (Bangladesh) are not enough to facilitate such power trades. A multilateral framework that includes India is a prerequisite.
To provide a discussions platform of this kind, a group of countries comprising Bangladesh, Bhutan,

India and Nepal (BBIN) has been formulated. BBIN holds Joint Working Groups (JWGs) twice a year. Therefore, it seems to be most effective to discuss regional power trades and interconnection in JWGs for the implementation of specific projects.

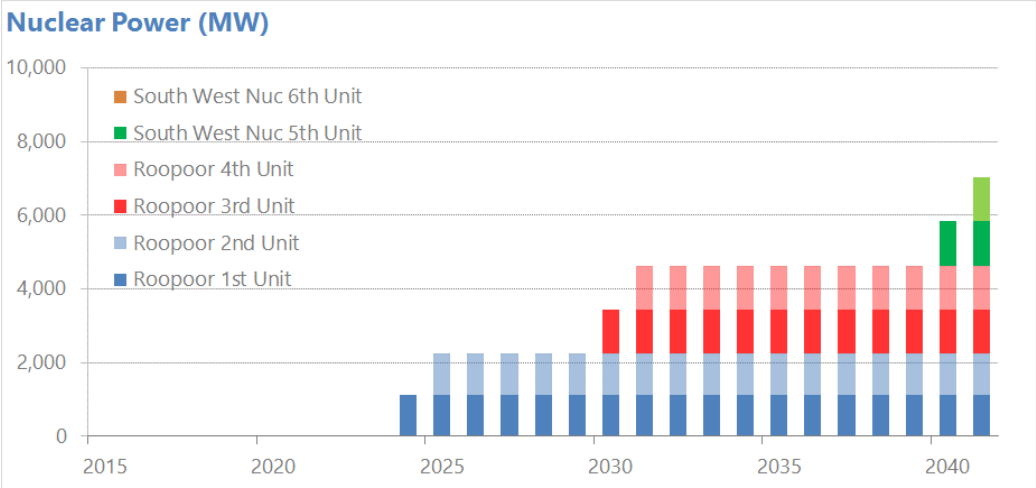
1.6.12 Nuclear Power

(1) Current Status and Issues

PSMP2016 aims to create a well-balanced power generation environment that maximizes the respective advantages of different types of power generation methods, including nuclear power, thermal power, hydropower generation, and power imports from neighboring countries, from the comprehensive perspective of stable supply, or energy security, environmental performance, and economic efficiency.

Daily power demand, or load curve varies according to season, temperature, and time of day. Since electricity cannot be stored, and must be used as it is produced. Gas and oil based thermal power generation, by virtue of its ability to respond quick flexibly to ever-changing power demand, supplies middle and peak load. Nuclear power, power import, hydropower, and coal-based thermal power generations are considered as a base load energy. This combination of different types of power sources is commonly referred to as the best mix of power sources. In this PSMP2016, nuclear power generation plays an important role in providing a stable base load.

The following figure shows the PSMP2016 scenario on nuclear power generation, following discussions with the relevant institutions. It is assumed the first unit 1200MW is to start operations by 2024 and the second 1200MW by 2025 on PSMP2016. These figures are preconditioned in the power development planning without alternative cases, which means nuclear power is assumed as one of the Fixed Factors in terms of generation capacity in the simulation, considering the government's nuclear power projects planning.



Source: JICA Survey Team

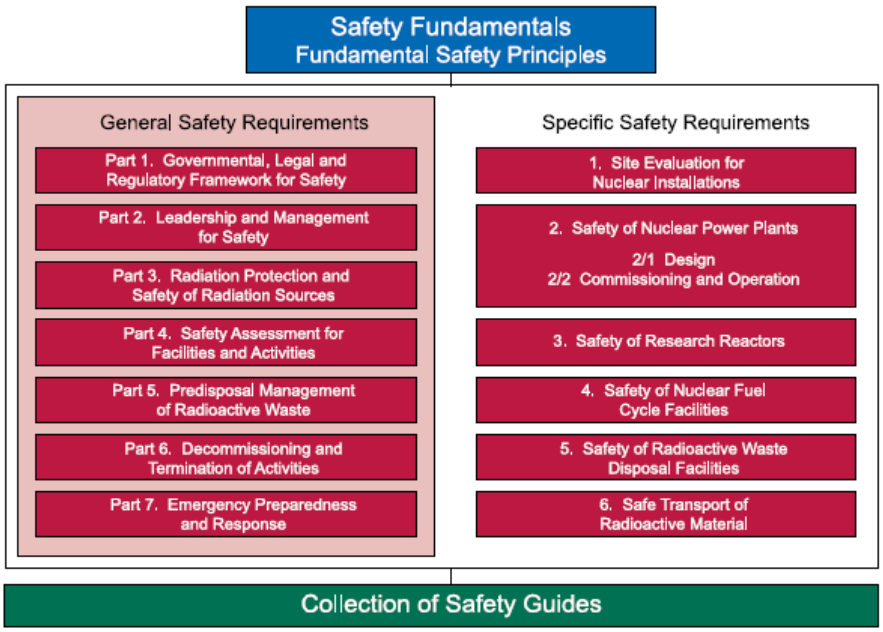
Figure 1-43 Nuclear Power Development on PSMP2016

(2) Targets to Achieve

Realization of development of nuclear generation facilities, many challenges shall be solved.

(i) Meeting IAEA safety standards2
Nuclear safety remains the highest priority for the nuclear sector. Regulators have a major role to play to ensure that all operations are carried out with the highest levels of safety. Safety culture must be promoted at all levels in the nuclear sector (operators and industry, including the supply chain, and regulators) and especially in newcomer countries (Nuclear energy roadmap actions and milestones, IEA, 2015) like Bangladesh. Followings are major frameworks to secure the nuclear safety to be followed and utilize for Bangladsh.

Nuclear safety is a global issue. There are many instruments for achieving high level of nuclear safety on a global basis, such as IAEA safety standards, safety review services provided by the IAEA. The IAEA safety standards provide a system of safety fundamentals, Safety Requirements and Safety Guides for ensuring safety. They reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. The IAEA safety standards are applicable throughout the entire lifetime of facilities and activities existing and new utilized for peaceful purposes, and to protective actions to reduce existing radiation risks. For proceed nuclear power project, all shall follow the IAEA safety standards.



Source: IAEA Safety Standards homepage

Figure 1-44 Structure of IAEA Safety Standards

IAEA recommends some critical issue for strengthen nuclear safety

- The regulatory body should be strengthened. The draft Bangladesh Atomic Energy Regulations Act of 2011 should be promulgated as soon as possible to establish an independent regulatory body.
- Management of the nuclear infrastructure development should be strengthened. Bangladesh should commit to ensure appointment of leaders (especially in future owner and regulatory body) with appropriate training and experience for leadership and management of safety. Integrated management systems (including quality management) should be planned and implemented in both BAEC and the regulatory body that define the organizational goals and key processes in sufficient detail.

[2] IAEA Safety Standards homepage

(ii) Establishment of fuel cycle management[3]

Based upon the existing nature of the nuclear business worldwide, Bangladesh is considering a long-term contract and transparent suppliers' arrangements with supplier(s) through backing of the respective government in order to ensure availability of fuel for the nuclear power reactor of the country. Examples would be fuel leasing and fuel take-back offers, commercial offers to store and dispose of spent fuel, as well as commercial fuel banks. On the other hand, at present there is no international market for spent fuel disposal services except for the readiness of the Russian Federation to receive Russian supplied fuel. Storage facilities for spent fuel are in operation and are being built in several countries.

Bangladesh is considering accessing detailed technical descriptions of the nuclear fuel assemblies offered from the supplier side, including physical, thermo-hydraulic, thermodynamic and mechanical data as well as calculations for batch planning (short term and long term). The supplier shall provide the QA programme, Handling and inspection methods for new and spent fuel and Tools for fuel and control rod manipulation and the scope of supply and services. The first core as well as the first reload should be included in the scope of supply for the plant. The bidders should include the supply of further reloads as an option.

IEAE points out that the general concerns of Bangladesh about the nuclear fuel cycle are as follows.

- The owner/operator of the nuclear plant in Bangladesh needs to ensure availability of fuel for the NPP from supplier(s) covering its entire life cycle.
- The above life cycle supply assurance shall include all services related to the front end of the fuel cycle. “Fuel leasing-fuel take-back” model (full or partial) is conceivable for Bangladesh.
- Alternate sources of services and supply of the front end of fuel cycle should be identified to accommodate any unforeseen circumstances.
- Depending on the size of the nuclear power programme, efforts will be made to acquire the technology of fabrication of fuel elements based on imported raw materials and enrichment services in order to ensure security of fuel supply.
- Pending a final decision on the back-end of the fuel cycle, the NPPs will have provision for on/ off -site spent fuel storage, the size of which shall be sufficient to store the spent fuel generated over their respective life cycles.
- Sufficient security and physical protection and safety of the fuel storage on-site will be provided in accordance with the relevant provisions of the non-proliferation regime, as well as national law and regulations on nuclear safety and radiation control.

Bangladesh will consider any suitable model of nuclear fuel cycle under the responsibility of the IAEA as the guarantor of service and supplies, e.g. as administrator of a fuel bank.

Bangladesh opines that as far as assurances of supply are concerned, the proposed multilateral approaches to nuclear fuel cycle could provide the benefits of cost-effectiveness for developing countries with limited resources. Bangladesh is strongly supporting the Agency’s approach of developing and implementing international supply guarantees with IAEA participation.

(iii) Proper knowledge about nuclear safety and Public Acceptance

Many kinds of programmes, such as meetings and seminaars with journalists, local people, have been arranged till now, and Bangladesh has established Nuclear Industry Information Center in 2013. [4] These kind of activities should be continued and enhanced for the public knowledge which will be the basis for public acceptance.

However, BAEC has conducted survey in 2015 on public acceptance / awareness for nuclear power

[3] IAEA Country Nuclear Power Profiles, 2016 update

[4] Presentation by MoST, “NATIONAL NUCLEAR POWER PROGRAMME OF BANGLADESH”, https://www.iaea.org/NuclearPower/Downloadable/Meetings/2014/2015-02-03-02-06/D1_S2_Bangladesh_Akbar.pdf

project and it is found that still concrete public opinion for nuclear power generation has not yet formed in Bangladesh since accurate information of nuclear generation technology has not became widely and correctly known.
Therefore, the government has to do more supporting enlightenment activities to enhance accurate technical knowledge on nuclear generation with good point and bad point as well as safety issue.
It is also recommended to review other countries' experience of interactive communication with public (citizen society) on nuclear technology and its safety, and ask for necessary cooperations.
As for emergency preparedness, several committees have been formed involving relevant stakeholders to formulate the emergency management system during the operation of Nuclear Power Plant in the territory of Bangladesh. These committees have already held several meeting with national and international experts. The Government is also very much eager to develop a standard emergency preparedness system for the densely populated country.



Source: Ministry of Science and Technology, 2015

Figure 1-45 Nuclear Industry Information Center

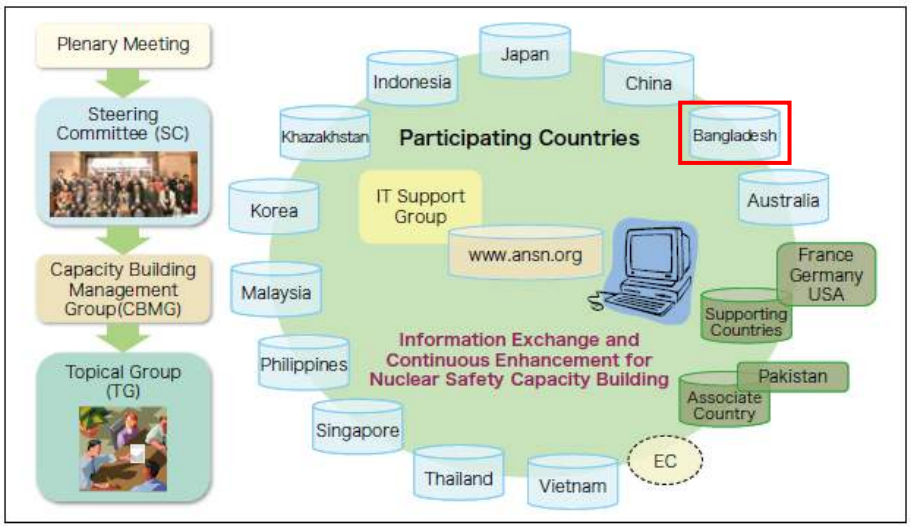
In addition, the government is preparing the Multi purpose information center around Rooppur NPP site to strengthen public communication strategy with public and media. Expected PR-program is as follows;

- Scientific workshops & round tables, discussion clubs
- Information center
- Social networks/ Social activities
- Expert opinions
- Televisions (talks shows, documentaries)
- Book "100" Facts bout Nuclear Energy
- Communication of press releases & organization of interviews
- Interaction with neighboring countries…etc

(iv) Participating international framework[5]
The Asian Nuclear Safety Network (ANSN) was launched in 2002 to pool, analyze and share nuclear safety information, existing and new knowledge and practical experience among the countries. Moreover, the ANSN is expected to be a platform for facilitating sustainable regional cooperation and for creating human networks and cyber communities among the specialists of those countries. Development of a regional capacity building system composed of knowledge network, regional cooperation and human networks will serve for enhancement of nuclear safety infrastructures in the

[5] Asian Nuclear Safety Network homegage

participating countries, and will serve eventually for ensuring and raising the safety levels of nuclear installations in the region. The ANSN has recently expanded to become a forum for broader safety strategy among countries in the region.
The current participating countries are **Bangladesh**, China, Indonesia, Japan, Kazakhstan, Republic of Korea, Malaysia, the Philippines, Singapore, Thailand and Vietnam. Australia, France, Germany and the USA are ANSN supporting countries. Pakistan is an associate country in activities related to the safety of nuclear power plants and/or strengthening their regulatory frameworks.
For proceed nuclear power project, all shall work with international framework.



Source: Japan Nuclear Energy Safety Organization

Figure 1-46 Asian Nuclear Safety Network (ANSN)

(v) Ratification to the international laws and standards
Bangladesh has not ratified the following critical international laws:

- Vienna Convention on Civil Liability for Nuclear Damage
- Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage
- Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, etc.[6]

For the implementation of RNPP, these international laws and standards should be followerd.

(vi) Other issues
There are many issues such as;

- Nuclear power planning integrated into the part of power & energy planning, such as alternative generation capacity in case of outage of nuclear power plant, reliability of the power supply system
- Development of science technology experience within the country
- Emergency planning
- Protection of the power plant from natural disaster (e.g. cyclone, flood, earthquake, etc) or outside human disaster (e.g. terrorist activities, etc)

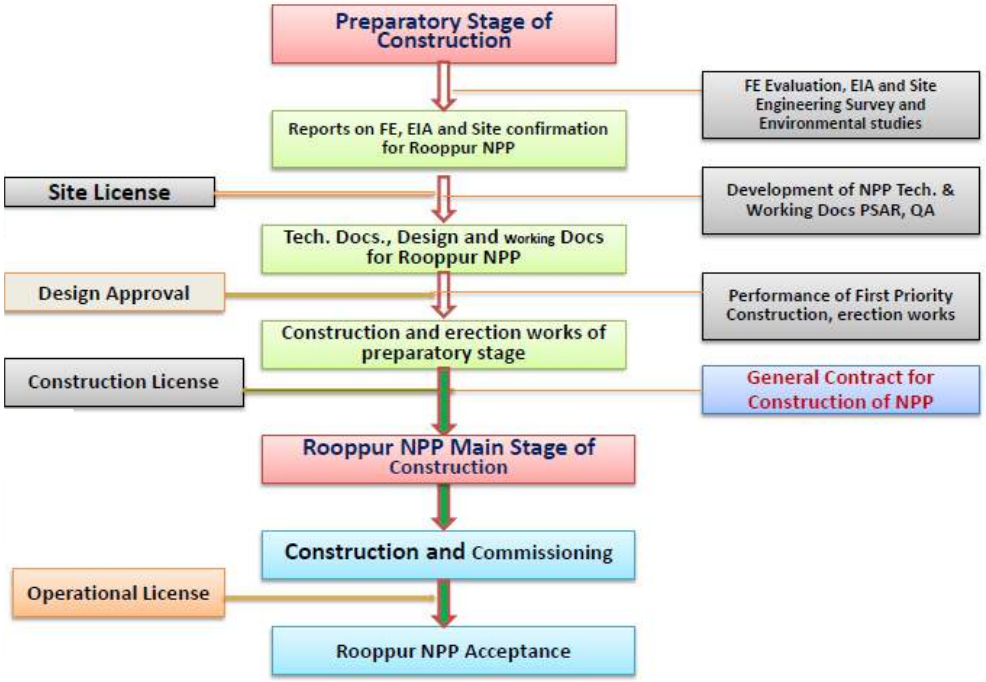
(3) Road Map

(i) Construction

[6] IAEA factsheet: https://ola.iaea.org/ola/FactSheets/CountryDetails.asp?country=BD

Consideration of the domestic legal and regulatory conditions to obtain;

- required licenses for building NPP,
- industrial base to support NPP construction,
- availability and competence of human resources for managing the NPP construction project,
- national resources as well as its social, economic and environmental condition to support NPP build.



Source: Ministry of Science and Technology, 2015

Figure 1-47 Roadmap for nuclear power development

(ii) Legal and implementation framework

All legal and implementation framework shall be established, and even be in an active before a commissioning of the first nucleare power generation as follows;

- Meeting IAEA safety standards
- Establishment of fuel cycle management
- Propoer knowledge about nuclear safety and public acceptance
- Participating international framework
- Ratification of the international law and standards

(iii) Comissioning of generation

- 2024/25: 1st and 2nd units
- 2030/31 3rd and 4th units
- 2040/41 5th and 6th units

1.6.13 Power System Plan

(1) Current Situation and Issues

1) Transmission Plan

The operating voltages of the Bangladesh power network system are below 230kV and 132kV, except for the 500MW HVDC link to India that began to be operated in 2014 at Bheramara. The 400kV transmission lines and substations have just recently started to be constructed. Many existing power stations have only a capacity of below 100MW, using domestic gas. They are currently distributed across the whole of the nation. The following figure shows the current national power network system of Bangladesh, which consists of 230kV and 132kV, without 400kV, and small-scale power stations connected to substations distributed across the whole of the nation.

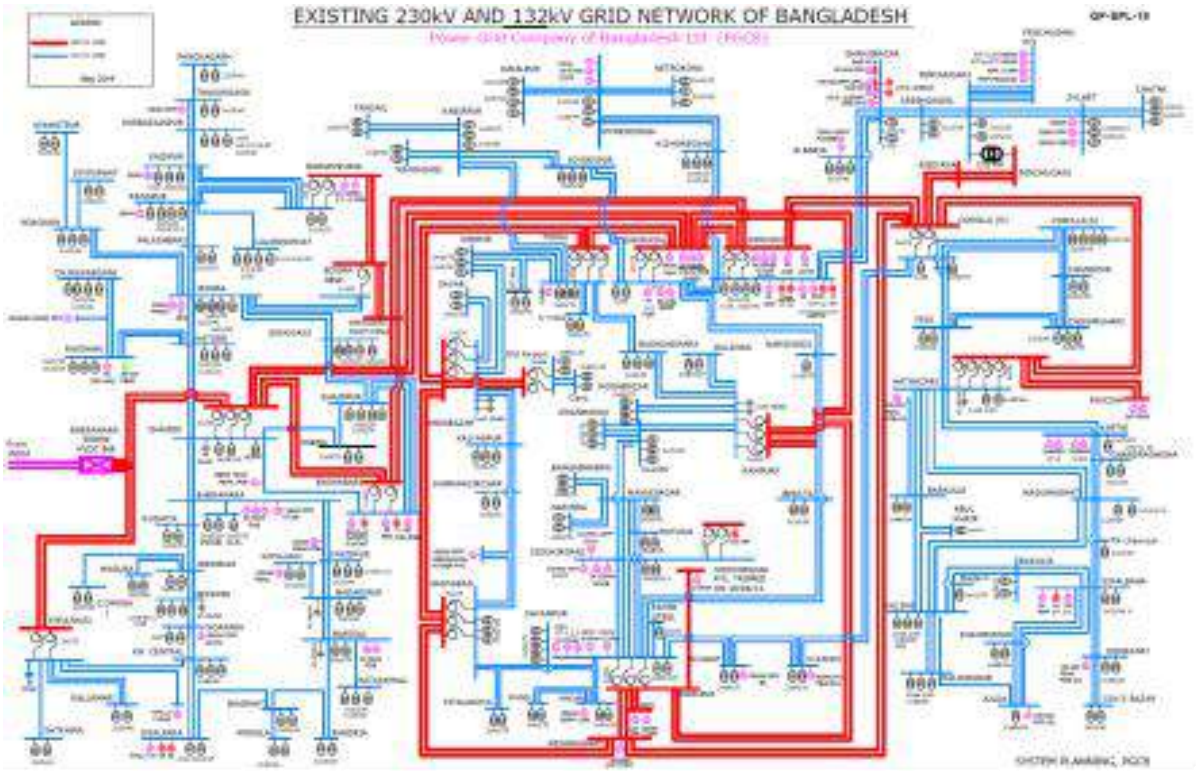


Figure 1-48 The Existing Bulk Power Network System of Bangladesh (2014)

An efficient power network system, including 765kV and 400kV transmission lines, needs to be studied in consideration with the plan for large scale power stations, the high density of power demand in and around Dhaka and Chittagong and the characteristics of Bangladesh's power network system as shown below.

- The rapidly deteriorating and inefficient small-scale power stations with capacity below around 100MW will be phased out in sequence.
- The future thermal power units will mainly use imported fuel such as coal or LNG. Because the locations where suitable seaports can be constructed to receive large scale ships for imported fuel are limited to south Chittagong and Khulna (Pyra and Patuakhali), the large scale power stations with a capacity of several thousand MW will be unevenly distributed in those areas.
- A nuclear power station with a total capacity of 4,800MW is planned for Rooppur.

- In the case of power transmission from hydropower stations located in Bhutan or Nepal through India, HVDC interconnections with a capacity of around 500–2,000MW will be required in the north western part of Bangladesh.
- The power demand density in Dhaka and Chittagong will increase further due to their rapid growth ratios.
- Although it is required to transmit power of several thousand MW from Chittagong to Dhaka, the number of circuits in the transmission lines is restricted on the route through Comilla because the width of the country is narrow and the population density is large in the Comilla region.
- The construction of transmission lines crossing between east and west in Bangladesh will incur much cost because Bangladesh has two large rivers, named Jamuna and Padma, flowing in the center of the country, with widths of at least around 4.5km to 6km.

2) Rural Electrification

While the government has established "Electricity for all" by 2021[7], in its Vision Statement, there is no single internationally-established definition for electricity access.
As of December 2015, the Power Division recognizes the electrification rate of Bangladesh as 77%. In government policy statements such as the 7th Five Year Plan, the Power Division's figure is adopted.

Table 1-11 Electrification Rate Calculation Details by Power Division

	BPDB	REB	DPDC	DESCO	WZPDCL	SHS
No. of Domestic (Residential) customer	2,721,205	12,223,002	910,336	641,978	728,453	4,000,000
Family member parameter	5.5	6.5	4.5	4.5	5.5	4.0
No. of people with electricity access	14,966,628	79,449,513	4,096,512	2,888,901	4,006,492	16,000,000
Total No. of population with electricity access	121,408,045					
Total population of Bangladesh	157.8 million					
Access to Electricity	77%					

Source: Power Cell, Power Division

The Electrification rate adopted by BPDB is the ratio of number of access and the whole population. Access to Electricity is calculated by the below equation.

$$Access\ to\ Electricity\ (\%) = \frac{Number\ of\ Electrified\ Customer \times 7^{*1} + Number\ of\ SHS \times 4^{*2}}{Total\ Population}$$

Source: BPDB System Planning Division

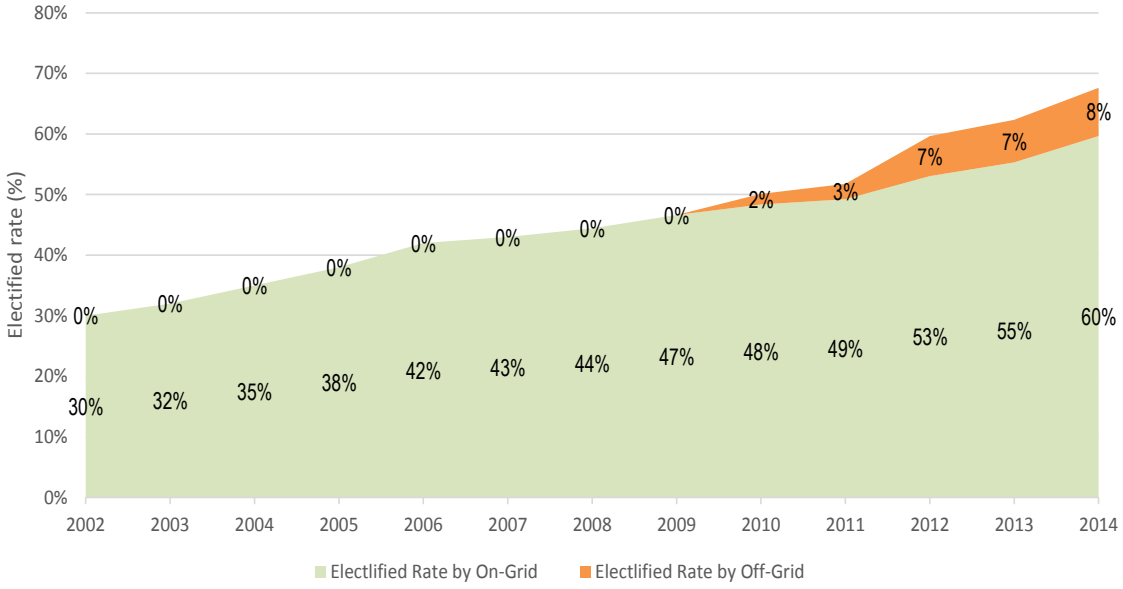
*1 It assumes that the number of people per grid connection (per household) is 7.
Household: Husband, wife, children x 2, father, mother + 1. There are big customers such as hospitals, so 1 is added.

*2 It assumes that the number of people per off-grid connection (renewable) is 4 (-2014) or 5 (2013-). This is based on the assumption that a household using SHS has fewer family members than a grid-connected household.

[7] In the 7th Five Year Plan adopted in December 2015, the target by 2020 is set as "electricity coverage to be increased to 96 percent with uninterrupted supply to industries".

This BPDB definition indicates that the electrification rate improvement has two paths: one is on-grid connection, the other is off-grid connection (e.g. SHS).

The following figure shows the Access to Electricity provided by BPDB. According to this figure, 60% of the population was electrified by grid connection; 8% was electrified by SHS installation. In total, 68% of Bangladesh was electrified in 2014.

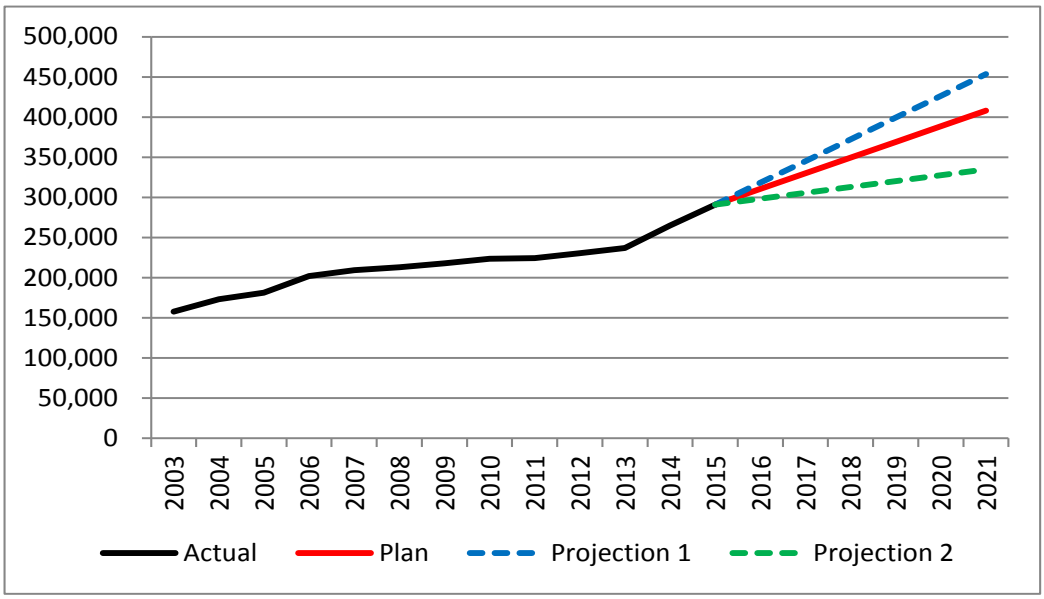


Source: JICA Survey Team, based on the data provided by BPDB

Figure 1-49 Development of Access to Electricity (BPDB definition)

The below Figure shows the BREB's grid extension projections by 2021, compared with the actual trend in the past up to 2015. The solid black line shows the actual implementation, and the red solid line indicates the sum of the individual grid extension projects (as of February 2016).

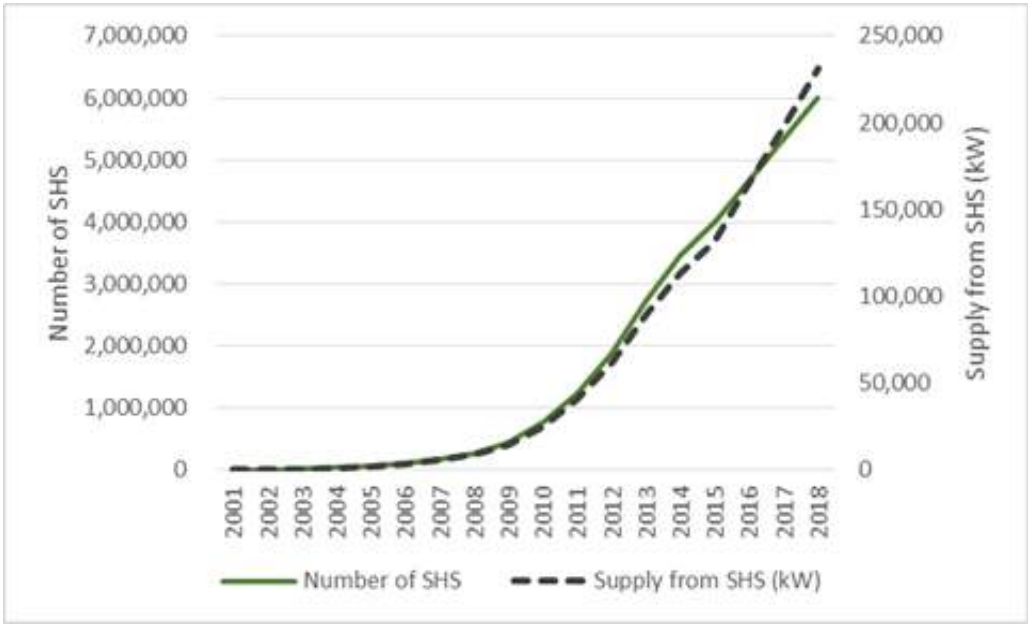
It should be noted that BREB made a great improvement in grid extension implementation between 2014 and 2015, when it substantially increased the grid extension speed compared with the past (between 2003 and 2013). The dotted blue line (Projection 1 in the Figure) means that if BREB keeps the implementation speed as fast as that between 2014 and 2015, it will in theory reach 100% on-grid extension (in other words, 440,000km distribution line development) by 2021 (it should also be noted, however, that there is a technical issue with on-grid extension, as described later). On the other hand, if BREB lowers its grid extension implementation speed to as slow as that between 2003 and 2013, it would end up far below its target (green dotted line, projection 2 in the Figure).



Source: JICA Survey Team

Figure 1-50 BREB On-grid Extension Plan Comparison

The SHS installment has been implemented by IDCOL and the progress is at a world-renowned pace (as seen in the below figure).



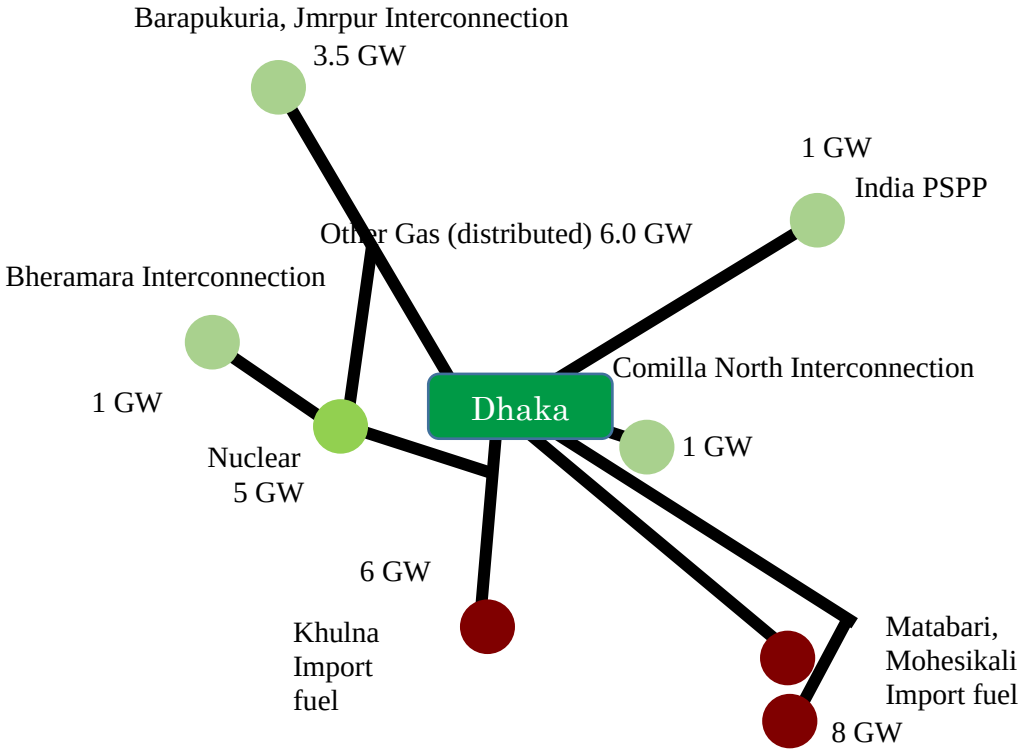
Source: JICA Survey Team

Figure 1-51 Number of SHS under IDCOL Program

(2) Target of the study

1) Transmission Plan

The power network system is examined by categorizing the study phase into mid-term (2025) and long-term (2035) through reviews of PSMP2010 in consideration of the application of 400kV and 765kV. The transmission lines and substations are planned in order to fulfill the criteria that are set as the rules for power network system planning and analysis.
An efficient bulk power transmission network is planned reflecting the results of the power demand forecast and power generation plan in this MP by recognizing the abovementioned current situation and issues.



Source: JICA Survey Team

Figure 1-52 Conceptual Map of Locations of Large Scale Power Stations Planned Up to 2035

2) Rural Electrification

- Only one definition of electrification rate should be selected. Also, the national census states that the average family member size is 4.6, while 7 is adopted by BPDB.
- Grid extension in the next 5 years requires the same implementation speed as that seen between 2014 and 2015, or twice as fast as the historical pace (average between 2003 and 2015).
- BREB and IDCOL coordination and communication should be improved for efficient planning and implementation. BPDB's current role as "coordinator" could be reconsidered.
- SHS waste recycling needs will drastically increase after the early 2020s. It should be confirmed whether the current scheme has proven effective and scalable.

1.6.14 Improvement of Power Quality

(1) Current Situation and Issues

1) Necessity of Power Frequency Quality Improvement

In general, the following objectives to improve frequency quality can be mentioned:

- To improve the quality of industrial products.
- To increase the allowable capacity of PV and wind power sources.
- To secure the stable operation of large capacity generation plants (especially, nuclear power plants).

All of the objectives may have high potential needs, but the methodology for determining the target value for improvement has not been established yet. And it becomes more difficult than before to determine the target value because the number of inverter circuits, which are inserted between the power grid and consumer's facilities or distributed power sources, is gradually increasing, though, qualitatively, it can be determined depending on the trade-off relationship between cost and benefit for consumers.
On the other hand, for stable operation of synchronous machines, such as large capacity generating units, there is a quantitative requirement that the frequency quality shall be raised to within ±1.0% of the standard value (50±0.5Hz).
In particular, the equivalent frequency quality is required in order to connect and operate stably the nuclear power plant planned to be commissioned in 2024. Therefore, ±1.0% can be set as a short-term target value.

Consequently, we set, in this Study, "±0.5Hz by 2024" as an essential target value, and "±0.2Hz by 2041 at latest" as a tentative value.

2) Current Situation

(a) Current conditions of generating facilities and significant deficiency of power sources

As seen in the results of the survey about the situation of supply-demand balance on days of maximum peak demand from 2013 to 2015, the load shedding operation is frequently performed, even though the installed capacity rate has been adequately secured at more than 130% every year.

The major factors involved in this situation are as follows:

- The available capacity is chronically insufficient due to decreases in the output and thermal efficiency and failures of power generators mainly due to the insufficient periodic maintenance, which results in a decrease of around 30% of installed capacity.
- Normally, full authority for preparing, approving and implementing the supply-demand balance plan should be given to NLDC in order to carry out the balancing operation properly. However, NLDC has no authority to coordinate the generating plans prepared by BPDB and other generation companies.

(b) The actual conditions of power frequency control

At present, adjustment of the output of generators is instructed by phone (online instructions from SCADA are not issued). System frequency deviation from 50 Hz often exceeds ±1.0 Hz even in the

normal operating condition (Grid Code stipulates that the system frequency shall be controlled within 50Hz±1.0Hz under normal conditions.)

The major factors contributing to this situation are as follows:

- There is almost no remaining power which can be offered for frequency control due to a significant deficiency in power sources. That is, all generators have no other choice except to keep their outputs at the maximum of available capacity.
- Grid Code in Bangladesh seems to have most of the necessary and minimum provisions related to frequency regulation and authority of NLDC. However, unfortunately, these provisions still seem to have poor effectiveness.
- There is no compensation system for the opportunity loss of power selling due to the contribution to frequency control.
- There is a strong desire to obtain detailed information about a power system among the stakeholders, because supply-demand control and frequency regulation should be performed under fair and transparent circumstances.

3) Issues regarding power quality

(a) Regulatory framework

Regulation by the Electricity Acts

A rough comparative study between the provisions of Electricity Acts in Japan and Bangladesh is performed.
As shown in the following table, there is only one obligatory provision (④) without penalty in relation to stable demand/supply operation and frequency control in Bangladesh, while there are five provisions with penalties in Japan:
Amendment is urgently required regarding several kinds of obligation rules and their penal provisions in order to enhance effectiveness.

Provisions				
	Article	Penalty	Article	Penalty
① **Obligation to supply**	18	Yes	None	-
② **Obligation of endeavor to maintain voltage/frequency value**	26	Yes	None	-
③ **Obligation to prepare a "Supply Plan"**	29	Yes	None	-
④ **Obligation to prepare "General Supply Provisions"**	19, 19-2 20, 21	Yes	22	None
⑤ **Restrictions on Use of Electricity**	27	Yes	None	-

Regulation by independent regulatory organization

The JICA survey team performed a comparative study of provisions between the two Grid Codes established by the regulatory commission of each country, BERC (Bangladesh) and OCCTO (Japan), in relation to the work process for supply-demand operation and frequency control, as shown in the following table:
From the results of this comparative study, it was found that the necessary minimum provisions for the supply-demand control process are appropriately stipulated in BERC's Grid Code. However, there seem to be no provisions for securing reserves (operating reserves, spinning reserves and so on).

Provisions	Details		
Supply Plans (Power Plants and Network Development Plan)		Yes	None
Demand Forecasting	**Variety of Forecasting**	Yes	Yes
	Responsibility of Forecasting	Yes	Yes
	Post Facto Inspection	Yes	None
Planned outage schedule	**Integration for the Draft Plans**	Yes	Yes
	Coordination between Users and Finalization of the Plans	Yes	Yes
	Particular Points to note	Yes	Yes
Demand/Supply Balance Schedules	**Preparation of the plan and Monitoring the balance**	Yes	Yes
	Operating Reserves	Yes	None
	Spinning Reserves	Yes	None
	Margin for lowering	Yes	None
	Measures when supply demand balance worsens	Yes	Yes
Real-time System Operation	**Frequency Control**	Yes	Yes
	Power Quality Analysis	Yes	None
Information Publication		Yes	None

(b) Prospect of frequency quality improvement and challenges in the future

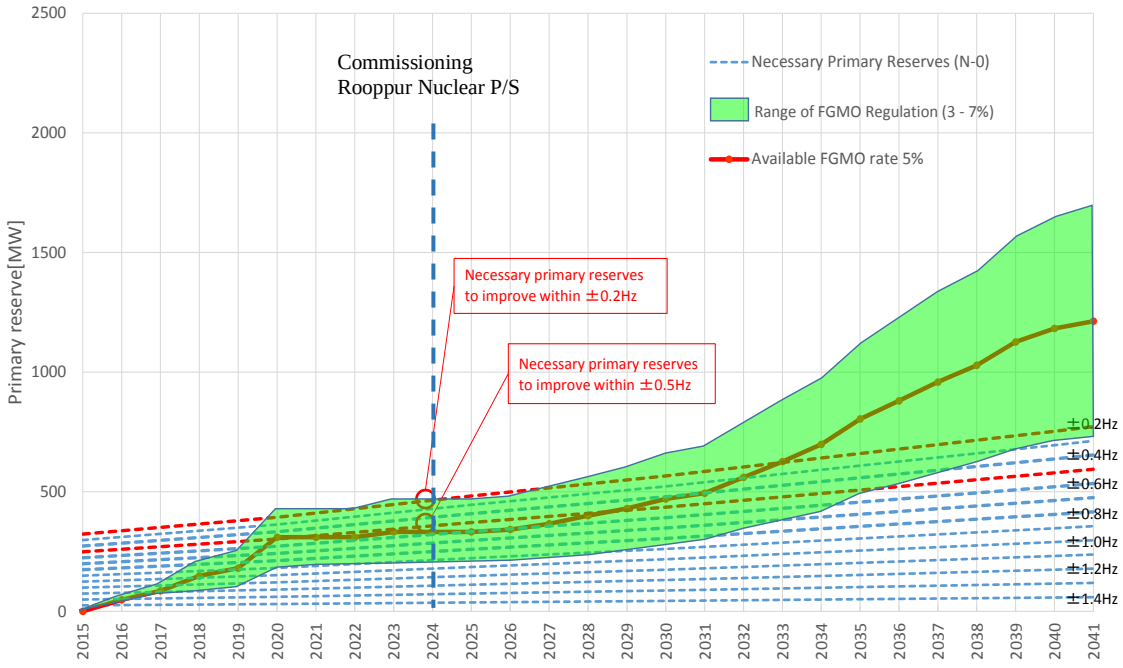
Frequency regulation control is usually realized by a combination of FGMO (Free-governor mode operation) and LFC (Load frequency control).
In this study, the JICA survey team conducted a trial calculation for future frequency improvement when the regulation control is performed by FGMO only, because:

- LFC function in SCADA/EMS is not prepared for use at present.
- LFC cannot follow the sudden change in supply-demand balance caused by the trip of a generating unit or load shedding.

Power frequency quality improvement in the N-0 Case (Normal Conditions)

Unfortunately, there is no globally standardized method to evaluate the frequency improvement. Therefore, in this study, the JICA survey team calculates the available spinning reserves provided by generators and the necessary amount of reserves to improve the frequency fluctuation per 0.1Hz, under certain conditions and assumptions. The trend of future frequency quality can be estimated by finding the balance point of available reserves and necessary reserves. For details, refer to the full final report.

The following graph shows the available spinning reserves and necessary amount of reserves each year:



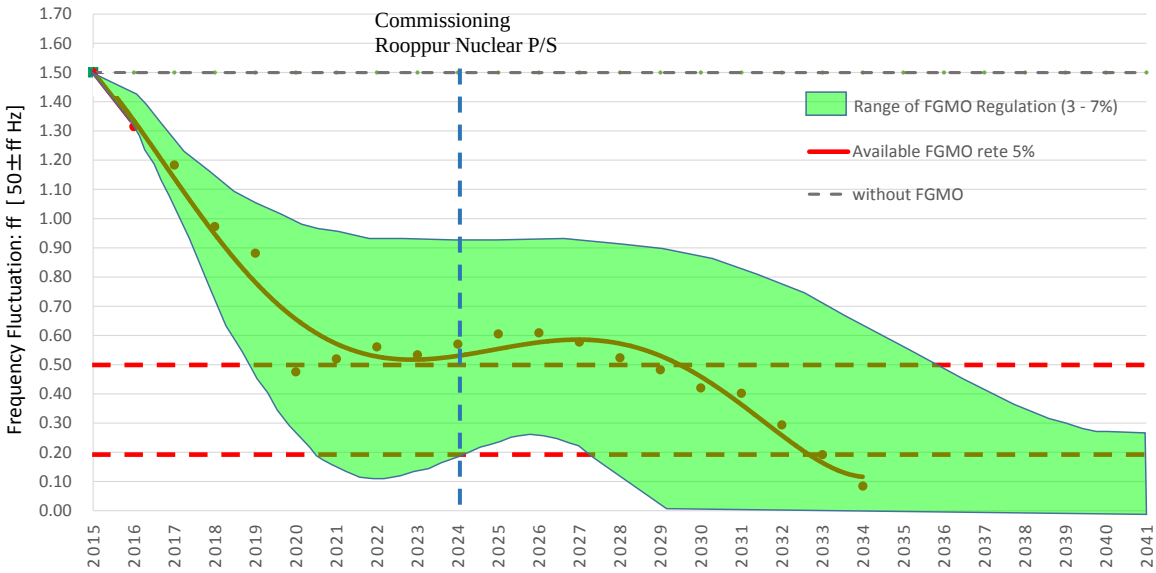
Source: JICA Survey Team

Figure 1-53 Comparison between the Necessary Reserves and the Available Reserves

Solid line in red + Range in green = Available spinning reserves
= [Hydro (100%) + Oil (100%) + Gas (100%) + Coal (50%)] newly installed after June 2015
× 80% (assumption of planned and unplanned outage rate)
× 3 - 7% (assumption of the effective range of adjustment by FGMO)

Dashed lines : $\Delta P = 0.263 * \sqrt{P}$ (MW/0.1Hz)
ΔP : Necessary amount of reserves to improve frequency per 0.1Hz
P : Total power demand
(Frequency fluctuation, at present, is assumed to be ±1.5Hz)

The following graph shows the trend of frequency quality improvement from the viewpoint of fluctuation range. Fluctuation range under normal conditions, at present, is set to ±1.5Hz according to the chart provided by NLDC.



Source: JICA Survey Team

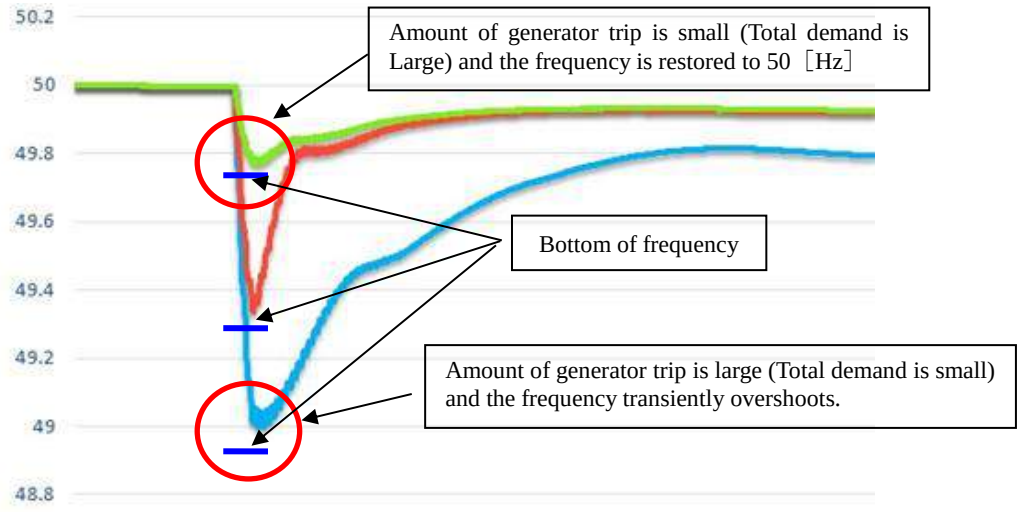
Figure 1-54 Trend of Power Frequency Quality Improvement

From the results of these analyses, there will be huge potential for appropriate frequency regulation under normal conditions, if sufficient reserves for FGMO can be prepared in a carefully planned way.

- By 2024, when a Rooppur nuclear power generating unit commences to be operated, sufficient reserves can be prepared so that the frequency fluctuation can be reduced to ±0.5Hz or so, if effectiveness of FGMO is expected to be 5% of total demand (average level)
- By 2041, sufficient reserves can be prepared so that the frequency fluctuation can be improved to ±0.2Hz or lower.

Power frequency quality improvement in the N-1 Case (Emergency Conditions)

Even when a significant frequency deviation occurs due to a sudden trip of large capacity generators, lowering of frequency should be limited to within a certain level and promptly recovered via sufficient reserves.



Source: JICA Survey Team

Figure 1-55 Schematic Diagram of the Frequency Deviation Immediately after the Generation Trip

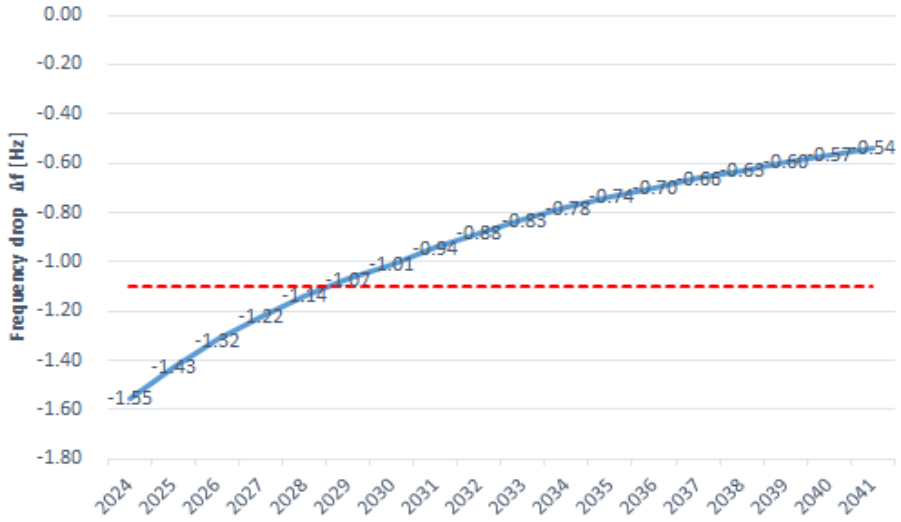
Overshoot of frequency immediately after the generation trip can be regulated only by FGMO and the inherent characteristics of the flywheel effect in load. Therefore, urgent preparation for FGMO is required in Bangladesh. The large capacity generator (power source) trip events which should be taken into consideration in Bangladesh are as follows:

Table 1-12 Supply Trip Amount and Factors Which Should Be Considered in Each Year

Year	Supply trip amounts	Factors
2015~2024	500MW	Single apparatus fault of HVDC 500MW
2024~2041	1180MW	Single unit trip of Rooppur nuclear power plant

Source: JICA Survey Team

The following graph shows the assumption for frequency deviation (Δf) using the standard value in TEPCO, when a sudden trip of a Rooppur nuclear power unit (1180MW) occurs under the minimum demand conditions each year after 2024.



Source: JICA Survey Team

Figure 1-56 Trend of minimum values of frequency immediately after a sudden trip of a Rooppur unit

As shown in the graph above, frequency overshoots below the UFR settings, 48.9Hz, due to the trip of the Rooppur unit in a low demand season or time zone, which leads to load shedding until 2028. However, it should be allowed in order to avoid a cascading outage and blackout.

(2) Targets to Achieve

1) Improvement of Electricity Act and Grid Code Framework

(a) The Electricity Act 1910

Amendment to add provisions for various obligations and penalties for improvement of power quality is urgently required.

(b) The Grid Code 2012

Grid Code in Bangladesh has necessary provisions to a certain extent, but provisions in relation to preparation of reserves should be enhanced.

2) Improvement of Frequency Quality

Adequate reserves for FGMO should be prepared in a planned way, enough to improve frequency fluctuation within ± 0.5 [Hz] (1/3 of fluctuation at present) as recommended in IAEA guidelines until the operation of Rooppur nuclear power plants start in 2024 and 2025.

Adequate reserves for load shedding by UFR should be set in order to prevent a blackout as a tentative measure.

(3) Roadmap

Key issues in PSMP2016	The goal	Action Plan	Target			Priority
			Short-term (2016~2021)	Medium-term (2022~2031)	Long-term (2032~2041)	
Power Frequency Quality	Improvement of Electricity Act and Grid Code Framework (Provisions for obligation and penalty)	Amendment of Electricity Act	→			H
		Amendment of Grid Code	→			H
		Improvement of NLDC Operation Procedures	→			H
	Improvement of Frequency Quality	FGMO by newly installed units				
		- Planning and Designing	→			H
		- Manufacturing/Conversion	→			H
		- Testing and simultaneous commissioning of units planned from 2015 to 2021	→			H
		- Promote systematically according to the installation plan after 2022	→	→	→	H
		LFC by newly installed units		→	→	M
		Preparation of reserves for load shedding by UFR	→			M

1.6.15 O&M Legal Framework

(1) Current Status and Issues

It has not been possible to suspend the operation of power generation facilities and inspect them regularly because of the permanent shortage of the power supply in Bangladesh. The legal framework for the preventive maintenance and O&M of these facilities is insufficient. BPDB is financially unsound because of the low power purchase price. Because of these reasons, the power generation facilities are not operating at their design performance level (in terms of power output, thermal efficiency, etc.). Therefore, the establishment of an integrated system for the stable power supply is required.
The analysis conducted on solving the problems concerning the preventive maintenance and O&M of the thermal power plants with the development of a system, or the establishment of a legal framework, is described in this subsection. In addition, the analysis conducted on solving the same problems with measures to be taken in the plants is described in the next subsection.

<Issues>

1) Necessity of institutionalization of periodic inspections

Since periodic inspection is not stipulated by law in Bangladesh, periodic inspections tend to be postponed due to reasons such as budget shortages or tight electricity demand, thus resulting in unplanned and undesirable shutdown.

2) Necessity of institutionalization of safety audits

Government agencies, as they do not visit power plants to check the inspection situation, do not know whether the machine conditions allow proper operations or not.

3) Necessity of institutionalization of chief engineer

As the responsibility for technical matters in a power plant is not clear, the organization doesn't function properly in the case of trouble.

4) Necessity of institutionalization of Safety regulations

Basic concept of security for operations in power plant is not documented.

5) Necessity of institutionalization of technical standards

National technical standards that would reduce the amount of accidental trouble and disasters are not regulated.

These five provisions are essential for stable operation in Bangladesh.

(2) Targets to Achieve

- Periodic inspections
  - Purpose
    - ✧ To avoid postponement of inspections due to budget shortages or tight electricity demand, etc. by securing periodic inspections.
    - ✧ To prevent serious accidents by conducting periodic inspections.

- Action
  - Authorities decide the intervals and inspection items for periodic inspections.
  - Generators have to conduct the periodic inspections.

- Safety audits
  - Purpose
    - To audit whether periodic inspections are implemented properly or not.
    - If there is a defect in the periodic inspection, auditors instruct on its correction.
  - Action
    - Authorities decide items for safety audits
    - Generators undergo periodic safety audits by authorities

- Chief engineer
  - Purpose
    - To clarify the responsibility for technical matters
    - To carry out technical management under the chief engineer
  - Action
    - Authorities order generators to stipulate the responsibility of chief engineer
    - Generators select chief engineer from among licensed persons

- Safety regulations
  - Purpose
    - To establish self-management system by making safety regulations
    - To establish PDCA cycle of operation independently
  - Action
    - Authorities order generators to set up safety regulations
    - Generators follow their safety regulations

- Technical standards
  - Purpose
    - To prevent accidents and disasters caused by technical issues
    - To reduce the amount of forced maintenance work
  - Action
    - Authorities make national technical standards
    - Generators follows the national technical standards

(3) Roadmap

The suggested O&M legal items mentioned above can be divided into three categories as mentioned below, and these measures are recommended to be taken step by step.

- Strengthening of control by government
  - Periodic inspections
  - Safety audits

- Self-management by Generators
  - Chief engineer
  - Safety regulations

- Enhancement of technical aspects
  - Technical standards

Based on the assumption that the preparation time for regulations is 2 years and the starting time for the respective categories has a 1 year difference, the schedule becomes as follows.

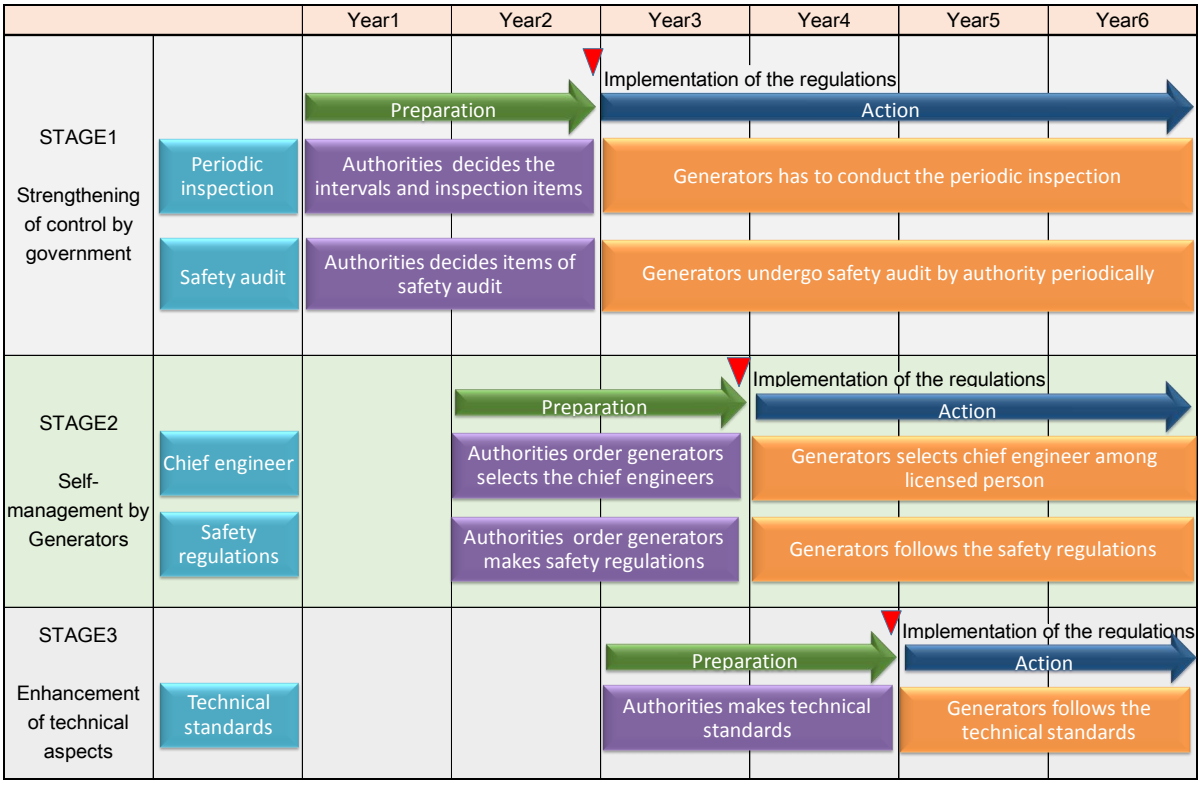


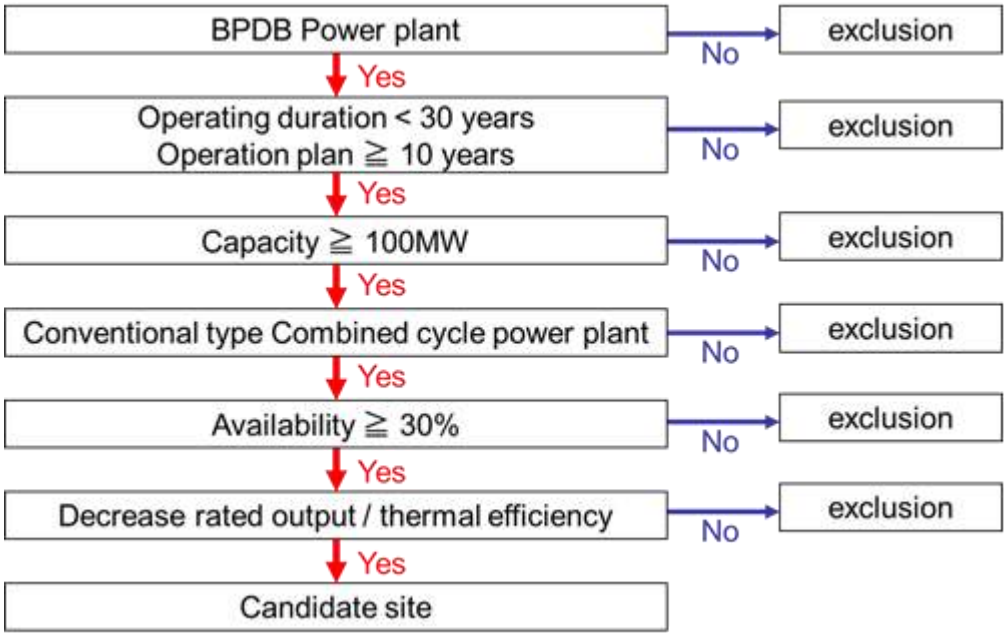
Figure 1-57 Schedule for Legal Reform

1.6.16 Thermal Power Plant O&M

(1) Current Status and Issues

In Bangladesh, some thermal power stations have a capacity problem due to a lack of O&M practice. This leads to the power production shortfall. Higher efficiency can be achieved by applying an appropriate O&M practice with sufficient skills, so that the plant capacity can be recovered. In order to comprehend the O&M situation in Bangladesh as a whole, the JICA study team carried out screening with the following selection criteria, and then, selected some target sites for rehabilitation and conversion to combined cycle as remodeling plans. The screening criteria are shown below.

(a) BPDB owned
Grounds: BPDB is the largest generation public company in Bangladesh
(b) Operation period: more than 10 years, less than 30 years
Grounds: 10 years of experience in O&M is preferable.
A unit older than 30 years may have large-scale malfunctions regardless of the application of the remodeling plan, therefore, 10-20 year long stable operation may not be expected after the completion of the remodeling works.
(c) Larger than 100MW
Grounds: There is little to expect from the rehabilitation effect on a small power unit.
(d) Availability higher than 30%
Grounds: This means the plant is very useful, and will continue to be vital in the future.
(e) Lowered output or efficiency
Grounds: A large effect can be expected.



Source: JICA Survey Team

Figure 1-58 Site Selection

BPDB Annual Report 2012-2013

Name of powerplant	For		COD (Year)	Type	Fuel	Installed	Derated	Plant factor	Efficiency (NET)	
	O&M	C/C				(MW)	(MW)	(%)	(%)	
Rauzan #1		○	1993	ST	Gas	210	180	23.94	27.98	*1
Rauzan #2		○	1997	ST	Gas	210	180	15.80	28.89	*1
Ashuganji #3、#4、#5	○	○	1987/87/88	ST	Gas	450	430	88.56	33.88	
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	30.32	
Barapukuria #1,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	27.56	
Chandpur	○		2012	CC	Gas	163	163	49.68	37.27	
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	53.33	21.16	
Ghorasal #3,#4	○	○	1987/89	ST	Gas	420(210*2)	360	69.53	31.09	
Ghorasal #5,#6	○	○	1995/99	ST	Gas	420(210*2)	380	33.72	28.76	
Tongi		○	2005	GT	Gas	105	105	38.38	25.93	
Baghabari		○	2001	GT	Gas	100	100	87.52	28.29	
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.53	
Fenchuganj	○		2011	CC	Gas	104	104	49.08	30.06	
Sylhet		○	2012	GT	Gas	150	142	51.96	29.16	

*1) Rauzan power station 1)lack of gas causes low availability
2)large scale of its generation capacity
Because of above reasons, Rauzan power plant also listed in candidate plants list.

Source: JICA Survey Team

Figure 1-59 Target Site List

The study was performed based on interviews with and questionnaires for the representatives of the target power plants. The results are categorized into Human Resources, Facility, Finance, and, Information, which are commonly referred to as organizational resources in management of an enterprise. As shown in the table below, the problems exist across the organizational resources.

Table 1-13 Problems in Organizational Resources

Core Missions and Areas	Human Capital	Facility	Finance	Information
Generation Capacity	—	Unit failure. Aging.	—	—
Daily Operation	Insufficient employee rotation. Lack of practical training equipment. Insufficient training facilities.	—	—	Lack of efficiency management.
Maintenance & Repairs	Insufficient employee rotation. Lack of practical training equipment and material. Insufficient training facilities.	—	No budget.	—
Maintenance Planning and Budget Creation	—	—	No budget.	Absence of supporting data for maintenance plan and shutdown permission. Lack of evaluation process.

Source: JICA Survey Team

While solutions to each problem are proposed in (2) Targets to Achieve, in accordance with the analytical method based on the organizational resources, some of the problems still remain unsolved in the tree, which are:

- Lack of standards for replacement
- LTSA does not exist
- Lack of standards for maintenance
- Absence of legal enforcement

These are firmly connected with the legal framework which should be enacted by the government. As the development of the legal framework has been examined in detail in the previous subsection, it is not described in this section. However, it is possible for owners of power generation facilities to conduct regular inspection without a legal regulation. It is necessary to make them aware that regular inspection at short intervals will lead to long-term stability of output and the sustainable profitability of power generators.

(2) Targets to Achieve

As a facility enhancement solution for the capacity problem, this Study proposes rehabilitation and conversion to combined cycle. It also proposes the following plans to facilitate regular maintenance which requires information management and plant crew trainings.

Table 1-14 Solution Proposals

Core Missions and Areas	Human Capital	Facility	Finance	Information
Generation Capacity	–	Steam turbine rehabilitation & conversion to combined cycle. Scheduled maintenance.	–	–
Daily Operation	Training center equipped with simulators and hi-tech training materials. Work rotation.	–	–	Collection of unit data and fuel data, and efficiency monitoring.
Maintenance & Repairs	Training center equipped with real machines and hi-tech training materials. Work rotation.	–	Mid-to long-term maintenance budget.	–
Maintenance Planning and Budget Creation	–	–	Procurement based on maintenance plan. Financial efficiency monitoring and cost optimization	Database for budgeting, shutdown planning, investment decision making and evaluation.

Source: JICA Survey Team

The study team proposes the following feasible plans to implement the solutions above, which are considered to be effective in human capital development, facility enhancement and efficiency improvement in financial decisions.

The human capital development proposal includes a new training facility with a practical training system (Training Center). The Training Center is purported to provide trainees with:

- High-tech education for new power facilities.
- Practical training courses and opportunities to experience real operations and maintenance practices.
- Education for certifications in compliance with laws and regulations.

In order to meet the training demand, the study mentions about inviting trainees to Japan during the construction of the training facility.

The facility enhancement proposal is based on a B&S (build and scrap) unit remodeling plan possibly applied to Haripur and Fenchuganj. Compared to the other plans, the B&S plan has smaller impacts on the production level of the power station. The capacity of the combined cycle unit is expected to be 100MW, which is responsive enough to fill the gap in the case where the frequency fluctuation indicates a gap between peak demand and supply.
A 100MW combined cycle unit has the following advantages:

- Quick start, short ramp-up (2 hours to reach the full load capacity).
- High efficiency in the low load range.
- Cost efficiency.

In order for the authority to improve efficiency in financial decisions, creation of mid-to long-term plans for procurement in alignment with facility maintenance plans is strongly recommended. The delays in budget and procurement approval would be reduced or removed, which should encourage plant managers to create feasible maintenance plans.

- Costs for regular maintenance should be allocated over time.
- Contingency reserve must be estimated based on failure/repair history.
- Spare inventory should be maintained at an optimal level.
- The budget process must be integrated across the power plants.

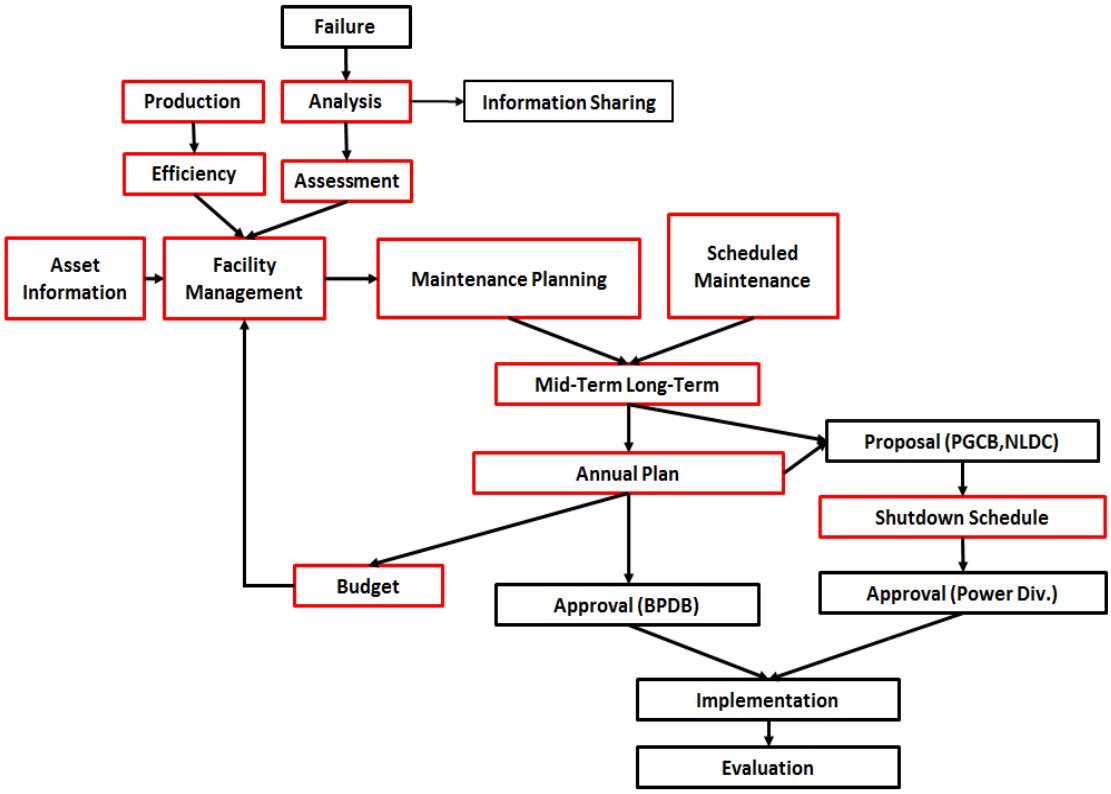
The implementation items of the proposed solutions are shown in the table below.

Table 1-15 O&M Solution Proposals and Implementation Plans

SOLUTION ITEM	DESCRIPTION
Facility	Facility Enhancement
Rehabilitation and Conversion	Scrap & Build/Build & Scrap remodeling for Fenchuganj and Haripur.
Human Capital	Human Capital Development
Education System	Technical support from Japan in creation of training curriculum and materials. Training provided in Japan. - Education for technological standards. - Learning about roles of Chief Engineer.
Training Facility	Construction of the facility. Technical support for introduction of facility and equipment such as simulator.
Finance	Efficiency Improvement in Financial Decisions
Budget Creation	Synchronization with maintenance plans. - Estimation for maintenance cost. - Supporting data for budget approval. - Mid to Long term budget creation in alignment with regular maintenance schedule.
Procurement Process Optimization	Planning - Procurement process redesign. - Spare inventory control. - Cost reduction planning. Procurement Efficiency Monitoring - Budget control and delay management. - Financial efficiency monitoring.

Source: JICA Survey Team

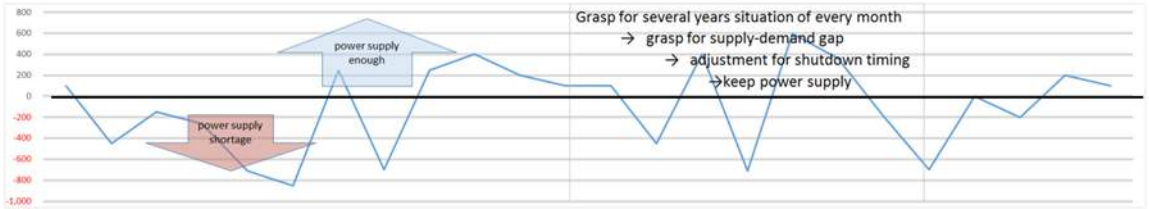
If BPDB has managed to establish a system for the centralized management of the data on the operation and the plans and records of repair of all the plants under its control, as a financial measure, it will be able to estimate the budget for the entire organization and to plan for the suspension of the plant operation and, thus, the delay in the approval of budget and suspension of the plant operation will be reduced. The implementation of measures to solve problems in the information sector is considered to improve the activities in the red rectangles in the figure below. It is considered that the information can be used effectively in facilitating the solution of various problems in the operation of power plants in general including problems concerning human resources, facilities and budget and improving the O&M activities.



Source: JICA Survey Team

Figure 1-60 O&M Efficiency Improvement Supported by Information Management

One of the advantages of information management is that scheduled shut down for maintenance can be aligned with demand and supply trends. This practice mitigates shutdown impacts on the grid.



Source: JICA Survey Team

Figure 1-61 Demand/Supply and Shutdown Planning

(3) Roadmap

In the area of operations and maintenance, the goal is to achieve efficient use of the enterprise resources. However, the first step towards practices of operations and maintenance needs to be legally obliged, which guarantees implementation of regular maintenance. It also facilitates prompt decision making on shutdown schedules and permissions. In the figure below, an O&M roadmap for implementation of the proposals is shown along with the implementation plans for the legal framework.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Legal Framework								
Strengthen Control by Government	Legislation		Enforcement					
Self-management by Generators		Certification		Enforcement				
Enhancement of Technical Aspects			Technical Standards		Application			
Facility	Facility Enhancement							
Rehabilitation and Conversion	Planning		Contract and Construction			Operation		
Human Capital	Human Capital Development							
Education System	Technical Support from Japan			Training in Japan			Operation	
Training Facility	Planning			Construction			Operation	
Finance	Efficiency Improvement in Financial Decisions							
Budget Creation	Synchronization with Maintenance Plan							
Procurement Process Optimization	Planning		Procurement Efficiency Monitoring					

Source: JICA Survey Team

Figure 1-62 Thermal Power Plant O&M Roadmap

1.6.17 Tariff Policy

(1) Current Status and Issues

1) Current Status and Issues

(a) Electricity Tariff

Serious Financial Situation of BPDB caused by the difference between electricity tariff and supply cost

The current electricity bulk rate is not set high enough to cover the whole electricity supply cost. Hence, BPDB, as the single buyer, continuously receives a subsidy as a form of long term loan. To improve this situation, the bulk rate should be increased but this means that the electricity tariff for final consumers should also be increased. Electricity tariff increase might have a negative impact on the national economy of Bangladesh.

Electricity tariff menu as measure for supporting low income households

The electricity tariff menu is categorized according to the volume of usage and a lower rate is set for low income households. When Bangladesh increases the electricity tariff, measures for low income households should be considered.

(b) Gas price

Difference between international gas price and domestic gas price

Currently, the domestic gas price is set at a lower level. However, if gas demand increases and Bangladesh starts imports of gas such as LNG, and the gas price is not increased, the gas sector will require subsidies from the government.

2) Results of analysis and challenges

If the electricity tariff and gas price are increased rapidly in a single year, it will effect a huge negative impact on the national economy of Bangladesh. It is desirable to increase the electricity tariff and gas price progressively.

GTAP was used to analyze the impact of electricity tariff increase and gas price increase on the national economy of Bangladesh. The following model was used for the GTAP analysis.

Area category: Bangladesh, Asian countries, other countries in other regions.
Sector category: Agriculture, coal*, oil*, gas*, electricity, industry, service.
*only for analysis for gas price increase.

(a) Electricity Tariff

To analyze the economic impact of an electricity tariff increase on the national economy of Bangladesh, impact in the current year only (single-year analysis) was first analyzed. The impact of a price increase in 2014, the year when the latest data set can be obtained, was analyzed.

The following scenarios were set for the electricity price:

Scenario (a): average electricity price increase of 10% in real USD
Scenario (b): average electricity price increase of 20% in real USD
Scenario (c): average electricity price increase of 30% in real USD

The above-mentioned percentages are increase rates in real USD. If we consider the average inflation ratio from 2010 to 2014, 7.9%[8], the ratios in nominal BDT become 19% in scenario (a), 29% in scenario (b), and 40% in scenario (c).

In Bangladesh, the electricity price menu for final consumers is different from the size of usage. However, as a methodological limitation of GTAP analysis, one average price increase ratio was set for each scenario in the analysis (for example, one "average" 10% electricity tariff increase was used for scenario (a) instead of different prices for different categories (e.g. 5% electricity increase for low income households and 15% for high income households)).

The results of the analysis are shown in the following table. A 10% electricity tariff increase produces a negative effect on real GDP of 0.72%, a 20% increase produces a negative effect on real GDP of 1.45%, and a 30% increase produces a negative effect on real GDP of 2.17%. If the electricity tariff is increased rapidly, it produces a huge negative effect on real GDP as compared with GDP current growth.

Table 1-16 Impacts of Electricity Tariff Increase on Bangladesh National Economy (single-year analysis)

Index	(a) 10% increase		(b) 20% increase		(c) 30% increase	
	Change ratio (%) in real USD	Change amount (million USD)	Change ratio (%) in real USD	Change amount (million USD)	Change ratio (%) in real USD	Change amount (million USD)
Impact on real GDP	-0.72	-810.7	-1.45	-1618.6	-2.17	-2424.0
Impact on real exports	-0.28	-79.3	-0.56	-157.7	-0.83	-235.1
Impact on real imports	-0.27	-94.7	-0.55	-189.5	-0.82	-284.2

Source: JICA Survey Team

Next, the impact of a progressive increase of electricity tariff was analyzed. Under the assumption that the cost of the electricity generation supply rises at 1.5% per year in real USD, the following scenarios were set and the impact on the macro economy of Bangladesh was analyzed. Scenario 1 was set as the electricity tariff becoming equal to the supply cost by 2021, scenario 2 was by 2031, and scenario 3 was by 2041.

Table 1-17 Scenarios of Electricity Tariff Increase: Case 1 (cost increase)

Scenario	Annual Increase in real USD
Increase in Cost	1.5%/year (9.5%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)
Base Scenario	1.5%/year (9.5%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)
1	4.2%/year until 2021

[8] Source: World Bank data site

Scenario	Annual Increase in real USD
	(12.4%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 1.5%/year from 2022 (9.5%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)
2	2.6%/year until 2031 (10.7% in nominal BDT in consideration of average inflation rate from 2010 to 2014) 1.5%/year from 2032 (9.5%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)
3	2.2%/year until 2041 (10.3%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)

Source: JICA Survey Team

Table 1-18 Scenarios of Electricity Tariff Increase: Case 2 (no cost increase)

Scenario	Annual Increase in USD
Increase in Cost	0%/year
Base Scenario	0%/year + minor fluctuation in the model calculation
1	2.6%/year until 2021 (10.7%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 0%/year + minor fluctuation in the model calculation from 2022
2	1.1%/year until 2031 (9.1%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 0%/year + minor fluctuation in the model calculation from 2032
3	0.7%/year until 2041 (8.7%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)

Source: JICA Survey Team

In comparison with the single-year analysis, the increase per year become small and the annual negative impact will be mitigated. Electricity tariff increase in Case 1 decreases GDP by 0.17%/year in 2014, and 0.26%/year in 2021, in Scenario 1. Electricity tariff increase in Case 1 also decreases GDP by 0.07%/year in 2014, and 0.17%/year in 2031, in Scenario 2. Electricity tariff increase in Case 1 decreases GDP by 0.04%/year in 2014, and 0.15%/year in 2041, in Scenario 3. In Case 2, similar impacts are expected. Furthermore, in the long run, negative impact on GDP is mitigated as compared with a sharp rise in the single-year analysis.

Table 1-19 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 1)

Scenario	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.06	-0.06
Scenario 2	-0.07	-0.09	-0.17	-0.06
Scenario 3	-0.04	-0.06	-0.1	-0.15

Source: JICA Survey Team

Table 1-20 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 2)

Scenario	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.04	-0.04
Scenario 2	-0.07	-0.09	-0.15	-0.03
Scenario 3	-0.04	-0.06	-0.09	-0.12

Source: JICA Survey Team

(b) Gas Price

To analyze the economic impact of a gas price increase on the national economy of Bangladesh, the impact in the current year only (single-year analysis) was first analyzed. The impact of a price increase in 2014, the year when the latest data set can be obtained, was analyzed.

The following scenarios were set for the gas price:
Scenario (a): average gas price increase of 50% in real USD
Scenario (b): average gas price increase of 100% in real USD

The above-mentioned numbers are rates in real USD. If average inflation ratio from 2010 to 2014 is considered, 7.9%, the ratios in nominal BDT become 62% in scenario (a), and 116% in scenario (b).

The results of the analysis are shown in the following table. A 50% increase in the gas price produces a negative effect on real GDP of 1.26%, and a 100% increase produces a negative effect on real GDP of 2.47%. The result shows that the impact of a rapid gas price increase on real GDP is relatively high in comparison with GDP current growth.

Table 1-21 Impacts of Gas Price Increase on Bangladesh National Economy
(Single-year analysis)

Index	(a) 50% increase		(b) 100% increase	
	Change ratio (%) in real USD	Change amount (million USD)	Change ratio (%) in real USD	Change amount (million USD)
Impact on real GDP	-1.26	-1407.9	-2.47	-2759.1
Impact on real exports	-0.72	-204.7	-1.35	-382.8
Impact on real imports	-1.36	-472.6	-2.70	-937.7

Source: JICA Survey Team

Next, the impact of a progressive gas price increase on the national economy of Bangladesh was analyzed. The following scenarios were set for the analysis. Scenario 1 was set as a progressive gas price increase to the desirable level considering the international price by 2021, scenario 2 was by 2031, and scenario 3 was by 2041.

Table 1-22 Scenarios of Gas Price Increase

Scenario	Annual Increase of Gas Price in real USD
Base Scenario	0%/year
1	47.2%/year until 2021 (58.8% in nominal BDT in consideration of average inflation rate from 2010 to 2014) 0%/year from 2022
2	17.3%/year until 2031 (26.6%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 0%/year from 2032
3	10.6%/year until 2041 (19.3%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)

Source: JICA Survey Team

The result shows that the negative impact is mitigated by retarding the speed of increase.
Gas price increase decreases GDP by 0.33%/year in 2014, and 5.13%/year in 2021, in Scenario 1. Gas price increase decreases GDP by 0.02%/year in 2014, and 2.82%/year in 2031, in Scenario 2. Gas price increase produces a positive impact in 2014, and a decrease of 1.08%/year in 2031, in Scenario 3. Negative impact on GDP in the current situation (e.g. in 2014) is mitigated as compared with a sharp rise in the single-year analysis.

Table 1-23 Impacts of Gas Price Increase on Bangladesh National Economy

Scenario	2014	2021	2031	2041
Scenario 1	-0.33	-5.13	0.52	0.18
Scenario 2	-0.02	-0.43	-2.82	0.09
Scenario 3	0.04	0.19	-1.08	-0.32

Source: JICA Survey Team

(2) Targets to Achieve

1) Electricity tariff reform

(a) Increase of household electricity price
Bangladesh should increase the domestic electricity tariff. BPDB should decrease subsidies and increase the electricity bulk rate and electricity tariff to cover the whole supply cost. Due to concerns regarding low income households, the category for lower income households should not be increased.
The electricity tariff menu is categorized according to the volume of usage. A lower rate is set for low income households. When Bangladesh increases the electricity tariff, measures for low income households should be considered.

(b) Discussion among stakeholders
An appropriate scenario for increasing the electricity price should be set in consideration of the negative impact on GDP. Therefore, the related ministries should discuss this. It is recommended for Bangladesh to organize meetings with related ministries and develop a plan for the electricity tariff increase.

2) Capacity building of human resources for financial review

Public acceptance of an electricity tariff increase will not be achieved without sufficient effort to increase the supply cost. Therefore, chances to reduce the supply cost should be identified and an increase in tariff should be proposed with the reduction of supply cost.
It is difficult for third parties to get involved in the cost reduction process because much information is confidential within companies. First, it is recommended for BPDB to launch a special team to determine processes that are inefficient in terms of cost. It is difficult to change the conditions of a signed contract, so it is recommended to establish a structure to check cost efficiency when BPDB makes new contracts. Support from donors such as JICA for capacity building is beneficial.

3) Gas Price Reform

Increase of gas price

In line with the importing of natural gas, the gas price in Bangladesh should also be increased. However, the price in the category for minimum usage should be maintained as a measure to support low income households. The gas price menu is categorized according to the volume of usage. A lower rate is set for low income households. When Bangladesh increases the gas price, measures for low income households should be considered.

(3) Road Map

1) Electricity price reform

The draft ideas for scenarios for increasing the electricity tariff are the ones used in the analysis. It is recommended to set the average increase of electricity price until 2021, 2031, and 2041 according to the scenarios in Table 1-24.

Table 1-24 Example of Scenarios for Electricity Tariff Increase

Scenario	Annual Increase in USD
1	4.2%/year until 2021 (12.4%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 1.5%/year from 2022 (9.5%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)
2	2.6%/year until 2031 (10.7%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 1.5%/year from 2032 (9.5%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)
3	2.2%/year until 2041 (10.3%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)

Source: JICA Survey Team

2) Development of Cost Reduction Plan

BPDB should launch a special team for cost reduction as soon as possible. Preferably by 2017 or 2018 the special team should be ready to start analysis.

3) Gas Price Reform

It is recommended to increase the gas price in line with scenarios such as those proposed in the analysis. However, in consideration of the supply cost increase, in Scenario 1, a 1.5%/year increase should be applied after 2022, and in Scenario 2, a 1.5%/year increase should be applied after 2032 to make them more realistic.

Table 1-25 Scenarios of Gas Price Increase

Scenario	Annual Increase of Gas Price in real USD
1	47.2%/year until 2021 (58.8%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 1.5%/year from 2022
2	17.3%/year until 2031 (26.6%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 1.5%/year from 2032
3	10.6%/year until 2041 (19.3%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014)

Source: JICA Survey Team

1.7 Road-map

To achieve VISION 2041, a road map has been prepared as Bangladesh's long term strategic power and energy development planning. The road map, classifiying into three timeline; short, mid to long, and super long, states specific targets to be achieved, and also shows by when, what items that the government of the Bangladesh shall implement. It is strongly desided that all indicated items on road map shall be implemented for certain to achieve VISON 2041.

Table 1-26 Roadmap for PSMP2016

Contents of PSMP2016		Target	Action Plan	Sort Term FY2016～2020	Mid-Long Term FY2021～2025/ 2026-2035	Super Long Term FY2036～2041
Economy	1. Economic Development	High-income country by 2041	Incentive for promoting foreign direct investment (Preferential Taxation)Other, Deregulation (Abolishment of entry regulation)			
			Implementation of program for improving skill			GDP per capita 11,000 USD (2041)
			Construction of industrial complex and SEZ			
			Other, Transportation infrastructure improvement(Port, Road, Railway)			
Energy Balance	2. Primary Energy Demand	Reduction of energy intensity by more than 20%	Implementation of recommendation by EECMP A-Appliance-labeling B-Energy management (reporting) C-Energy-saving building code D-Low interest loan program for EEC equipment		Energy intensity 3.42-->2.56 million USD/toe	
			Program of Ecologically friendly car			
			Improvement of road network			
			Improvement of railway network			
	3. Domestic Gas Supply	Introduction of IOCs which has technological and financial advantages	Revised PSC to attract IOCs			
			International Tender for new onshore and offshore acreage			
			Partnership between foreign investor and BAPEX、BGFCL、SGFFL			
		Acqsition of energy assets in overseas	Revise the role of BAPEX			
			Transform the capacity of BAPEX			
			Acquisition of oversea energy asset			
		Efficient use of Gas	Development of legal framework regarding efficient use of gas			
			Improve efficiency towards international standard and decommission of inefficient facilities			
		Introduction of advanced operation and infrastrucure management system	Introduce electronic mapping system for gas transmission and distribution system	Transmission	Distribution	
			Introduce gas flow monitoring and safety management system			
		Domestic biogas production: 790,000m3/day (including additional 600,000m3/day by 2031 and 3 million m3/day by 2041	Import duty/levy on glass-fiber biogas digester/material removal			
			Glass-fiber biogas digester domestic manufacture development			
			Glass-fiber biogas digester roll-out through IDCOL loan scheme			
	4. LNG Supply	Introduction of LNG	LNG F/S, FEED, EIA and Land Acquisition			
		Onshore LNG Terminal to Supply 3,000 mmscfd of Gas by 2041	Construction of onshore LNG Terminal (3 sets of tank) to be operational from 2027. Additional tank will be installed after COD of 1st Phase.		Initial Phase	Terminal Expansion
			Prepare strategy for LNG procurement		Initial phase completed and commercial operation started (2027)	
			Construction of pipeline to connect into onshore pipeline			
			Commencement of commercial operation			
			Impact study of LNG introduction to existing gas infrastructure and gas processing facilities			
		FSRU to Supply 500 mmscf of Gas by 2019	Construction of FSRU and related infrastructure of 1st and 2nd Phase	1st 2018-19 start operation	2nd 2023 start operation	1st phase of FSRU completed and commercial operation started (2019)
			Commencement of commercial operation			
	5. Coal Supply	60 million ton to be expected imported Coal by 2041	Implementation of F/S Imported Coal infrastructure			
			CTT (Phase1～2)FY2025, FY2029			
			Construction based on F/S			
			CTT (Phase1)commencement of operation in 2025			
			CTT (Phase2)commencement of operation in 2029			
		Mining technology acquisition for Bangladeshi	Establishing technology acquisition system for Bangladesh in order to secure stable production at Barapukuria Mine			
			Establishing a system in order to proceed to new mining development mainly in Bangladesh			
		Commencement of construction for pilot site at Barapukuria Mine based on open-cut mining technology	To be crystallized after 2017			
			Commercial Operation in 2021			
		Development Permission for Digipara Mince, Karaspir Mine	Commencement of Construction after 2022			
			Commencement of production after 2027			
		Small scale open-cut mining of Phulbari Mine	Review the result of pilot operation of Barapukuria Mine and commencement of small scale open-cut mining of Phulbari Mine after 2021		Commencement of Construction Barapukuria Mine open -cut mining (2025)	
			Commencement of construction after 2025			
	6. Oil Supply	Oil imprt 30 million tons/yr	Analysis b/w domestic refinery and oil product import completed and decision made			
			Exit strategy on oil subsidy established and implemented			
			Oil import facility (storage tank or domestic refinery) developed to meet increased oil demand		Oil import: 5 --> 30 million tons/yr	
	7. Power Development Plan	Optimized energy mix	**Energy mix: 3E-Value(Economy/Environment/Energy Security)**			Energy Mix-Min 3E
			Capacity building for MP revision	Well-organized planning climate		
			-Collaboration between organizations for MP			
			-Periodical rolling revision for milestoned-MP			
			-Strengthen comprehensive statistical work function			
			-Introduction of KPI management			
			Improvement in the investment climate	Well-organized investment climate		
			-PPA improvement			
			-FDI improvement			
			-Prompt procedure of invenstment application			
			-Introduction of financial credit approval by Int'l Organization			
			No load shedding		Power for all	
			Exiting from high cost rental power			
			Securing low cost power supply for baseload			
			Integrated energy infrastructure (Port facility for fuel terminal)			
			Tariff reform			
			O&M reform			

Contents of PSMP2016		Target	Action Plan	Sort Term FY2016～2020	Mid-Long Term FY2021～2025/ 2026-2035	Super Long Term FY2036～2041
Energy Balance	8. Hydropower	To be achieved for realization of hydropower development in the Chittagong hilly area	Preparation of maps by 2018			
			Completion of Feasibility Study for a PSPP by 2020			
			Completion of Detailed Design by 2023			
			Commencement of Construction of a PSPP by 2024			
			Commissioning of the first unit of a PSPP by 2030			
	9. Renewable Energy	Renewable Energy : Maximizng generation potential under the limited land availability	Transparent and competitive bidding process for utility-scale RE generation project (1 project)			
			Completion of wind resource assessment			
			Technical standards and regulation/rules for RE grid-connection			
			Transparent and competitive bidding process			Maximising RE generation potential under limited land
			FIT and reverse auction system			
			Utility-scale solar project roll out			
		Biogas production: 62 mmcfd by 2041	Removal of import duty and levy on high-quality glass-fiber biogas digester			
			Nurture of domestic glass-fiber biogas digester manufactures and dealers		Biogas production : 4 --> 62 mmcfd	
			Cost competitiveness of biogas over LPG maximized			
	10. Power Import/ Nuclear Power	[Import Power] Increase power import from neighboring counties up to 9,000 MW	Advanced development of the Case 3 line		H: 5,500 MW L: 3,000 MW	
			Securing power transmission capacity in India			H: 8,500 MW L: 5,000 MW
			Direct connection of PSPP in Meghalaya state to Bangladesh system			H: 8,500 MW L: 7,000 MW
		[Nuclear Power] Development of nuclear power up to 7,200 MW	Establishment of legal and implementation framework			
			Meeting IAEA safety standards			
			Establishment of fuel cycle management			
			Propoer knowledge about nuclear safety and public acceptance			
			Operation of nuclear power plants		1&2 Units	3&4 Units / 5&6 Units
	11. Power Transmission Planning	Robust power system development	Direct connection of Dhakka - Chittagong			
			Strengthening trunk lines for regional development			
			Transmission facility developed to meet increased power demand			
	12. Distribution (Rural electrification)		Electrificaion for All by 2021			
			SHS waste management process established			
Power Balance	13. Improving Power Quality	Development of laws and rules (obligation and penalty etc.)	Amendment of Electricity Act			
			Amendment of Grid Code			
			Amendment of NLDC's operational rule			
		Implement ensuring frequency adjustment margin and control	Governor-free operation of new installed generator			
			- Engineering			
			- Construction			
			Commissioning and commencement of operation new installed plant from Jun 2015 to 2021			
			Implement plan based on the review of new installed plant After 2022			
			Fulfillment of new installed generator of LFC control			
	14. Thermal O&M	Development of laws	Strengthen monitoring by government			
			Strengthen utilities' self-management			
			Technology enhancement			
		Thermal power plant O&M	Upgraded combined cycle thermal power plant			
			Building information management system			
			Establishment of traning center			
Energy Cost and Tarrif Balance	15. Energy Tarrif Policy	No gap between tarrif and supply cost	Power tarrif increase		2-6%/year	1.5%/year
			Gas tarrif increase		10-20%/year	1.5%/year

Source: JICA Survey Team

Part II POLICY

Chapter 2 Energy and Power Sector Overview

In this Chapter, Bangladesh energy and power sector main players, especially those who have strong impact on policy and price making are described.

First of all, Bangladesh's all prices of main energy sources, natural gas, oil and electrical power are controlled by either government or regulatory control and not market-oriented pricing. Power generation entities are partly corporatized and some private companies, but natural gas entities are all state-owned, and substantial oil import/refinery entities are also state-owned.

2.1 Overall Entity

2.1.1 Ministry of Power, Energy and Mineral Resources (MoPEMR)

MoPEMR is the main ministry to deal with primary energy and electrical power policy and administration in Bangladesh. As of May 2016, the Prime Minister holds both prime minister and the minister of MoPEMR (another post, "State Minister in Charge" exists). Under MoPEMR, Energy Division (Energy and Mineral Resources Division) and Power Division exist.

Source: www.emrd.gov.bd

2.1.2 Bangladesh Energy Regulatory Comission (BERC)

BERC was established in 2003, under BERC Act. BERC has set rules and regulations to ensure transparency of operation and tariffs in electricity, domestic natural gas, and oil subsectors. Commission protects the benefit of consumer and industry, and promotes competitive market. Commission consists of one chairperson and four members.

In respect of the electricity, BERC Act (in particular Chapter 4 of the Act) defines the Commissions major responsibilities are taking regulatory measures for efficient generation of electricity, transmission and distribution of quality electricity, creating enabling environment for private sector investment, management of the sector through fixing reasonable tariff with transparency and creating competitive market.

Specifically the energy prices, BERC only exercises its authority on natural gas and electricity prices, while the BERC Act (2003) Chapter 7, Article 34 Tariff (1) stipulates the following:

Notwithstanding anything contained in any other law for the time being in force, the price of power generation in wholesale, bulk and retail, and the supply of energy at the level of end-user, shall be determined in accordance with the policy and methodology made by the Commission in consultation with the Government

Currently oil prices except LPG are determined by Energy and Mineral Resources Division (to be described in the following section), based on the discussion with BPC (to be described in the following section). LPG price is currently determined in the market base, but some regulation will be introduced shortly for the sake of customer protection (further information on LPG pricing policy can be referred in Chapter 10).

As of December 2015, BERC is drafting Feed-In-Tariff (FIT) to promote renewable energy. More details are discussed in Chapter 13 of this Report.

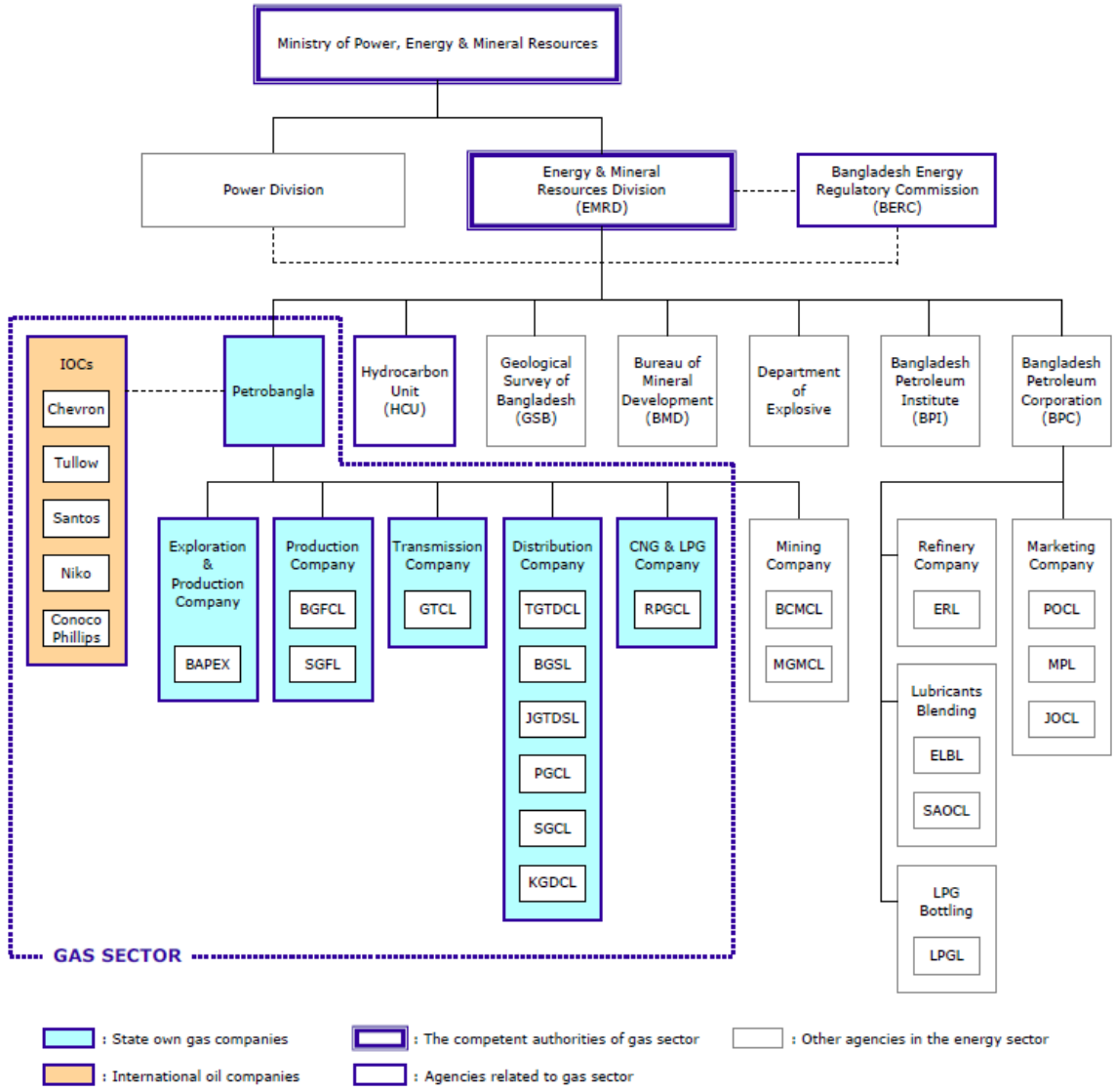
Furthermore, it should be noted that the Commission has responsibilities of two critical areas namely i) to set codes and standards for quality electricity supply, and ii) to facilitate energy efficiency, energy audit and setting standards for the power plants. These areas have been undermined in power sector

operation; however, the strengthening BERC's capability and related regulations are indispensable for the further development of the Bangladesh's power sector hence the PSMP2016 has conducted the in-depth analysis and recommendations of these areas. The detailed are discussed in Chapter 16 and Chapter 17.

Source：www.berc.org.bd, and interview with Energy Division

2.2 Energy Sector Overview

Under Energy Division, there are several main players. Petrobangla manages exploration, development, production and sales of domestic natural gas, gas- associated condensate and coal. BPC manages oil (crude oil and oil products) import, refinery and sales. These two groups have many subsidiary entities (see below figure).



Source: JICA Data Collection Survey on Bangladesh Natural Gas Sector, Final Report, January 2012

Figure 2-1 Bangladesh Energy Sector Overview

In addition to the above state-owned entities, International Oil Companies (IOCs) are important players in Bangladesh's gas sector, as they are responsible for more than half of the domestic

production. Details are described in Chapter 7.

2.2.1 Energy and Mineral Resources Division (Energy Division)

Energy Division is responsible for energy policy in Bangladesh. They established the Energy Policy in 2005; however, they do not succeeded in finalizing Coal Policy or Domestic Gas Strategic Allocation. Since then, the latest approved Energy Policy is the one in 2005.

Alternatively, as described in detailed in the Chapter 3, "Gas Sector Master Plan (GSMP)" was developed in 2006 with support from the World Bank. Recently "Gas Sector Master Plan Update" is planned to be conducted with support from the World Bank again. Further detail of GSMP is described in Chapter 3.

2.2.2 Petrobangla

Petrobangla has 13 state-owned companies under its umbrella, including companies dealing with natural gas, CNG/LPC and coal. For natural gas, three companies for exploration, development and production, one company for transmission, six companies for sales and distribution –here are in total ten companies. For CNG/LPG, one company exists. For mining (coal and granite), there is another company. Especially because natural gas has been the sole major primary energy in Bangladesh, Petrobangla has played a vital role in energy policy and planning.

Petrobangla administrates IOC activities through PSC (Product Sharing Contract). Petrobangla PSC Directory also organizes and administrates the bidding to a new off-shore lot. Petrobangla also organizes and administrates the on-going FSRU project (more detail is discussed in Chapter 8).

Furthermore, Petrobangla also owns Barapukuria Coal Mine Company Limited (BCMCL), which manages the only one operating coal mine in Bangladesh. Petrobangla manages a contract between BCMCL and a foreign operator (more detail is discussed in Chapter 9).

Gas sales and distribution companies under Petrobangla are corporatized under Corporation Law; however, the 55% of the profit from the gas sales is to be delivered to the national coffer, and the rest is allocated to each companies based on the pre-determined ratio. This system does not allow Petrobangla companies to autonomously operate and pursue the profit. In addition, the profit allocated under this system does not support each company for future investment or maintenance. Further detail is discussed in Chapter 7.

Coal operation company under Petrobangla, BCMCL, on the other hand, has own discretion to the negotiation with the foreign operator, although the coal sales pricing requires the government approval. BCMLC produces 3 billion Taka profit each year, and has ample investment capital for investment for machine and equipment[9].

2.2.3 Bangladesh Petroleum Corporation (BPC)

BPC is another state-owned company, who almost exclusively deals with crude oil and oil product import. BPC owns one refinery company, three sales companies and one LPG bottling company (LPG sales is private business), and two oil blending companies under its umbrella.

BPC used to retail oil products under market (=import) price, and the gap was approximately 10 Taka per litter. As a result, BPC's sales deficit accumulated to 10 billion Taka in FY2010, and reached 86 billion Taka in FY2012, which was equivalent to 0.9% of GDP. BPC received "subsidy" from the

[9] Petrobangla Annual Report 2013 and 2012,, "Consolidated Income Statement".

government to meet such deficit. In recent years, IMF set the conditions for its structural reform loan, i.e. Extended Credit Facility (ECF); the reduction of BPC's accumulated deficit and the government subsidy. More recently, the decline of oil price from 2014 benefited the BPC's deficit reduction. BPC's domestic retail price becomes in fact higher than the import price, and BPC delivered the profit to the national coffer (more details about the subsidy to BPC are described in Chapter 19).

BPC's supply capacity and its expansion plan, as well as details of LPG are discussed in Chapter 10.

2.2.4 Other State-owned Entities

(1) Hydro Carbon Unit (HCU): HCU was established in 1999, with support from Norway government. HCU's main responsibility is gas field appraisal. ADB also supported the establishment of HCU with a part of its loan in 1993[10]. In 2010 HCU employed a US consulting firm and conducted a reserve evaluation. As mentioned in the previous chapter "PSMP2010 Review", however, the current Petrobangla production scenario does not employ the HCU analysis.

(2) Geological Survey of Bangladesh (GSB): Responsible for geological survey for mineral resources.

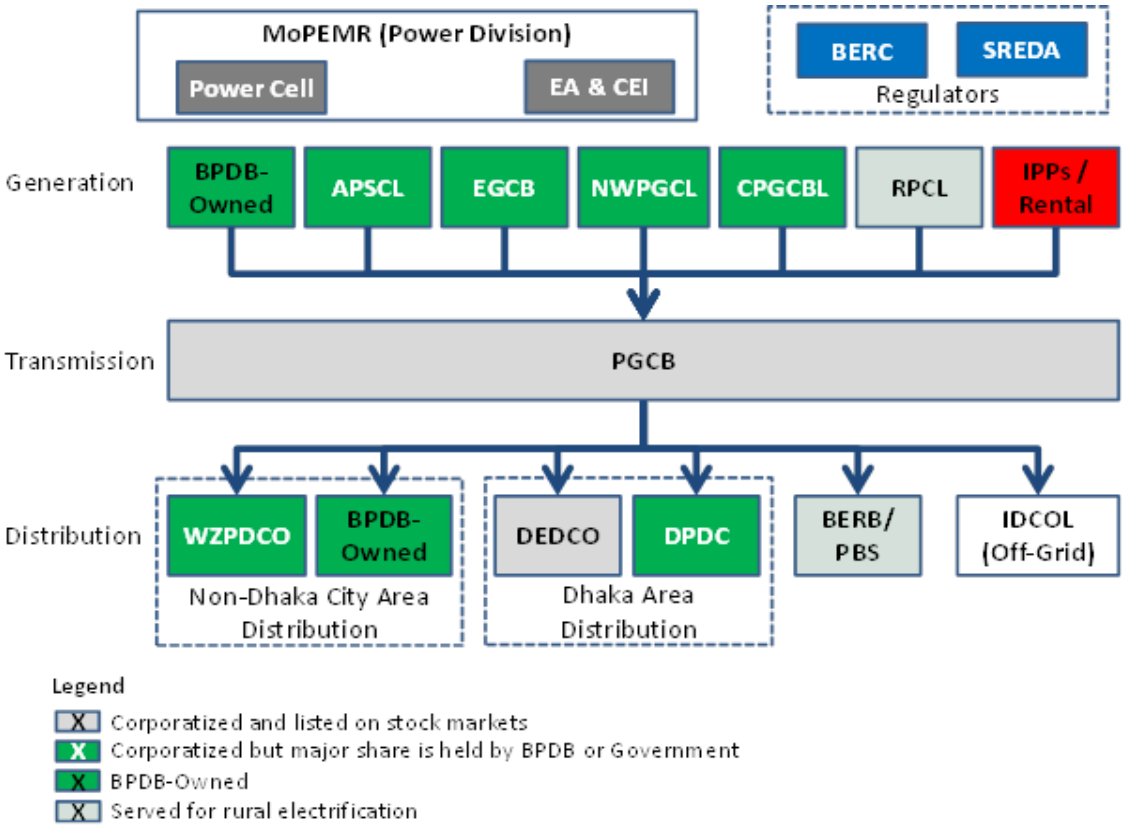
(3) Bureau of Mineral Development (BMD)：Responsible for managing mining concessions.

(4) Department of Explosive (DE)：Responsible for managing explosive materials.

[10] ADB, Technical Assistance Consultant's Report, People's Republic of Bangladesh: Preparing the Gas Sector Development Program, April, 2009

2.3 Power Sector Overview

In Bangladesh power sector (mainly on-grid related) entities exist under the supervision and administration of Power Division, as shown below. From early 1990s, Power Sector Reform made substantial progress and led to the corporatization of then vertically integrated power giant Bangladesh Power Development Board (BPDB). These corporatized entities have in general improved operational performance.



Source: JICA Survey Team

Figure 2-2 Overview of Bangladesh Power Sector

2.3.1 Power Division

Power Division is responsible for all activities related to power generation, transmission and distribution. Its scope also covers the coordination with other divisions and ministries to promote public-private partnership, private investment, rural electrification and renewable energy, and energy efficiency and conservation. Power Division also monitors the performance of public-owned power utilities with key performance indicators (KPIs). If a utility performs below the pre-determined/agreed KPI, then the utility needs to pay the penalty.

Power Division has below sub-division organizations:

(1) Power Cell: Power Cell was established in 1995 as a promoter of the power sector reform. They played a central role of the sector reform in the late 1990 to the early 2000s and contributed to the establishment of public generation companies and distribution companies. Recently Power Cell provides strategic advices on business planning and human resource development for those public power utilities. In addition to those rolls, Power Cell takes a counterpart role in land-based LNG terminal project to ensure stable primary energy supply for power sector. Details of LNG terminal project are discussed in the Chapter 8. (Source :www.powercell.gov.bd.)

(2) Office of the Electrical Advisor & Chief Electric Inspector and Energy Monitoring Unit: Electrical Advisor and Chief Electrical Inspector (EA & CEI): This office was established to ensure the safety of those who work for power generation, transmission and distribution, by not only licensing for high tension and medium tension consumers, electrical contractors, engineers and electricians, but also inspecting installations, substations and lines. The subdivision office of Energy Monitoring Unit (a subdivision of EA & CEI) ensures that industries are using energy efficiently and energy is being conserved were possible. (Source : www.eacei.gov.bd)

2.3.2 Sustainable and Renewable Energy Development Authority

SREDA[11] was established in 2012 based on the SREDA Act. The main mission of SREDA is to ensure the Bangladesh's energy security through promoting renewable energy, and energy efficiency and conservation (EEC). SREDA is responsible for promoting and approval of renewable energy projects, and sets an ambitious target, additional renewable energy capacity approximately 3,200MW by 2021 (more details are discussed in the Chapter 13). SREDA is also responsible to develop an energy audit/ energy management system and administrate related activities to promote energy efficiency and conservation.

Regarding the EEC promotion, SREDA is considered to be responsible for demand side, while BERC is responsible for supply side (e.g. power generation plants), although such demarcation is not in a publically opened written document. As of May 2016, SREDA is designing various EEC systems, based on the JICA-supported Energy Efficiency and Conservation Master Plan (2015).

2.3.3 Bangladesh Power Development Board (BPDB)

BPBD was initially established as Water and Power Development Board under East Pakistan administration. After the independence, it became Power Development Board in 1972, with the installed capacity just 200MW. Until 1990s, when the power sector reform made a substantial progress, BPDB was a vertically integrated power entity. Even now BPDB owns 30 to 40% of installed capacity and distribution lines (however, as details are described in Chapter 18, BPDB-owned thermal power plants in general suffer poor maintenance and low efficiency, which results in the BPDB-own power

[11] http://www.sreda.gov.bd/oldsreda/index.php/about-sreda/function

plants contribute less than 30% of electricity generation). BPDB Board consists of chairperson and other 6 members.

BPDB plays a vital role as a single buyer of power sector (more details are described in Chapter 21). As a result of non-cost recovery tariff, BPDB has accumulated operation deficit, and it once reached 64 billion Taka in FY2012. Currently Bangladesh has strived for continuous power tariff raise, and also benefited from the oil price decline (this reduces the BPDB's expense for fuel subsidy to the renal power plants). These factors contributed to the reduction of the accumulated deficit to 52 billion in FY2015.

BPDB's distribution networks were unbundled and corporatized into public distribution companies in the 1990s to the early 2000s. Two distribution companies were established in Dhaka area, and another one in the western area.

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2.3.4 Power Generation Entities[12]

(1) Ashganji Power Station Company Limited (APSCL): Established in 2000. The APSCL started based on the transferred asset from BPDB. As of 2016 its generation capacity reaches 960MW and contributes to the 9% of the county's power generation. APSCL has also a good track record of development partner's funded projects, such as ADB.

(2) Electricity Generation Company of Bangladesh (EGCB): Established in 2004. As of 2016, it has 622MW installed capacity, and contributes to the 7% of the Bangladesh's power generation. EGCB also has attracted development partner's funding, including JICA, World Bank and ADB.

(3) North West Power Generation Company Limited (NWPGCL): Established in 2007. As of 2016, it has 368MW mainly in western part of Bangladesh, and contributes to the 5% of the Bangladesh's power generation. NWPGCL also has attracted development partner's funding, including JICA. Recently, NWPGCL has launched a project of LNG import from West Bengal, India, to ensure fuel supply for its gas-fired power plants.

(4) Coal Power Generation Company of Bangladesh Limited (CPGCBL): Established in 2011. CPGCBL is an executing agency of JICA-supported Matarbari Ultra-Super Critical (USC) coal fired power plant. It has yet any working power generation plant.

(5) Rural Power Company Limited (RPCL): Established in 1993. BREB (described later) owns 30% of equity and 12 PBS own the rest (no capital ties with BPDB). Its installed capacity is 77MW and impact to the grid network is limited.

(6) Independent Power Producers (IPPs) and Quick Rentals: There are in total 16 IPPs in Bangladesh with total installed capacity 2627MW. After 2010 "Crash Program", about 40 "rental" and "quick rental" power plants (most of them are oil-based) have been introduced (these power plants can be quickly constructed and contract period is as short as 3 years). The total power generation from IPP and these rental and quick rental power plants can be up to 50% of entire power generation in Bangladesh. This rapid expansion of rental and quick rental power plants greatly contributed to the

[12] The installed capacity varies depending on the source. Therefore in this section, the installed capacity is solely based on the BPDB web site as of February 2015, and BPDB Annual report FY2014-2015.
http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=193&Itemid=120

reduction of power outage; however, the expensive power purchase price also expands the deficit of BPDB. Further analysis of the generation cost is discussed in Chapter 21.

(7) Ministry of Science and Technology: Ministry of Science and Technology and Bangladesh Atomic Energy Commission are the main body to implement Bangladesh's first nuclear power plant. More detail is described in Chapter 14.

2.3.5 Power Grid Company of Bangladesh (PGCB):

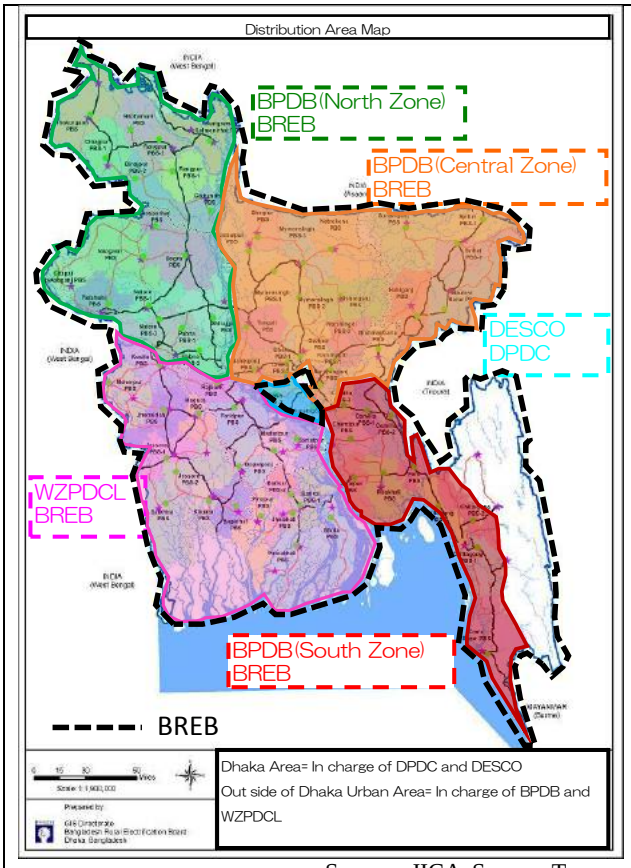
PGCB was established in 1995, as a result of unbundle of power sector, and the sole transmission company in Bangladesh. It has National Load Dispatch Center (NLDC) of its sub-division. As discussed in later Chapter 15, the independence of NLDC from PGCB will be an important institutional issue of network operation for Bangladesh. PGCB also semi-private company, where 25% of its issued shares are listed in a stock market (the rest 75% is owned by the Government). PGCB's main assets are 400kV, 230kV and 132kV transmission lines, and the wheel charge is the only revenue source. PGCB has also a long list of development partner's funded projects, including JICA, World Bank and ADB.

2.3.6 Distribution Entities and Rural Electrification

There are five area urban distribution companies in Bangladesh. DESCO and DPDC are in charge of Dhaka area, WZPDCL is in charge of the western municipalities including Khulna and Barisal areas. The rest municipal power distribution is still under BPDB's operation (see the below figure).

DESCO and DPDC have made significant operational improvement sometime after its corporatization. DESCO outsourced its meter-readers and introduced performance-based compensation and reduced the meter-reader's frauds. DESCO and DPDC introduced prepayment billing system and improved billing collection rate. With these operational efforts, both companies achieved system loss less than 9%, and billing collection ratio more than 98% at DESCO and 90% at DPDC, which is higher than other distribution entities.

Bangladesh Rural Electrification Board (BREB) was established in 1977, with reference to the US's rural electrification cooperatives. BREB supervise and manages 72 PBS (Palli Bidyut Samity, or electrification cooperatives) all over in Bangladesh, and monitor the electrification projects in PBSs. BREB also promotes use of electricity to facilitate socio-economic development and improve agriculture in rural areas. The number of BREB's customer (the total contracts of all sectors including industry, commercial and domestic) is more than 14 million, as of February 2016.



Source: JICA Survey Team

Figure 2-3 Distribution Companies and Areas



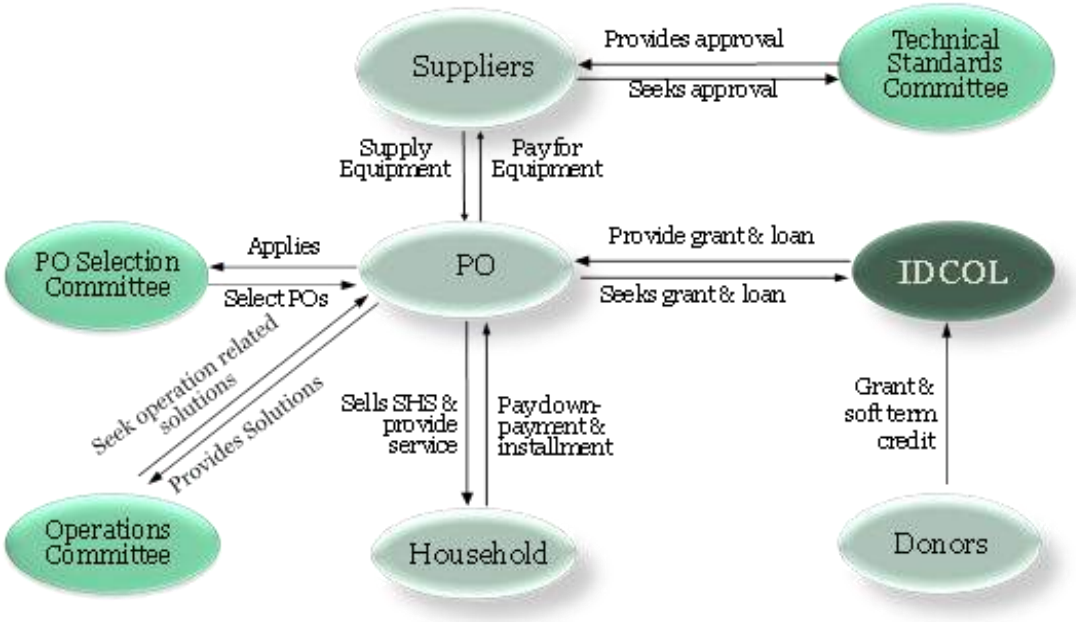
Source: BREB

Figure 2-4 PBS

2.3.7 Infrastructure Development Company Limited (IDCOL)

IDCOL was established in 1997 as a non-bank financial institution for infrastructure financing, 100% owned by the Government. While IDCOL has financed to infrastructures, such as telecommunication, ICT and port, it has also financed to the millions of solar home system (SHS) and contributed to the improvement of access of energy in Bangladesh. IDCOL has also financed to renewable energy technologies other than SHS, such as solar irrigation, mini grids, biogas. IDCOL also has a long list of projects financed by development partners, including JICA, World Bank, ADB, GIZ and KfW.

The renewable energy project profess flow is as shown below. IDCOL appraise projects submitted from "partner organizations (PO)" (Refer to Chapter 13 for more details), and provide subsidy and loan to SHS users. As of December 2015, 4 million sets of SHS (equivalent to 125MW) have been installed – approximately 16 million people (more than 10% of entire population) have benefited for electricity access.



Source: IDCOL

Figure 2-5 Process Flow for Renewable Energy Project

Chapter 3 Energy and Power Policies

3.1 World Trend of Energy Policy ~ SDGs and COP21

Before describing Bangladesh energy policy, it is worthwhile to take a look at the "world" energy trend.

3.1.1 Sustainable Development Goal[13]

In 2015, the United Nations adopted the Sustainable Development Goals (SDGs) as a new development target up to 2030. SDGs are based on Millennium Development Goals (MDGs), but intend to cover more comprehensive agendas and wider stakeholders. In short, MDGs were targeted only for "developing countries", and adopted development goals in 8 areas, extreme poverty and hunger, preventing deadly but treatable disease, and expanding educational opportunities to all children. MDGs have established measurable, universally-agreed objectives for these goals, and monitored the progress. Each member state of UN has strived for these goals, the MDGs has made substantial progress in income poverty, access to improved source of water, primary school enrollment and child mortality.

On the other hand, SDGs matter "developed countries" as well. SDGs' 17 goals focus on more global issues, with the sustainable development as the cross-sectoral theme. These goals address remaining issues from MDSs and call for the international efforts to address not-included issues in the MDGs.

Out of 17 goals of SDGs, the following three have strong connection with the energy and power sector development:

Goal 7: Affordable and clean energy. Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 9: Industry, innovation, infrastructure. Build resilient infrastructure, promote sustainable industrialization and foster innovation

Goal 13: Climate action. Take urgent action to combat climate change and its impacts

The sustainable development can be defined as an approach of the development, in which the current generation's demand is met but the life support system of the globe, on which the current and future generation of mankind depends for the prosperity, is still protected[14]. This implies that the energy and power system development, which is indispensable for the modern socio-economic activities but having huge negative impacts on the global warming, cannot be separated from the international goals, and Bangladesh also should not be exempted.

3.1.2 Paris Agreement

In December 2015, COP21 was held in Paris, and Paris Agreement was adopted as a new framework for the countermeasures of the global warming and replace Kyoto Protocol adopted in 1997. This Agreement will have a legal binding force effective to all the 196 participating member states and areas to the Agreement. Further details are discussed in Chapter 4.

[13] UNDP web site is well referred for this sub chapter : http://www.undp.org/content/undp/en/home/sdgoverview.html
[14] http://www.unforum.org/teigen/37.html

3.2 Road to the Vision 2041

During 2008-2011, Bangladesh sustained real GDP growth at 6.2% on average mainly led by the growth of exporting sectors, predominantly garment sector (80% of export, employing 4 million people), although it is provisioned to slow down in FY2012 to 6.3%[15]. In order to realize its vision to become a middle income country by 2021 and developed country by 2041, however, Bangladesh needs to keep its economic growth pace at 7%, especially by diversifying and sophistication of industry sectors, and creating high income jobs in the formal sectors. Although economic growth itself is not the only necessary and sufficient condition for Bangladesh to achieve its vision, it is well recognized that removing infrastructure-related bottlenecks and improving doing-business environments are the critical pre-conditions for further growth of Bangladesh. Especially sufficient, stable and affordable electricity supply is the key for Bangladesh to unleash its growth potential.

As described later on the international comparison of per-capita energy consumption and per-capita GDP a strong coherence between per-capita energy consumption and per-capita GDP can be seen. It can also observed that that the Bangladesh's per capita energy consumption has steadily grown around 5-6% annually accompanied with the economic growth, and has grown doubled in the last three decades. But the absolute amount it still low compared with other ASEAN and South Asia countries.

One thing to be noted from this comparison is that, other ASEAN and South Asia countries had much higher per capita energy consumption, when they had equivalent level of GDP per capita to the today's Bangladesh. In other words, it can be said that Bangladesh is producing the same amout of national wealth with much less energy input than other higher income Asian countries had done (see Table 3-1), and with properly addressing energy supply issues, Bangladesh has potential to achieve higher (or faster) economic growth than other preceding middle-income countries. This point complementally supports the Bangladesh's priority on energy and power supply enhancement, for its further economic growth.

Table 3-1 Other Countries' Per Capita GDP (current USD) and Energy Consumption Historical Situation

Country	Bangladesh	India	Indonesia	Sri Lanka	Thailand	Vietnam
GDP per Capita (current USD) closed to today's Bangladesh	Year: 2014	2009	2003	2004	1988	2008
	1,087	1,125	1,066	1,075	1,123	1,165
Per capita energy consumption in the above year (Unit: kg of oil equivalent)	216 (2013)	545	752	458	596	571

Source: World Bank WDI Database

3.3 7th Five Year Plan (2016~2020)

Bangladesh's superior development policy is called "Five Year Plan", which comprehensively discusses the cross-sectoral national strategies such as macro economy, poverty reduction, and public service/governance. The Five Year Plan also discusses individual sectors, such as industry, agriculture, water, energy and power, education, health, culture and social protection. The latest 7th Five Year Plan is published in December 2015. The priority target and plans are as follows:

- Installed Generation Capacity of electricity to be increased to 23,000 MW by 2020

[15] International Monetary Fund, March 2013 "IMF Country Report No.13/61"

- Ensure energy mix for energy security
- Electricity coverage to be increased to 96 percent with uninterrupted supply to industries
- Reduce system loss from 13% to 9%, improve energy efficiency & conservation
- Construction of 6.15 km. long Padma Multipurpose Bridge at Mawa-Janjira (gas transmission pipeline will be accompanied)

Source: 7th Five Year Plan and JICA Survey Team

The difference of the generation capacity between the 7th Five Year Plan and PSMP2016 is mainly due to the fact that the generation plan of PSMP2016 is developed later. PSMP 2016 power generation plan should be considered the latest.

3.4 Energy Sector Policy

The current national energy policy is the 1995 National Energy Policy (NEP), and it was once updated in 2005. The main objectives of the NEP 2005 are as follow:

i) To provide energy for sustainable economic growth so that the economic development activities of different sectors are not constrained due to the shortage of energy,
ii) To meet the energy needs of different zones of the country and socio-economic groups,
iii) To ensure optimum development of all hte indigenous energy sources
iv) To ensure sustainable operation of the energy utilities
v) To ensure rational use of total energy sources
vi) To ensure environmentally sound sustainable energy development programmes causing minimum damage to environment
vii) To encourage public and private sector participation in the development and management of the energy sector

NEP2005 also prioritizes the following subjects:

a) Primary energy resources
b) Primary bio mass fuel
c) Animal power
d) New and renewable energy technology
    i) Mini hydro power
    ii) Solar
    iii) Wind
    iv) Tidal and wave power
e) Imported fuel
f) Power:
    i) Power generation, distribution and consumption
    ii) Rural electrification programme
    iii) Load management
    iv) Energy conservation

It should be noticed that NEP2005 7.1.6 Pricing Policy clearly points out that “(a)ll forms of non-renewable energy are to be priced at their economic cost of supply”. NEP2005 also underpinned the vital role of renewable energy to meet the energy demand in rural areas.
While the NEP2005 points out many important agendas, no update has been made especially after the domestic natural gas crisis. Alternatively, the World Bank assisted to develop the Gas Sector Master Plan (GSMP) in 2006. Again in 2016, the Word Bank is supporting the “GSMP Update”. As of June 2016, Petrobangla as the executing agency is finalizing the selection of consultant for the GSMP Update. Since the GSMP Update will come after the completion of PSMP2016, the consultant team of GSMP Update is expected to utilize the data and analysis of PSMP2016.

3.5 Power Sector Policy

The Power Division of MoPEMR has a clear vision and mission statement that the universal access to quality electricity in a cost-effective and affordable manner, and ensuring reliable electricity for all by 2021 through integrated development of power generation, transmission and distribution system[16]. In order to seek a practical and short-term solution toward this vision, Power Division enacted "Power and Energy Fast Supply Enhancement (Special Provision) Act 2010", to expedite the introduction of highly expensive quick rental power plants[17].
Power Division also called for JICA for a holistic master plan development; that was the PSMP2010. However, as described in the Chapter 1, the coverage of PSMP2010 did not fully address the Bangladesh power sector development. In the PSMP2010, the planning policy was described as 3E; economy, energy security, and environment. However, two assumptions supporting the then 3E (availability of domestic coal and domestic natural gas) have been drastically changed in the last few years. In other words, the progress of these domestic resources development is much less than what had been assumed. Moreover, Bangladesh-unique issues such as the world-fastest deployment of off-grid renewable energy, hydro-origin power interconnector (power import from hydro-rich neighbors), and nuclear power development were not fully discussed in the previous PMSP2010. In Bangladesh context, these power generations should be treated as vital complements to the conventional thermal power plants. Therefore, in PMSP2016, these issues are well studied in this Survey.
Lastly, the quality of power supply, and the thermal power plant operation and maintenance (O&M) have never been addressed in the past Bangladesh power policy. However, these issues are quite critical for Bangladesh to achieve the Vision 2041. Especially for the better quality of industrial products hence for the further economic development industrial and sophistication, stable frequency is critical. For stable power supply at reasonable cost, fuel cost reduction by plant efficiency improvement through periodical maintenance is indispensable, especially when the most of the power plant fuel will be imported and the fuel cost is expected to substantially increase. These two issues are discussed in detail in Chapter 16 and Chapter 18 respectively.

3.6 Renewable Energy Policy and Sustainable Renewable Energy Development Authority (SREDA) Act

In response to the revision of the NEP2005, the Renewable Energy Policy was prepared in 2008. It explicitly defines the renewable energy targets: by 2015 Bangladesh will introduce renewable energy 5% of all generation, and by 2020, 10%.

Bangladesh is in fact the world-renowned photovoltaics (PV) system, and as of April 2016, 4 million sets of solar home systems (SHS) t have been installed. The initiative has been implemented by a government-owned financial institution IDCOL (Infrastructure Development Company Limited) and its active implementation partners (such as local NGOs[18]) and supported by concessional funds from development partners. Now Bangladesh is aiming to distribute another 2 million by 2017 to reach the poorest households. By then, the total installed capacity of SHS will be 220MW[19]. Also a small number of biogas-based power generations, a wind power plant in total contribute some 20 MW.

However, the number is still unsatisfactory to the Government target: the renewable energy 5 % of all generation, which means roughly 500MW equivalent. Even with the 230MW Kaptai hydro-power is

[16] http://powerdivision.portal.gov.bd/site/page/e224f7e6-6d8d-403e-b64b-5d7c958140b9/Vision-&-Mission
[17] Quick rental is mainly an oil-based, small capacity, privately owned short-term power generator. Because the construction period is short, and can be quickly developed, these power plants are called "quick rental".
[18] In the IDCOL initiative, such NOGs are called "Partner Organizations" (in abbreviation POs).
[19] http://idcol.org/home/solar

counted, the total renewable-base generation in Bangladesh is merely 404MW.
In December 2012, the Sustainable Renewable Energy Development Authority (SREDA) Act was approved by the Parliament and SREDA was established. The purpose of this authority is to ensure the energy security, by promoting renewable energy and energy efficiency and conservation. The Act defines the roles of SREDA, and the capability of accepting loans (from GoB and international sources), as well as developing systems such as Energy Audit, Energy Auditor and Energy Manager.

In 2013, GoB announced "500MW Solar Program" to accelerate the renewable/PV solution deployment[20]
It is the high time for Bangladesh to deal the conventional on-grid and off-grid (such as PV) in one development plan, with an integrated manner.

3.7 Energy Efficiency and Conservation Policy

For Bangladesh, a very low altitude country and vulnerable to the sea-level raise caused by global warming, becoming a low-carbon emission society is not a fashion of middle-income country, but a very fundamental risk mitigation measure for climate change. Also, for the society which will encounter high-price fuels in near future, demand side management (DSM) is also a critical countermeasure.
These are the background of the GoB to seek policy making in energy efficiency and conservation, and with JICA assistance, "Energy Efficiency and Conservation Master Plan" was developed in March 2015. SREDA is currently finalizing the draft Energy Efficiency and Conservation Rule, which will govern related programs such as Energy Management and Labeling program, and implement them with support from development partners.

3.8 Role of PSMP2016 as Complemental Energy and Power Policies

As seen above, the energy policy with GoB initiative has not made substantial progress in the past years. PSMP2016 on the other hand exercises in-depth analysis and brings recommendations, not only on the power generation development plan but also on the energy demand analysis as a basis for energy policy, and energy policy itself.
Specifically, Chapter 6 and Chapters on individual primary resources, and Chapters on future energy cost and energy tariff can be in fact considered as parts of the energy policy. These analysis are expected to be well referred by policy makers and executing agencies for the Bangladesh energy sector.
PSMP2016 brings new agendas into power policy, namely the quality of power, and thermal power plant O&M as discussed above, and provides in-depth recommendations. PSMP2016 also addresses the renewable energy policy and targets to achieve, based on the latest situations. In fact PSMP2016 is far beyond an ordinary "power development plan" and delineates strategic targets in multiple areas, as well as the approaches (detailed roadmap) to materialize the targets.
All of the existing policies and plans on energy and power sector in Bangladesh provide the precious inputs to the PSMP2016. The complementarity between the existing policies/plans and PSMP2016 can be described in the following table.

[20] Power Division website:
http://powerdivision.portal.gov.bd/sites/default/files/files/powerdivision.portal.gov.bd/page/db9495b8_6dec_4336_980f_560c2f7ba68f/500_MW_Solar_Programm1.pdf

Table 3-2 Complementarity of PSMP2016 and Existing Policies/plans in the Energy and Power Sector

Policies/ Plans	①	②				③	④	⑤								⑥	⑦
	Economic Development Policy	Energy Demand	Natural Gas	Coal	Oil	Energy Efficiency and Conservation	Climate Change	Power Generation	Hydro Power	Renewable Energy	Power Import	Nuclear	Power System Plan	Power Supply Quality	Thermal Power Plant &M	Tariff Policy	Human Capital Development
PSMP2016	✓✓	✓✓	✓✓	✓✓	✓✓	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
PSMP2010		✓	✓✓	✓✓	✓			✓✓		✓	✓	✓	✓✓			✓	✓✓
Energy Efficiency and Conservation MP 2015						✓✓											✓✓
7th Five Year Plan 2015	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓
National Energy Policy 2005		✓	✓	✓	✓	✓		✓	✓	✓		✓				✓	✓
Gas Sector Master Plan 2006			✓✓													✓	
Renewable Energy Policy 2008										✓							
SREP2015										✓✓							

Legend:
①: Economic , ②: Energy Balance, ③: Energy Efficiency and Conservation , ④: Environment, ⑤: Power Balance, ⑥: Pricing, ⑦: Human resources
✓✓: Concrete targets are provided based on the logical assumptions. In-depth approach and recommendation is also provided.
✓ : Issues, targets and/or approaches are mentioned, or existing policy/plan is mentioned.
None: Not mentioned, or out of scope.

Source: JICA Survey Team

Chapter 4 Environmental Policy

4.1 Current Position of Bangladeshi Government Concerning Greenhouse Gas Emission

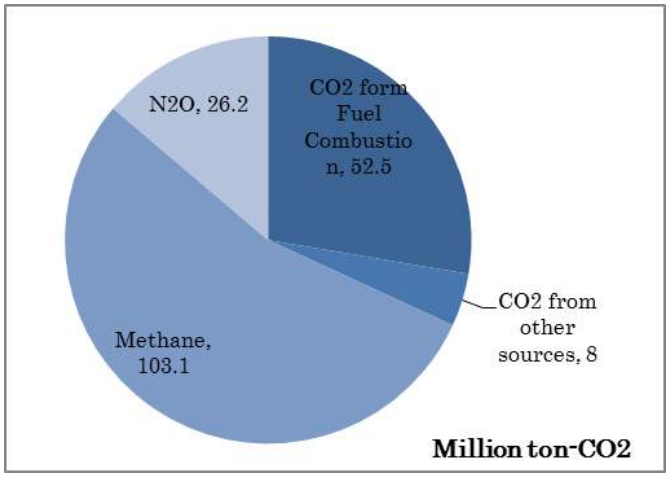
4.1.1 Status of GHG emission in Bangladesh

IEA's "CO2 emissions from fuel combustion" compiles the estimated emission of all kinds of greenhouse gasses including the CO2 deriving from fuel combustion in each country. Its 2015 edition provides the greenhouse gas emission in Bangladesh as of 2010, as seen inTable 4-1. Figure 4-1 illustrates its breakdown in a pie-chart. At present, the CO2 emission from fuel combustion, including that from power generation, accounts for only a little more than a quarter of the total GHG emission.
If we discuss the environmental policy to prevent global warming in Bangladsh based on the current status of GHG emission, it appears that measures against methane emission in the agricultural sector should be strengthened with priority, because methane accounts for the largest share in GHG emission and it mainlyderives from the agricultural sector.

Table 4-1 Greenhouse Gas Emissions in Bangladesh (million t-CO2e, as of 2010)

CO2				
Fuel Combustion	Fugitive	Industrial processes	Other	Total
52.5	0.2	2.4	5.4	60.5
CH4				
Energy	Agriculture	Other	Other	Total
12.4	70.4	20.3	0.0	103.1
N2O				
Energy	Industrial processes	Agriculture	Other	Total
1.8	-	22.0	2.4	26.2
Total GHG				189.7

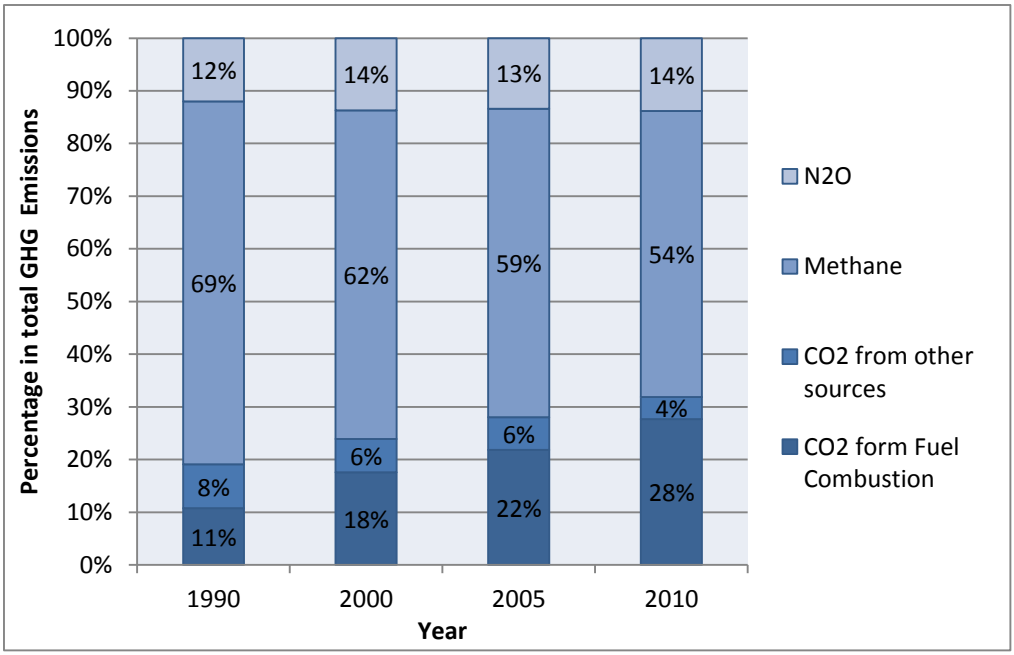
Source: IEA "CO2 Emissions from Fuel Combustion"



Source: IEA "CO2 Emissions from Fuel Combustion 2015"

Figure 4-1 Greenhouse Gas Emissions in Bangladesh (as of 2010)

However, as shown in Figure 4-2, the share of CO2 emission from fuel combustion including power generation has seen a growth, and as shown Figure5-3, it is expected to grow rapidly towards 2030. Hence, measures by UNFCCC, which addresses GHG emissions as a whole, will probably influence the power supply policy in Bangladesh more than now.



Source: Adapted from IEA "CO2 Emissions from Fuel Combustion 2015"

Figure 4-2 Historical Trend of Breakdown of Total GHG Emissions by Gas

4.1.2 Measures declared by GoB in INDC (Intended Nationally Determined Contributions)

At the nineteenth Conference of the Parties (COP19) of the United Nations Framework Convention on Climate Change (UNFCCC), which was convened in Warsaw, Poland, in November 2013, the member countries were mandated to formulate what actions they intend to take, including the target of GHG emission beyond 2020, following official procedures of policy-making, and to submit this prior to the twenty-first conference (COP21) slated for being convened in Paris, France, in 2015.
The Government of Bangladesh (GoB) submitted its own intended contribution, formally called "Intended Nationally Determined Contributions (INDC)" in September 2015. The main points of INDC submitted by GoB are summarized as follows.

Table 4-2 Outline of INDC by GoB and Assumed Actions Related to Power Sectors

Mitigation contribution

■Unconditional contribution (Contribution assuming no additional international support)

- Reduce GHG emissions in the power, transport, and industry sectors by 12 MtCO2e by 2030 or 5% below BAU emissions for those sectors

■Conditional contribution (Contribution assuming additional international support)

- Reduce its GHG emissions in the power, transport, and industry sectors by 36 MtCO2e by 2030or 15% below BAU emissions for those sectors

Measures assumed in Unconditional contribution

■Power

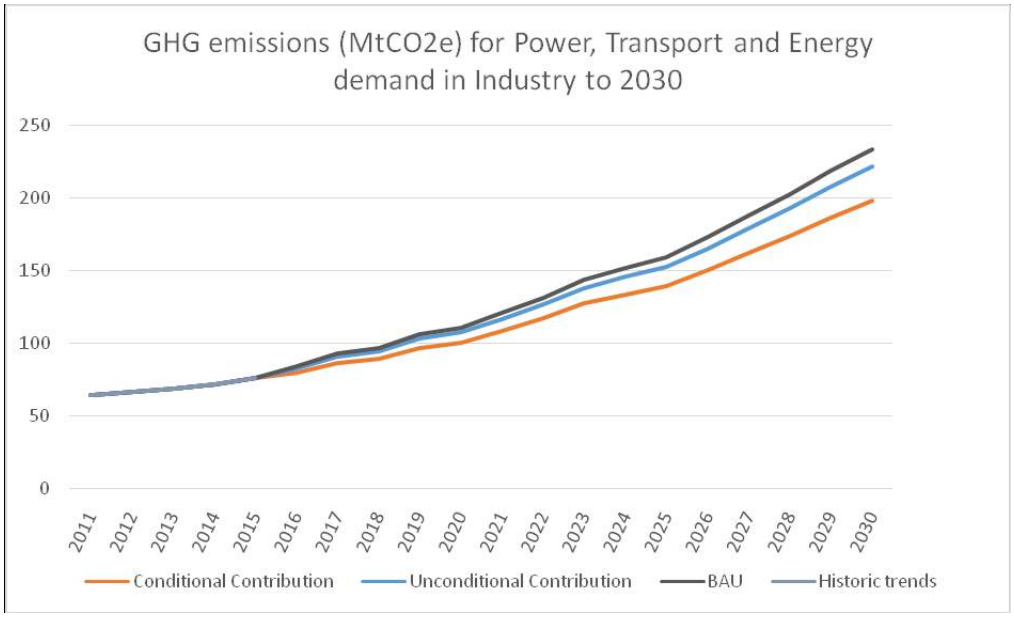
- A target to deliver 5% of energy from renewable sources by 2015, and 10% by 2020 (2008Renewable Energy Policy)
- Construction of Combined Cycle Power Plant (CCPP) by the Government of Bangladesh and utilities companies

Measures assumed in Conditional contribution (with international support)

■Power
- Ensure all new coal generation uses super-critical technology (100% of new coal based power plants use super-critical technology by 2030)
- Increased penetration of wind power (400 MW of wind generating capacity by 2030)
- Implement grid-connected solar plant to diversify the existing electricity generation mix (1000 MW of utility-scale solar power plant)

Source: JICA Survey Team

In the document of the INDC by GoB, projected GHG emissions pathway of power sector, transport sector and industry sector is shown as in Figure 4-3 and Taable4-3.
Emissions from power sector accounts for 91 million ton CO2 equivalent in 2030 BAU scenario, 86 million ton CO2 equivalent in 2030 unconditional contribution scenario and 75 million ton CO2 equivalent in 2030 conditional contribution scenario.
However, INDC document does not specify the assumptions of the projection including power supply configuration, and it says this projection will be updated in conjunction with assumptions change.



Source: JICA Survey Team

Figure 4-3 Projection of GHG Emissions in Power, Transport and Industrial Sectors from 2011 to 2030 (MtCO2e) in INDC by GoB

Table 4-3 Projected Emissions Reductions in Power, Transport and Industrial Sectors by 2030 in INDC by GoB

Sector	Base year (2011) (MtCO2e)	BAU scenario (2030) (MtCO2e)	BAU change From 2011 to 2030	Unconditional contribution scenario (2030) (MtCO2e)	Change Vs BAU	Conditional contribution scenario (2030) (MtCO2e)	Change Vs BAU
Power	21	91	336%	86	-5%	75	-18%
Transport	17	37	118%	33	-9%	28	-24%
Industry	26	106	300%	102	-4%	95	-10%
Total	64	234	264%	222	-5%	198	-15%

Source: JICA Survey Team

4.2 Recent Trend and Future Prospects of UNFCCC and IPCC

4.2.1 IPCC Fifth Assessment Report (AR5)

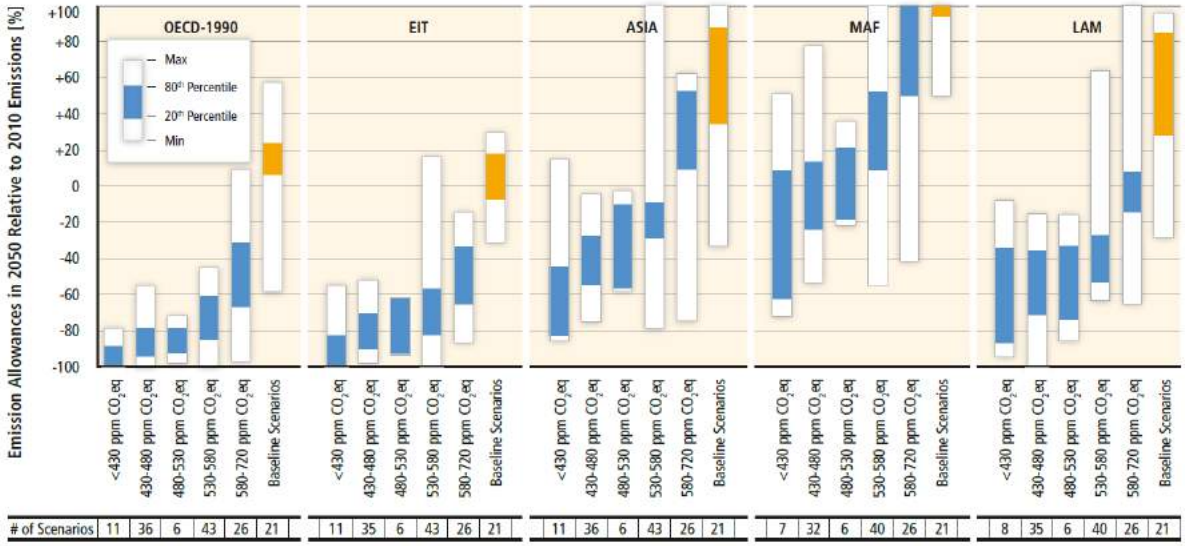
The Fifth Assessment Report (AR5) is the latest compilation of wide area of scientific views on climate change by the Intergovernmental Panel on Climate Change (IPCC). This report contains the mitigation scenarios of GHG emissions and the pathways developed in the latest scientific articles in its Chapter 6 of WG3 report.
These scenarios are classified into seven categories of CO2-equivalent concentration levels, as shown in Table 4-4. Paris agreement refers to the GHG reduction goal with 2 degrees stabilization and balance between anthropogenic emissions and absorptions of GHG in 2100, which is approximately consistent with the scenarios classified into 430-480ppm category.

Table 4-4 Classifications of GHG Emissions Scenarios in IPCC-AR5

CO_2-equivalent concentration in 2100 (ppm CO_2eq) (based on full radiative forcing)[1]		Secondary categorization criteria[2]		Corresponding RCP[3]	No of scenarios extending through 2100	
CO_2eq concentration (ppm)	Radiative forcing (W/m^2)	Kyoto gas only CO_2eq concentration in 2100 (ppm)	Cumulative total CO_2 emissions 2011–2100 ($GtCO_2$)		Total[4]	With Overshoot Greater than 0.4 W/m^2
430–480	2.3–2.9	450–500	< 950	RCP 2.6	114 (114)	72 (72)
480–530	2.9–3.45	500–550	950–1500		251 (257)	77 (77)
530–580	3.45–3.9	550–600	1500–1950		198 (222)	22 (22)
580–650	3.9–4.5	600–670	1950–2600	RCP 4.5	102 (109)	8 (8)
650–720	4.5–5.1	670–750	2600–3250		27 (27)	0 (0)
720–1000	5.1–6.8	750–1030	3250–5250	RCP .6	111 (120)	0 (0)
> 1000	> 6.8	> 1030	> 5250	RCP 8.5	160 (166)	0 (0)

Source: IPCC AR5, WG3 report Chapter6

Figure 4-4 describes allowance of CO2 emissions in 2050 of each mitigation category for respective regions in the world. As for Asia region, emissions reduction is needed in 2050 by 30 to 50 percent relative to 2010 with a view to achieve 430-480ppm concentration scenario. However, total amount of GHG emissions reduction stipulated in INDCs of parties of UNFCCC looks insufficient in the light of the 430-480ppm scenario, according to UNFCCC analysis (see Figure 4-6). Further is discussed in the next section.)



Source: IPCC AR5, WG3 report Chapter6

Figure 4-4 Allowance of CO2 Emission in 2050 for Each Mitigation Scenario (IPCC-AR5)

4.2.2 Outcomes of COP21

(1) Outline of the Paris Agreement

The first and most outcome of COP21 (Paris, December 2015) was adoption of the Paris Agreement, which covers several issues including long-term goal, individual country's contribution (INDC), loss and damage, technology development and transfer and finance.
For long term reduction goal, it describes ambitious visions up to both 2050 and 2100 as below. It refers to the limit of temperature increase by 2 degrees and pursuing efforts to keep the temperature increase within 1.5 degrees.

Table 4-5 Articles Related to Long Term GHG Reduction Goal in Paris Agreement

Article 2

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a)**Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels**, recognizing that this would significantly reduce the risks and impacts of climate change;

Article 4

1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible (omission) **so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century**, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

(2) Global stocktake

As a manner to achieve the long term goal, each country shall prepare, communicate and maintain successive intended nationally determined contributions (INDC), which are thought to be including emissions reduction target of respective countries. (The outline of INDC by Bangladesh is written in 4.1.2 and INDCs by other Asian countries are written in4.2.3 .)
Besides, there will be reviewing process called "global stocktake" every five years. The outcome of the global stocktake will inform counties in updating and enhancing their actions and support.
Related articles in Paris Agreement are as below.

Table 4-6 Articles Related to Global Stocktake in Paris Agreement

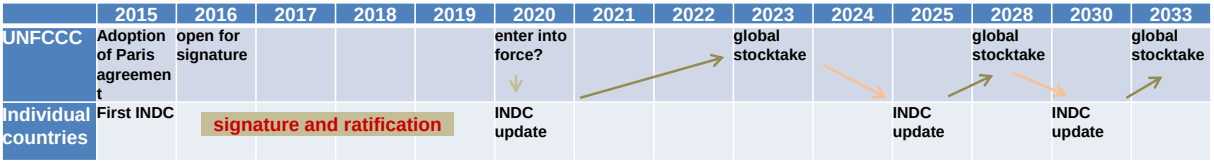
Article 4

9. **Each Party shall communicate a nationally determined contribution(INDC) every five years** (Omission) and be informed by the outcomes of the global stocktake referred to in Article 14.

Article 14

1. The Conference of the Parties serving as the meeting of the Parties to this Agreement shall periodically **take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals (referred to as the "global stocktake")**.
2. The Conference of the Parties serving as the meeting of the Parties to this Agreement **shall undertake its first global stocktake in 2023 and every five years thereafter** unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to this Agreement.
3. **The outcome of the global stocktake shall inform Parties in updating and enhancing, in a nationally determined manner, their actions and support in accordance with the relevant provisions of this Agreement, as well as in enhancing international cooperation for climate action.**

Figure4-5 shows presumed time schedules related to enforcement of Paris Agreement, INDCs submission and global stock take.
Paris Agreement will enter into force when at least 55 Parties to UNFCCC accounting in total for at least an estimated 55% of the total global GHG emissions have deposited their instruments of ratification, acceptance, approval or accession. If Paris Agreement enters into force in 2020 for example, the first global stocktake will be held in 2023 and every five years thereafter.

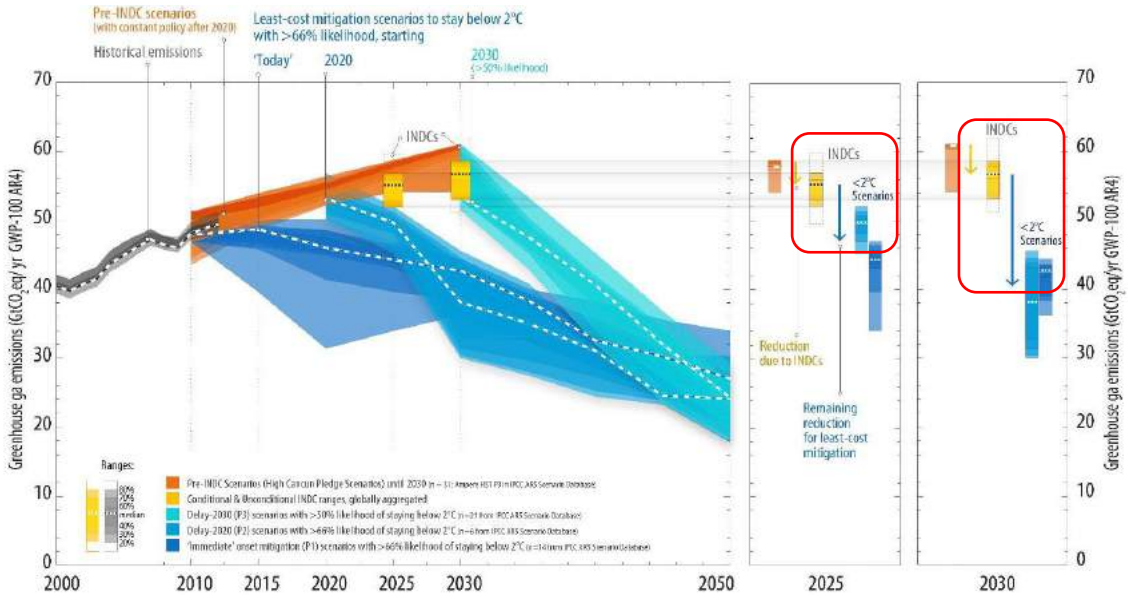


Source: JICA Survey Team

Figure 4-5 Schedules of INDCs and Global Stocktake Determined in Paris Agreement

(3) Remaining GHG reduction for the long term target

UNFCCC analyzes the comparison between submitted INDCs and 2°C goal scenarios as shown inFigure 4-6. There is large amount of remaining GHG reduction needed with a view to 2°C goal. Accordingly, it is presumed that Bangladesh might be one of the countries who are under political pressure of GHG emission reduction in future at the "global stocktake" year, under Paris agreement applicable to all the countries.



Source: UNFCCC

Figure 4-6 Difference between 2 Degree Scenario and INDCs

4.2.3 Overview of INDCs submitted by other Asian Countries

The outline of INDCs submitted by other Asian countries is summarized as follows. For example, India refers to state of the art technologies in power sector such as IGCC in its INDCs. These technologies may be one option to pursue further ambitious actions for GoB.

Table 4-7 Outline of INDCs Submitted by Other Asian Countries

Country&date	Emission reduction goal	Policies described	Technology context
India 1 Oct. 2015	・Reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level. ・Achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low-cost international finance including from Green Climate Fund (GCF). ・Create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030 ・India declared a voluntary goal of reducing the emissions intensity of its GDP by 20‐25%, over 2005 levels, by 2020, despite having no binding mitigation obligations as per the Convention	(1) Introducing new, more efficient and cleaner technologies in thermal power generation. (2) Promoting renewable energy generation and increasing the share of alternative fuels in overall fuel mix. (3) Reducing emissions from transportation sector. (4) Promoting energy efficiency in the economy, notably in industry, transportation, buildings and appliances. (5) Reducing emissions from waste. (6) Developing climate resilient infrastructure. (8) Planning and implementation of actions to enhance climate resilience and reduce vulnerability to climate change	■Clean Coal Technologies (CCT) · Pulverized Combustion Ultra Super Critical (PC USC) · Pressurized Circulating Fluidized Bed Combustion, Super Critical, Combine Cycle (PCFBC SC CC) · Integrated Gasifier Combined Cycle (IGCC) · Solid Oxide Fuel Cell (SOFC), Integrated Gasifier Fuel Cell (IGFC) · Underground Coal gasification (UCG) ■Nuclear Power · Pressurized water reactor, Integral pressurized water reactor, Advanced Heavy Water Reactor (AHWR) · Fast breeder reactor (FBR) · Accelerated-driven systems in advanced nuclear fuel cycles ■Renewable Energy · Yeast /enzyme based conversion to high quality hydrocarbon fuels · Conversion of pre-treated biomass to fuels and chemicals · Gasification technologies like fluidized bed, plasma induced etc. for power generation · Wind Energy technologies: -Development of smaller and efficient turbines -Wind turbines for low wind regime -Designs of offshore wind power plants · Solar PV technologies: -Based on p-type silicon wafers and n-type silicon wafers -Hetero junction with Thin Interfacial (HIT) Module, Back Contact Back Junction

Country&date	Emission reduction goal	Policies described	Technology context
			(BCBJ) Modules -Crystalline silicon photovoltaic cells of > 24 % cell efficiency -High efficiency Concentrating PV (CPV) -Non-silicon based solar PV technologies · Composite cylinders for on-board hydrogen storage · Advanced biomass gasification technologies · Low temperature Polymer Electrolyte Membrane Fuel Cell (PEMFC) for stationary power generation and for vehicular applications · Energy storage technologies for bulk storage and Renewable Energy integration, frequency regulation, utility Transmission & Distribution applications and for community scale projects.
Indonesia 24 Sep. 2015	■Unconditional Reduction Reduce 26% of its greenhouse gasses against the business as usual (BAU) scenario by the year 2020. Reduce 29% against BAU by 2030 ■Conditional Reduction Reduce 41% (additional 12%) by 2030	■Enabling conditions for climate resilience ・Certainty in spatial Planning and land use; Tenurial security; food security; water security; renewable energy ■Economic resilience ・Sustainable agriculture and plantations; Integrated watershed management; reduction of deforestation and forest degradation; land conservation; utilization of degraded land for renewable energy; improved energy efficiency and consumption patterns ■Social and livelihood resilience ・Enhancement of adaptive capacity by developing early warning systems, broad-based public awareness campaigns, and public health programs; Development of community capacity and participation in local planning processes, to secure access to key natural resources; Ramping up disaster preparedness programs for natural disaster risk reduction; Identification of highly vulnerable areas in local	

Country&date	Emission reduction goal	Policies described	Technology context
		spatial and land use planning efforts; Improvement of human settlements, provision of basic services, and climate resilient infrastructure development.; Conflict prevention and resolution. ■Ecosystem and landscape resilience ・Ecosystem conservation and restoration; social forestry; coastal zone protection; integrated watershed management; climate resilient cities.	
Myanmar 28 Sep. 2015	The information required to estimate GHG emissions was collected and an estimate produced. However, given the deadline and the current available data, it was decided not to include the estimate in the INDC, as deemed not sufficiently reliable. ■Forestry Sector The Government of Myanmar is following the implementation plan as set out in the 30-Year National Forestry Master Plan (2001-30).By 2030, Reserved Forest (RF) and Protected Public Forest (PPF) = 30% of total national land area, Protected Area Systems (PAS) = 10% of total national land area ■Energy Sector (1)Renewable energy - Hydroelectric power :Increase the share of hydroelectric generation within limits of technical Hydroelectric potential (Indicative goal - 9.4 GW by 2030) (2)Renewable energy – Rural electrification: at least 30% renewable sources as to generate electricity supplies (3)Energy efficiency - Industrial processes 20% electricity saving potential by 2030. (4)Energy efficiency - Cook-stoves: Distribute	■Forestry Sector In 2011 joined the UN-REDD Programme. In 2014, joined the European Union’s Forest Law Enforcement Governance Trade (FLEGT) programme ■Energy Sector (1) Renewable energy - Hydroelectric power: The Long Term Energy Master Plan and The National Electrification Master Plan. (2) Renewable energy – Rural electrification: The Ministry of Livestock, Fisheries and Rural Development has received co-funding from a number of international development partners to develop mitigation actions in this sub-sector (3)National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar (4)Comprehensive Plan for Dry Zone Greening (2001-31), National Forestry Master Plan and National Energy Policy ■Climate Change & Environment National Climate Change Strategy, National Climate Change Policy, Green Economy Strategic Framework, National Environmental Policy, Framework and Master Plan (2030),update the National Environmental Policy (1994), Environmental Conservation Law (2012) ■Forest Management	There is a clear need for the transfer of Environmentally Sound Technologies (ESTs) such as ・renewable energy ・energy efficiency technologies for mitigation ・flood control technology ・early warning technologies for adaptation. Myanmar’s technology development and transfer needs also include technologies and skills transfer which support the implementation and operation of ESTs such as those that ensure the operation, repair and maintenance of EST.

Country&date	Emission reduction goal	Policies described	Technology context
	approximately 260,000 cook stoves between 2016 and 2031 ■Climate Change & Environment Achieve climate resilient, low-carbon, resource efficient and inclusive development, mainstream environment and climate change into the national policy development, strengthen the climate change related institutional and policy environment, promote, increase awareness of climate change, promote an economy based on green growth. monitor and take stock of the status of national environmental quality ■Forest Management Decrease the rate of deforestation, Preserve natural forest cover, Decrease the risk of floods and landslides, Increase the resilience of mangroves and coastal communities, Increase capacity Sustainable Forest management, Rural electrification through the use of at least 30% renewable sources. ■Energy Achieve the optimal level of renewable sources, increase the understanding of the potential of renewable power, realize a 20% electricity saving potential by 2030, ■Other Key Sectors Reduce the increasing rate of GHG emissions, ensure that increasing urbanization takes place in a sustainable manner, mitigate emissions, generate power and reduce pollution from non-recyclable waste, mitigate GHG emissions from the agriculture sector	National Forestry Master Plan(2001), National Biodiversity Strategy and Action-Plan(2011), forest plantations, agroforestry practice, community forestry, coastal zone management plan, ■Energy National Energy Policy (2014), Long Term Energy Master Plan(2016), National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar(2015), National Electricity Master Plan, Myanmar National Rural Development and Poverty Alleviation Programme(includes a Rural Electrification Plan(2017)) ■Other Key Sectors National Transport Master Plan and National Implementation Plan on Environmental Improvement in the Transport Sector, National Urban and Regional Development Planning Law, a National Housing Policy, National Urban Policy, National Waste Management Strategy and Action Plans(2017).	
Philippines 1 Oct.	Undertake GHG (CO2e) emissions reduction of about 70% by 2030 relative to its BAU scenario of	INDC is consistent with the -Philippine Development plan,	Technology transfers and innovations are needed to support adaptation and minimization of

Country&date	Emission reduction goal	Policies described	Technology context
2015	2000-2030. Conditioned on the extent of financial resources, including technology development & transfer, and capacity building, that will be made available. Assumptions Used For the Baseline scenario · historical GDP from 2010 – 2014 and an annual average of 6.5% for 2015 – 2030 · Average annual population growth of 1.85% · Loss-and-Damages from climate change and extreme events will not require substantial diversion of resources for rehabilitation and reconstruction thereby affecting development targets as well as mitigation commitments under this INDC. · Identified co-benefits for mitigation options such as environmental and socio-economic benefits are realized. · Climate projections were considered in the assessment of mitigation options	-the National Framework Strategy on Climate Change, -the National Climate Change Action Plan -the National Disaster Risk Reduction and Management Plan. These plans and the INDC were developed through exhaustive, inclusive and participatory processes. The Philippines is already undertaking initiatives to mainstream and institutionalize climate change adaptation and mitigation into the plans and programs of the government as reflected in government expenditures. The Philippine government has installed a system for tagging its expenditure for climate change adaptation and mitigation and is envisioned to use this system for its annual budgeting process starting 2015.	loss-and-damages as well as enhanced capacity for mitigation. Technical inputs and assistance are critical for certain sectors such as -grid efficiency improvement, -standard development for energy and water efficiency, -cost-effective renewable energy, -alternative or high-efficiency technology for conventional power generation, among others.
Thailand 1 Oct. 2015	■Unconditional reduction reduce greenhouse gas emissions by 20 percent from the projected business-as-usual (BAU) level by 2030. (BAU2030: approx. 555 MtCO2e) ■Conditional reduction increase up to 25 percent	- National Economic and Social Development Plans - Climate Change Master Plan B.E. 2558 – 2593 (2015-2050) - Power Development Plan B.E. 2558 – 2579 (2015-2036) - Thailand Smart Grid Development Master Plan B.E. 2558-2579 (2015-2036) - Energy Efficiency Plan B.E. 2558 – 2579 (2015-2036) - Alternative Energy Development Plan B.E. 2558–2579 (2015-2036) - Environmentally Sustainable Transport System Plan B.E.2556–2573 (2013-2030) - National Industrial Development Master Plan B.E.	Thailand’s TNA report formulated in 2012 has identified three highly impacted sectors in urgent need of adaptation technologies. These are: (1) Agriculture in need of forecasting and early warning system technologies, crop improvement technologies, and precision farming technologies (2) Water Resource Management in need of networking (via pipes and canals) and management of infrastructures (including zoning), seasonal climate prediction, and sensor web using observation and/or modeling data (3) Modeling in need of an integrated national data center,

Country&date	Emission reduction goal	Policies described	Technology context
		2555-2574(2012-2031) - Waste Management Roadmap	national data transfer/management process and the advanced research, weather research and forecasting (WRF - ARW) model, and an integrated model to address the need of agricultural sector and water resource management sector
Vietnam 30 Sep. 2015	■Unconditional contribution With domestic resources, by 2030 Viet Nam will reduce GHG emissions by 8% compared to BAU, in which: ・ Emission intensity per unit of GDP will be reduced by 20% compared to the 2010 levels; ・ Forest cover will increase to the level of 45%. ■Conditional contribution ・The above-mentioned 8% contribution could be increased to 25% if international support is received through bilateral and multilateral cooperation, as well as through the implementation of new mechanisms under the Global Climate Agreement, in which emission intensity per unit of GDP will be reduced by 30% compared to 2010 levels.	■Strengthen the leading role of the State in responding to climate change ・Integration of climate change into development strategies, and development plans; Improving and strengthening institutions ■Improve effectiveness and efficiency of energy use; reducing energy consumption ・ Innovate technologies and apply advanced management and operation procedures; Apply energy savings and efficiency, and renewable energy applications; Develop public passenger transport; Establish standards on fuel consumption. ■Change the fuel structure in industry and transportation ・Assure national energy security; Change the energy structure towards a reduced share of fossil fuel; Encourage buses and taxis to use compressed natural gas and liquefied petroleum gas (LPG); Apply market instruments to promote structural change and improve energy efficiency; Label energy-saving equipment and issue national standards ■Promote effective exploitation and increase the proportion of new and renewable energy sources ・Develop and implement mechanisms and policies to support research and the application of appropriate advanced technologies; Develop a renewable energy technology market	Technology transfer: (i) technology for real-time forecasting, early warning, and sharing information system on real-time hydro-meteorological monitoring; (ii) tools to assess climate change impacts, vulnerability, exposure and climate change adaptation measures; (iii) technology for the sustainable use of water resources, prevention of water pollution, and urban water supply; (iv) technology to prevent erosion and protect the coastline and riverbanks; and (v) technology for sustainable agriculture, forestry and aquaculture production; biotechnology to develop new varieties that are more resilient to climate change

Country&date	Emission reduction goal	Policies described	Technology context
		■Reduce GHG emissions through the development of sustainable agriculture ・Research and develop solutions to reduce GHG emissions; Research and apply production processes and economic technologies that efficiently use seedlings; Widely replicate technologies that treat and reuse by-products and waste from agricultural production ■Manage and develop sustainable forest, enhance carbon sequestration and environmental services; conservation of biodiversity associated with livelihood development and income generation for communities and forest-dependent people ・Review and identify the areas and objects to apply sustainable forest management; Develop and improve policies to promote sustainable forest management; Integrate and effectively use resources; Strengthen and expand international cooperation for investment ■Waste management ・Develop waste management planning and enhance capacity; Research and apply advanced waste treatment technologies; Utilize landfill gas and solid waste combustion for power generation. ■Communication and awareness raising ・Raise public awareness of GHG mitigation activities; Encourage and provide technical assistance; Encourage and support communities to develop models of eco-cities, green rural areas, green housing, ■Enhance international cooperation ・Enhance cooperation in scientific research; Enlist the support of other countries and international organizations; Facilitate international cooperation to implement foreign direct investment	

Source: JICA Survey Team

4.2.4 Other environmental considerations

As written in 4.1.1 , reduction of GHG emission from other sectors than energy supply also needs to be dealt with priority in Bangladesh. Recently more attention has been paid to short-lived climate pollutants such as black carbon and tropospheric ozone, which have relatively short lifetime in the atmosphere but have strong greenhouse effect.
An international initiative called CCAC (Climate and Clean Coalition) summarizes the main issues concerning short-lived climate pollutants as follows.

- Cook stoves: black carbon
- Brick kilns: black carbon
- Vehicular emission: black carbon
- Open burning: black carbon
- Rice parboiling systems: black carbon
- Paddy rice cultivation: methane
- Municipal waste deposits: methane
- Livestock (manure and enteric fermentation): methane

4.3 Implications for the PSMP

PSMP scenarios in this report are roughly consistent with INDC submitted by GoB. Presumed CO2 emissions amount from power sector in PSMP is at the same level as the projection in INDC. In regards to technology, CCGT (Combined Cycle Gas Turbine) is referred in Unconditional contribution and USC (Ultra Super Critical) is referred in Conditional contribution in INDC. They are all assumed in PSMP scenarios.
However, we should bear in mind there may be political pressure to take more ambitiousness by global stocktake of Paris Agreement.
We should also bear in mind that PSMP also gives us ripple effect of benefit to environment by electrification. Electrification of residence will address black carbon emission reduction from cook stove and rice parboiling systems, which lead to significant global warming mitigation.

PART III PRIMARY ENERGY BALANCE

Chapter 5 Prospects of Economic Development

5.1 History of Bangladesh Economy

Since its independence in 1971, Bangladesh economy has seen a constant growth, but it has been only recently that the economy started taking on a track of rapid growth.
From 2016, Bangladesh government started the seventh five-year development plan. In the past, the five-year plan has been formulated six times, as seen in Table 5-1, which summarizes the target and the actual results of socio-economic indicators during the period of each five-year plan.
During the period of the initial stage, i.e. from the first plan to the third plan, the actual growth rate of GDP was around 4% p.a. It is also observed that the growth rate of GDP per capita during that period was between 1% and 2%, which means that the GDP growth for the first twenty years since independence was due to the natural increase of population rather than the improvement of economic level.
From the fourth plan, the GDP growth rate started accelerating, which is driven by the increasing growth rate of per capita GDP this implies that the country's economic level started growing rapidly.
During the period of sixth five-year plan (from 2011 to 2015), the average GDP growth rate reached 6.3% and the average per capita GDP growth rate around 5%. In the meantime, socio-economic indicators such as life expectancy and headcount poverty ratio have seen a remarkable improvement during the same period, which indicates that the national living standard started improving remarkably along with the economic development.
It also has to be noted, however, that the actual result of GDP growth constantly underperformed compared to the initial target of the government; that is, the government target is apt to be set too optimistically regardless of the actual status of national economy.

Table 5-1 Key Ecnomic Indocators during the Past Five-Year Plan Periods

Specific Plan	Plan Periods (FY)	Average GDP Growth Rate		Per Capita GDP growth	Per Capita GNI**	Life** Expectancy	Forex Reserve	Headcount Poverty Ratio***
		Plan (%)	Actual (%)	(%)	USD	Years	Million USD*	(%)
First Plan	1973-1978	5.5	4.0	1.3	111	53.07	-	82.1
Second Plan	1980-1985	5.4	3.8	1.5	145	55.10	395	69.9
Third Plan	1985-1990	5.4	3.8	1.6	204	56.10	520	56.6
Fourth Plan	1990-1995	5.0	4.2	2.4	253	58.70	3070	50.1
Fifth Plan	1997-2002	7.1	5.1	3.5	431	64.90	1583	48.9
Sixth Plan	2011-2015	7.3	6.3	4.9	1314	70.70	24141	24.8

Source: Bangladesh Bureau of Statistics (BBS) and Sixth Plan;

*Balance of last day of corresponding terminal year

**For the terminal year of Plan period

***Corresponding HES, HIES year's figure

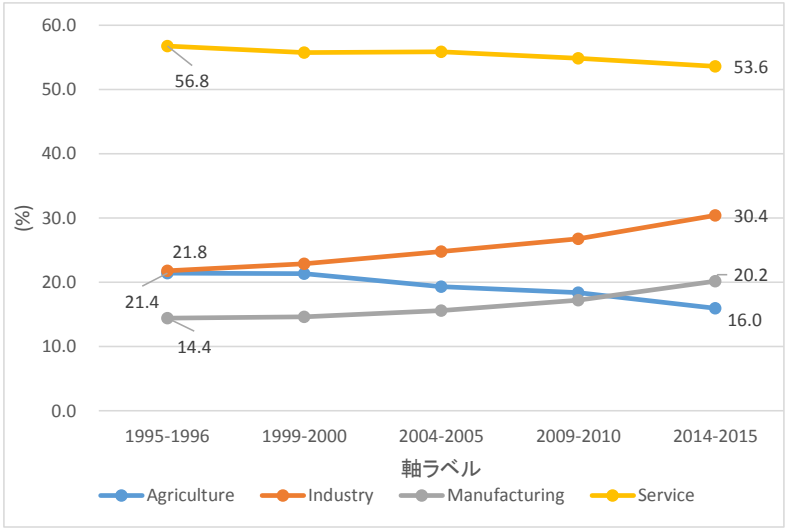
Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

The historical trend of sectorial share of GDP (constant price) for the past 20 years is shown in Table 5-2 and Figure 5-1. The share of industrial sector in the national economy started increasing remarkably after the year 2000 in exchange for the decreasing share of agricultural sector whereas that of commercial sector kept an almost constant share.

Table 5-2 Sectorial Share of GDP Since 1995

	Agriculture	Industry		Service
			Manufacturing	
1995–1996	21.4	21.8	14.4	56.8
1999–2000	21.3	22.9	14.6	55.8
2004–2005	19.3	24.8	15.6	55.9
2009–2010	18.4	26.8	17.2	54.8
2014–2015	16.0	30.4	20.2	53.6

Source: Prepared by the JICA Survey Team using the statistical data of Bangladesh National Account Statistics (BBS)



Source: Prepared by the JICA Survey Team using the statistical data of Bangladesh National Account Statistics (BBS)

Figure 5-1 Sectorial Share of GDP Since 1995

With the rapid growth of national economy, the structure changes of national economy, i.e. industrialization, has started. Until early-1980s, jute and jute goods have been the main industries in and the major products for export. These industries, however, has lost competitiveness in the market with the diffusion of synthetic fiber.

Since mid-1980s, ready-made garment (RMG) has emerged as the major industry, and the export of RMG exceeded that of existing exporting industries by around 1990. The export of RMG continued increasing, and now it accounts for over 80% of the country's earnings from export.

Diversification of exporting goods, i.e. promoting other exporting industries besides RMG is becoming a new big challenge for Bangladesh. There is a potential of developing new industries that utilize domestically available resources and labor forces of the country as well as industries that already exist in Bangladesh and have a potential for further advancement. These prominent industries are footwear and leather products, light engineering products, pharmaceuticals and ceramics etc. Promoting these industries is expected to help Bangladesh economy to grow continuously beyond 2020.

5.2 Scenario Analysis of Economic Development

Bangladesh economy has taken on a track of rapid growth, and structural changes are expected to occur in the upcoming years. It needs to be noted that simply extending the past trend of a country's economic development linearly to the future may not be cogent enough for formulating long-term prospects of Bangladesh economy.

It is widely observed that a country's economic development can be triggered by a non-continuous

structural change of the industries and hence the study will look at the possibility of non-continuous changes of economic fundamentals of Bangladesh by formulating future scenarios considering the "likely to occur" structural changes of its economy.
The basic model as the preconditions of the analysis in this study can be described as follows.

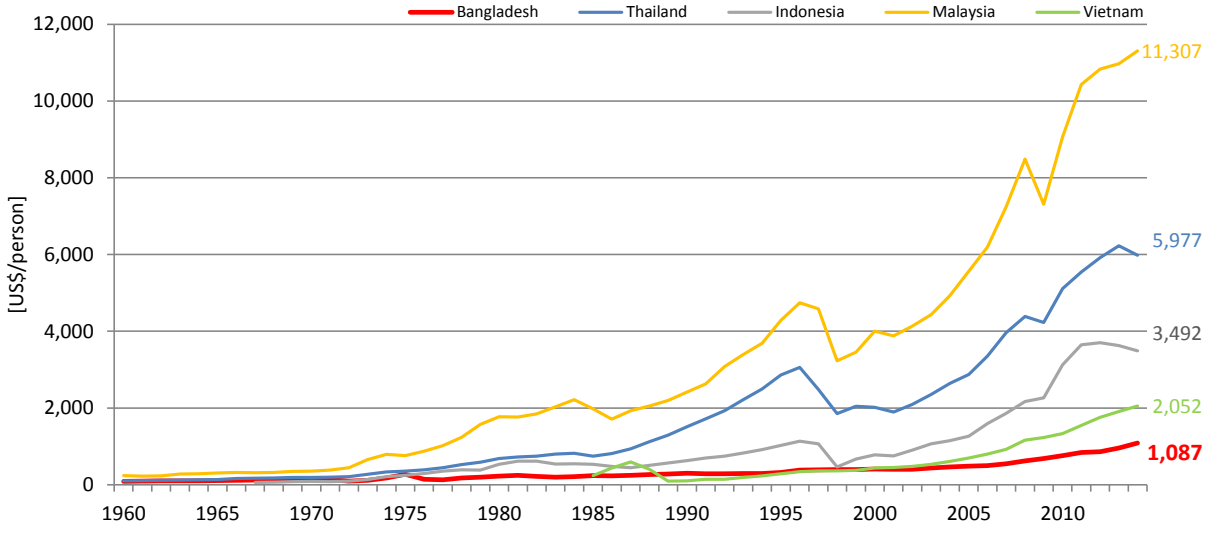
Technology spillover→Structural changes of industry→Economic development→Energy consumption

As well known, many countries in Southeast Asia, although the situation differs significantly among them, have achieved economic developing remarkably for the last decades. Therefore, studying on the history of industrial and economic development of those countries as the role model can be a useful reference in considering the future scenario of Bangladeshi economy.

5.3 Historical Trend of Economic Indices and Energy Demand in Southeast Asian Countries

5.3.1 Historical trend of economic indices in Southeast Asian countries

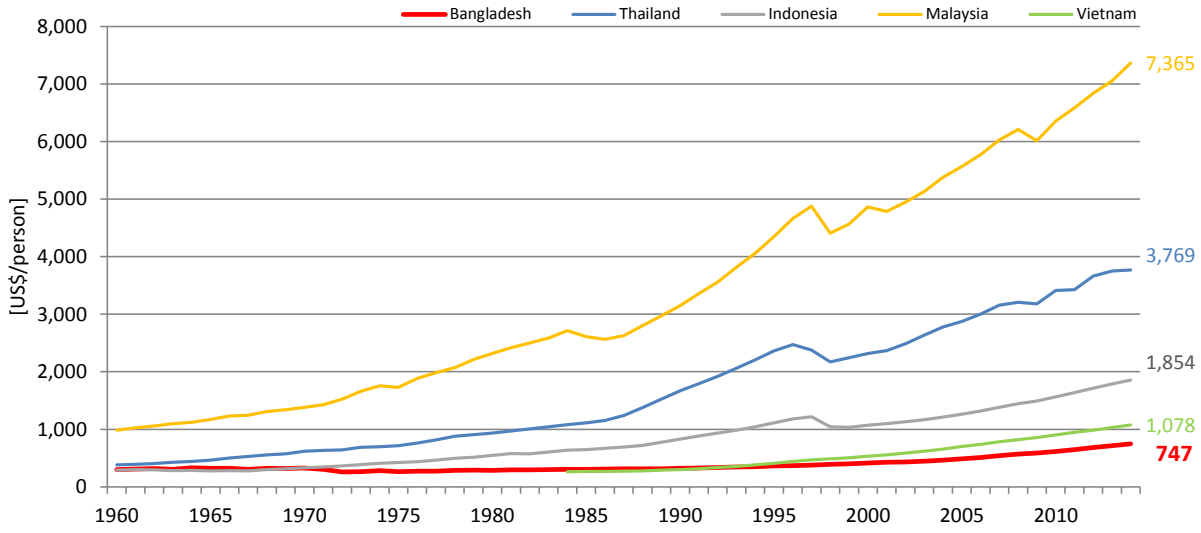
Historical trend of GDP per capita of Bangladesh in comparison with Malaysia, Thailand, Indonesia and Vietnam is shown in Figure 5-2. Malaysia, which has achieved advanced economic development among ASEAN countries along with Brunei and Singapore, has yielded higher number than the other three ASEAN countries in the figure. Thailand, Indonesia and Vietnam are positioned as second-tier countries to follow them and the experiences of these countries are expected to provide implications for studying the direction of economic development of Bangladesh towards 2041.
The GDP per capita (at current USD) of Bangladesh as of 2014 is 1,087 USD, which is only one-fifth of Thailand, one-third of Indonesia and one-half of Vietnam. Vietnam achieved this level of 1,087 USD in GDP per capita in 2008, Indonesia did in 2004, and Thailand in 1988 that is 26 years before.



Source: World Bank database

Figure 5-2 Trend of GDP per Capita (current USD) in Southeast Asian Countries and Bangladesh

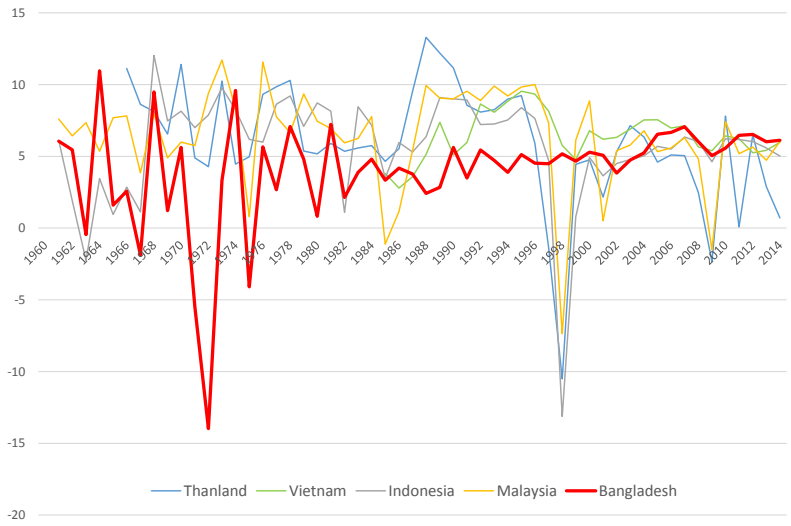
Figure 5-3 shows the same comparison in terms of GDP per capita at constant price of 2005 USD. In this figure GDP per capita of Bangladesh as of 2014 is 747 USD which is around one-fifth of Thailand like in Figure 5-2. In this case, Vietnam achieved this level of 747 USD in GDP per capita in 2008, Indonesia did in 1989 that is 25 years before, and Thailand in 1977 that is 37 years before.
Because this study aims to project the economic development of Bangladesh in 2041, which is after 26 years from now, the past experience of economic development of Thailand and Indonesia can be a good reference.



Source: World Bank database

Figure 5-3 Trend of GDP per Capita (constant 2005 USD) in Southeast Asian Countries and Bangladesh

Figure 5-4 shows the historical trend of GDP growth (constant 2005 USD basis) of the same five countries as in Figure 5-2 and Figure 5-3. Whereas Bangladesh has performed a stable growth, the other four countries occasionally experienced huge fluctuations of growth rate for the past thirty years. Considering that these fluctuations are largely the effect of external factors such as the incidents on global economy, these four countries also have achieved relatively constant economic development without these irregularities. If Bangladeshi economy continues to grow constantly for a long period with this relatively high growth rate, the country's industry is expected to reach a certain level of development towards 2041.



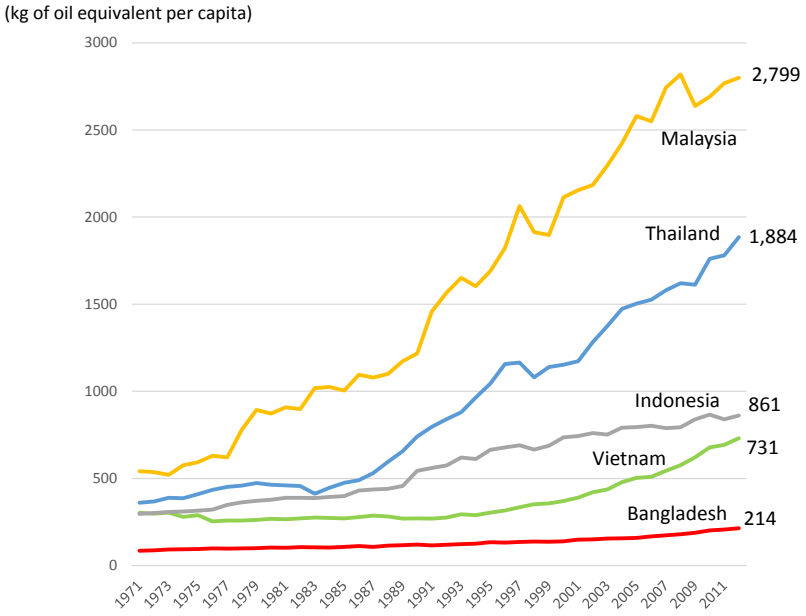
Source: World Bank database

Figure 5-4 Historical Trend of GDP Growth Rate in Southeast Asian Countries and Bangladesh

5.3.2 Historical trend of energy consumption

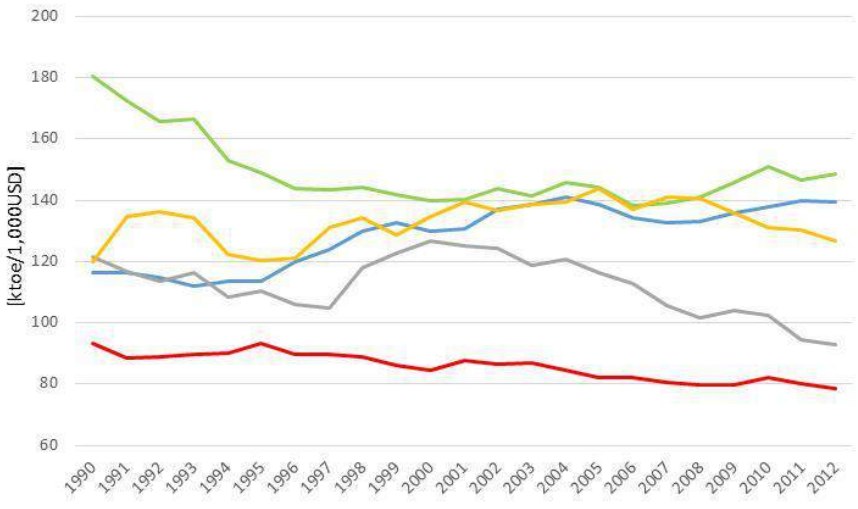
Figure 5-5 shows the historical trend of energy consumption per capita of the aforementioned five countries. The energy consumption per capita of Bangladesh as of 2012 is 214 kg of oil equivalent, which is one-ninth of Thailand, one-fourth of Indonesia and over one-third of Vietnam. That is, there is a wider gap among the performance of these countries than that for GDP per capita as seen in Figure 5-2. This means that Bangladesh has used less energy for producing the same economic value than the other four countries, and as shown in Figure 5-6, the energy intensity in Bangladesh has seen a declining trend. In other words, Bangladesh economy has been growing with relatively low energy input until now.

It is highly possible, however, that energy consumption of Bangladesh will increase more rapidly than ever in the course of industrial structure modernization and the introduction of advanced industrial technologies that inevitably demand huge volume of energy consumption.



Source: IEA Statistics and World Bank database

Figure 5-5 Trend of Energy Use per Capita in Southeast Asian Countries



Source: World Bank database

Figure 5-6 Trend of GDP per Unit of Energy Use in Southeast Asian Countries

5.4 Study on the Economic Development Scenarios

5.4.1 Identification of the role model

(1) Thailand as the role model

Among the four ASEAN countries that are discussed in the previous sections, this study chooses Thailand as the role model for drawing future scenario of economic development of Bangladesh. The reasons for this are as follows.

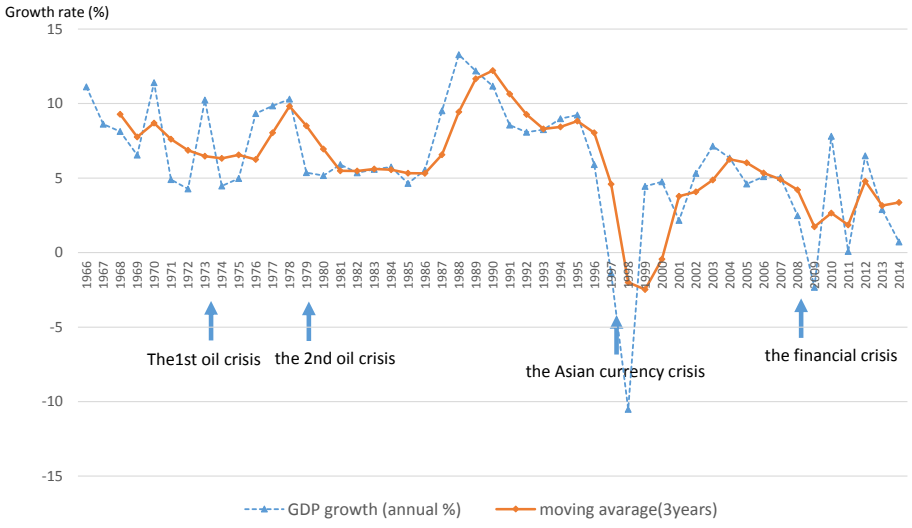
- Thailand has achieved the industrialization and the modernization of the society with a relatively high growth rate of economic development for a long period;
- Thailand is now positioned as one of Upper Middle Income Countries (UMICs) by DAC (Development Assistance Committee), which can be an ambitious but realistic target for Bangladesh;
- As discussed in Figure 5-2 and Figure 5-3, Bangladesh is expected to reach the present economic level of Thailand by 2041 if the current economic growth rate continues;
- In the meantime, Thailand also has a plenty of agricultural resources and the agricultural products still accounts for around 10% of its merchandise exports even now, though it was also helped by the protective policy of agriculture;

(2) Economic development of Thailand

1) Historical trend of GDP growth

Figure 5-7 shows the long term trend of annual GDP growth of Thailand at constant 2005 USD basis. In order to remove the noise of short term fluctuation, three-year moving average is also shown in addition to the annual growth rate.
Thai economy has kept a high growth rate of GDP for a long time though it was occasionally affected by the turbulence of global economy in the past, such as the Global Financial Crisis precipitated by the bankruptcy of Lehman Brothers in 2008, the Asian Financial Crisis in 1997 and the Oil Crises in 1973 and 1979. The economy especially kept a relatively high growth rate during the following periods.

- From 1976 to 1978: GDP growth rate around 10% p.a.;
- From 1988 to 1997: GDP growth rate around 10% p.a.;
- From 2001 to 2008: GDP growth rate around 5% p.a.;

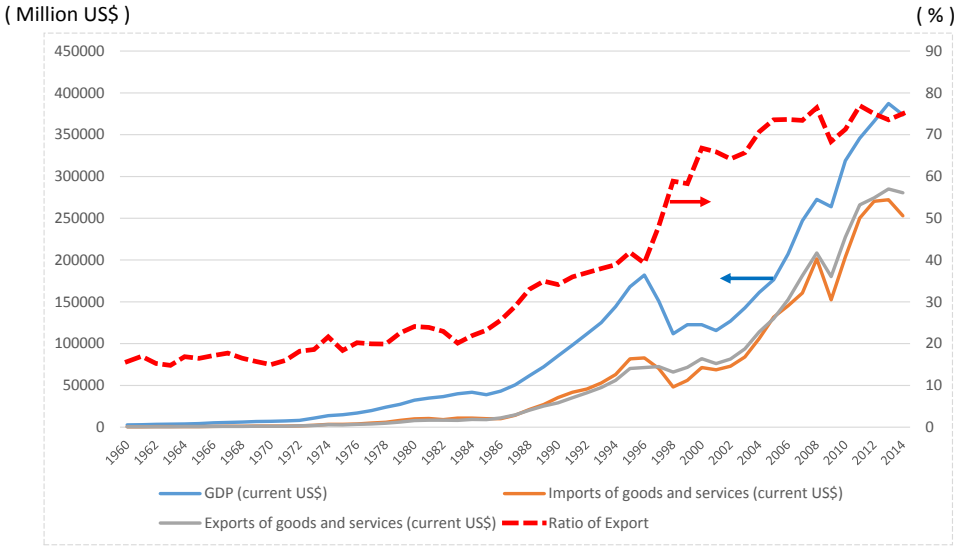


Source: World Bank database

Figure 5-7 Historical Trend of GDP Growth Rate of Thailand

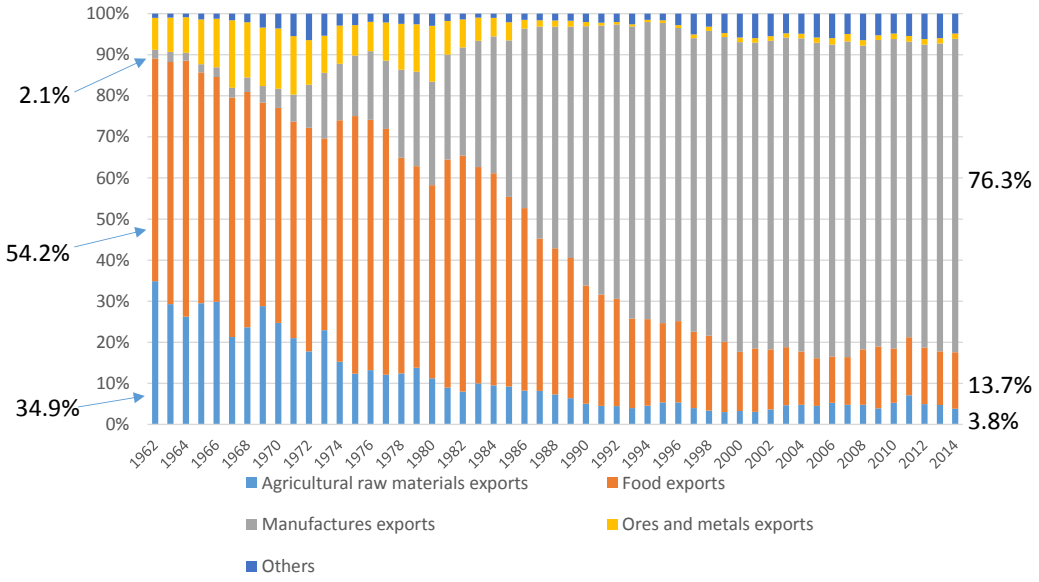
2) Historical trend of goods import and export

The solid lines in Figure 5-8 show the historical trend of goods import and export along with that of GDP. It is observed that both import and export took a similar trend of increase to that of GDP. There are two implications from this observation. One is that the economic growth of Thailand has been strongly driven by the growth of export. And another is that Thailand's economy has been supported by the processing trade so that the country imports raw material and exports a value-added product.
The red dotted line in the figure shows the ratio of export to GDP. Until mid-1980s this ratio was low around 20%, but afterwards, especially after 1996, it started increasing rapidly, and currently the ratio of export against GDP has reached around 75%. This clearly indicates that goods export has pushed up Thai economy.
Figure 5-9 shows each sector's share in the merchandise export every year. In 1962 the share of manufacturing was only 2.1%. Since then this ratio has been growing rapidly in line with the economy's dependence on export as aforementioned and recently it has become more than three quarters of merchandise export. Another thing to be noted in the figure is that the total share of agricultural product and foods in merchandise export, though it has been declining, still keeping nearly 20% for the past fifteen years. This means that Thailand's export is characterized not only by industrial products such as machines and machinery parts but also by agricultural products and value added foods.



Source: World Bank database

Figure 5-8 Historical Trend GDP, Import and Export of Thailand

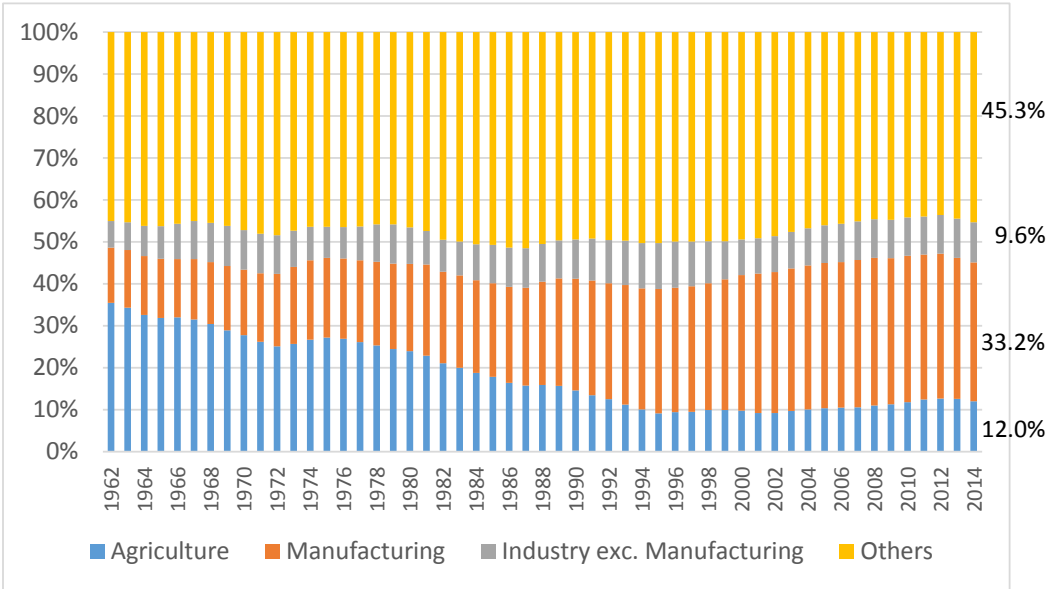


Source: World Bank database

Figure 5-9 Historical Trend of Sectorial Share in Merchandise Export

3) Historical trend of industrial structure

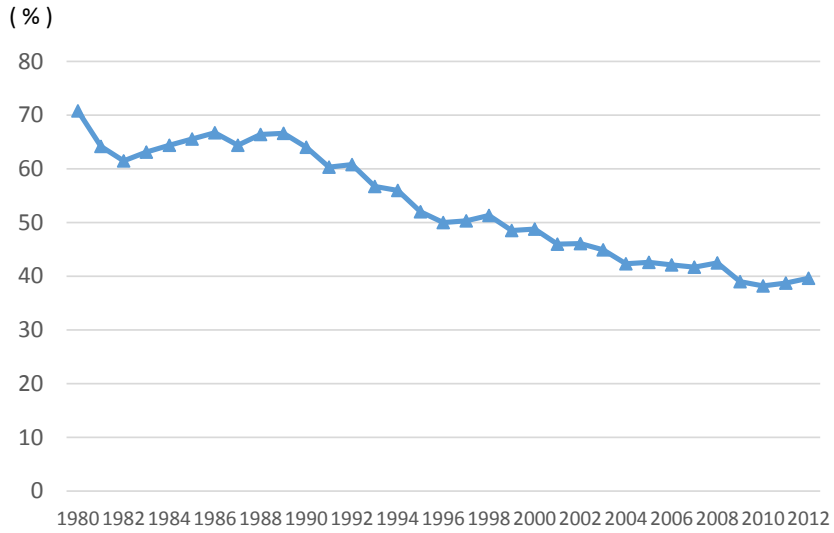
Figure 5-10 shows each sector's share in the GDP of Thailand. The long-term trend is that the share of agriculture has decreased while the share of manufacturing has been growing, but recently the share of agriculture stopped declining and has maintained about 10% share for the past fifteen years.



Source: World Bank database

Figure 5-10 Historical Trend of Sectorial Share in Merchandise Export in GDP

Figure 5-11 shows the ratio of employment in agricultural sector against total employment. Likewise the percentage sees a declining trend, but it still keeps relatively high level at 40%. Looking at the historical trend of industrial structure, along with that of import-export as aforementioned, it can be said that Thailand endeavors to maintain agriculture as one of main components of its economy even at present when the industrialization has reached certain level.



Source: World Bank database

Figure 5-11 Share of Agriculture in Total Employment

4) Industrial policy of Thailand

As seen in the previous section of this chapter, Thailand was traditionally an exporting country of agricultural products and the country has been taking policies to protect agriculture and to support the business of farmers. In these days when the competition of agricultural exports against Asian emerging countries such as China and Vietnam has become severer, Thailand has shifted its position to the exporter of more value-added products, such as fresh fruits, jasmine rice and processed foods so that the agriculture still remain and important part of Thai economy.

In the meantime, the role of manufacturing was minor until 1960s. In 1961, Thai Government launched the first National Economic and Social Development Plan for promoting investment and industrial development. Since then the government has been taking policies on industrial development continuously while changing its focal point in accordance with the economic development. Table 5-3 summarizes the outline of industrial policies stipulated in the National Economic and Social Development Plans from First to Eleventh.

Table 5-3 Outline of Industrial Development Policy Stipulated in National Economic and Social Development Plan (from 1st to 11th)

National Plan	Period	Key policies on industrial development
1st	1961-1966	● protection of domestic industry
2nd	1967-1971	● import substituting industrialization ● promote investment by private sector
3rd	1972-1976	● promote exports ● export-driven industrialization ● selective foreign capital introduction policy
4th	1977-1981	● continue of promotion of export-driven industrialization
5th	1982-1986	● development of petro-chemical industry
6th	1987-1991	● promote investment by private sector ● privatization of energy sector
7th	1992-1996	● promote high value added industry through technology transfer ● local dispersion of the industrial development ● improve of quality of life
8th	1997-2001	● people-centered development ● human resource development ● maintain international competitiveness ● promote small and medium enterprises (SMEs)

National Plan	Period	Key policies on industrial development
9th	2002-2006	● Sufficiency Economy philosophy ● sustainable development ● improve of quality of life
10th	2007-2011	● Human development ● community development and alleviation of poverty ● Reform the economic structure for balance and sustainability ● safeguard natural resources and the environment
11th	2012-2016	● empowerment of social capital ● strengthening of economic capital ● restoration of natural resource and environmental capital

Source: JICA Survey Team

The main point at the initial stage of industrialization was that the country adopted a policy to protect domestic industry to promote industrialization to substitute import. Afterwards, when the domestic industries had accumulated basic technologies and enough experiences, the government shifted to the policy for export-driven industrialization and for promoting export. In Thailand 1971 was the turning point. After turning to the policy for export-driven industrialization, the Thai government started adopting policies for promoting exports such lowering import tax on raw materials and machinery parts for manufacturing export products, incentives for promoting export with low-interest loan on exporters and establishment of export-promoting zone.
During the period of Thailand's import substituting policy in 1960s, Japanese manufacturing companies started to develop business in Thailand for domestic production in the fields of home appliances, motor cars etc. With the progress of technology transfer, the production increased gradually. According to an old Japanese study report, the share of local products in home appliance industry before 1990 was only 20-50%. In 1990s the share of local products increase as the manufacturing of cathode-ray tube (CRT) for color TV started in Thailand.
The Seventh National Economic and Social development Plan (1991-1996) chose six industries as prioritized one; food processing, textile, metal, electronics device, petrochemical and steel. Then the Eighth National Plan (1996-2001) nominated four industries as prioritize; car manufacturing, electric and electronics, machinery, and telecommunications.

5.4.2 Implications for the future scenarios of economic development in Bangladesh

Bangladesh has some advantages in its fundamentals for future economic development compared to other countries, such as:

- Bangladesh has a huge area of rich farmland that can yield a good plenty of agricultural products;
- Bangladesh has a huge population, which helps the country to provide a good amount of labor force with relatively low cost compared to neighboring countries;

In addition, Bangladesh has already started the process of industrialization and the economic development is already on a good track centering on the following industries:

- Bangladesh has already become a production base of production for garment industry globally:
- In the field of manufacturing home electric appliances such as lumps, fans, and refrigerators, some local companies are growing up and a part of them already started export to Europe;
- Beside electric appliances, there already exist some industries locally grown in Bangladesh, such as food, pharmaceutical, ship building, and they have unique position as Bangladeshi company.

In general the latecomer developing countries are said to have advantages of shortening the duration of economic development because of speed of technology transfer. Taking into consideration the current

status of Bangladeshi economy and the lessons from the experience of Thailand's industrial and economic development, there is a high possibility that Bangladesh has a good potential to achieve the same level of economic development towards 2041 as that of the present Thailand. The challenges for bringing the country on the track of long-term economic development are summarized in Table 5-4.

Table 5-4 Challenges for Bangladesh to Achieve Long-term Economic Development

Industrial Sector	Future Scenario
Agriculture	● Productivity improvement ● Improvement of farmers' income
Food and beverage	● Improvement of quality ● Export of products
Garment	● Evolution from consignment manufacturing to manufacturing by original design and own brand
Other secondary industries	● Catch up of technologies for manufacturing ● Export of products ● Capacity development of human resources

Source: JICA Survey Team

5.5 Future Scenarios of Economic Development of Bangladesh

5.5.1 Manufacturing sector in Bangladesh

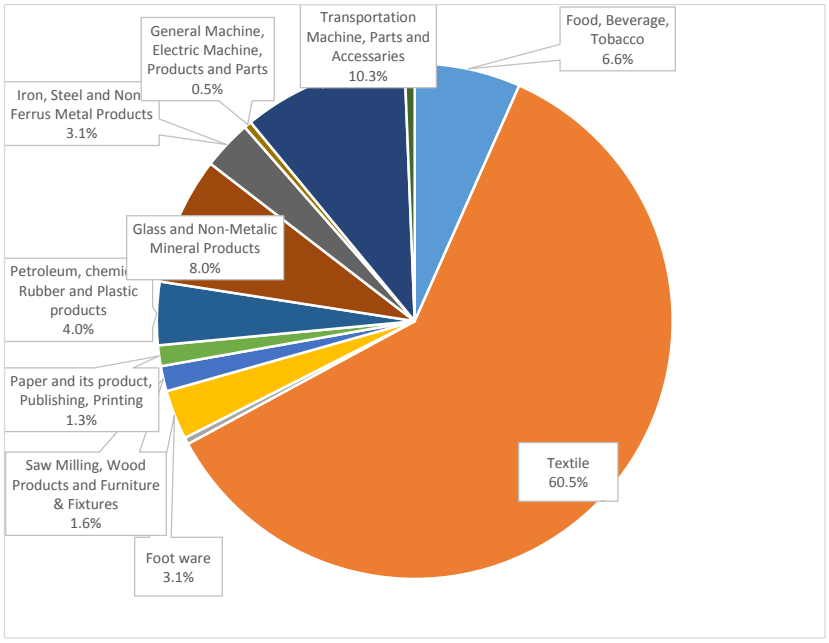
There are some statistics, though not many, which provide quantitative data on the manufacturing sector in Bangladesh. Table 5-5 and Figure 5-12 show the gross value added in large & medium-scale manufacturing sector broken down by industrial subsectors. Textile is the largest industry among manufacturing and is expanding from the share of 41.4% at 2008-09 to 60.5% at 2013-14. Those that follow textile industry are 'Transportation machine, parts and accessories' (10.3% in 2013-2014), 'Glass and non-metallic mineral products' (8.0%), 'Food, beverage, tobacco' (6.6%), 'Petroleum, chemical, rubber and plastic products' (4.0%), 'Foot ware' and 'Iron, steel and non-ferrous metal products' (3.1%) .

Food industry is one of the prominent industries which would increase value added and gain foreign currency through export because Bangladesh is rich in agricultural and fishery resources. Furthermore, the fact that industrialization has already come to a certain level in some sectors such as machinery, plastic products, steel, non-ferrous metal products etc. implies that Bangladesh has a good possibility of further industrialization by placing appropriate policy measures to promote this trend.

Table 5-5 Gross Value Added in Large & Medium Scale Manufacturing Sector

	2008-09		2013-14(p)	
	Million Tk.	Share	Million Tk.	Share
Food, Beverage, Tobacco	84,268	9.0%	121,772	6.6%
Textile	386,477	41.4%	1,107,888	60.5%
Leather and its product	5,312	0.6%	7,753	0.4%
Foot ware	28,196	3.0%	56,789	3.1%
Saw Milling, Wood Products and Furniture & Fixtures	26,284	2.8%	28,990	1.6%
Paper and its product, Publishing, Printing	18,980	2.0%	23,859	1.3%
Petroleum, chemical, Rubber and Plastic products	71,734	7.7%	72,556	4.0%
Glass and Non-Metalic Mineral Products	107,320	11.5%	146,580	8.0%
Iron, Steel and Non-Ferrus Metal Products	48,982	5.2%	56,687	3.1%
General Machine, Electric Machine, Products and Parts	7,980	0.9%	8,694	0.5%
Transportation Machine, Parts and Accessaries	145,146	15.5%	189,588	10.3%
Others	2,902	0.3%	11,529	0.6%
Total	933,581	100.0%	1,832,685	100.0%

Note: (p) denotes provisional,
The data in the table are at Current Price,
Source: Prepared by the JICA Survey Team using Bangladesh National Account Statistics: Sources and Methods 2013-14 (BBS)



Note: (p) denotes provisional
The data in the table are based on Table 5-5 at 2013-2014(p).
Source: Prepared by the JICA Survey Team using Bangladesh National Account Statistics: Sources and Methods 2013-14 (BBS)

Figure 5-12 Gross Value Added in Large & Medium Scale Manufacturing Sector

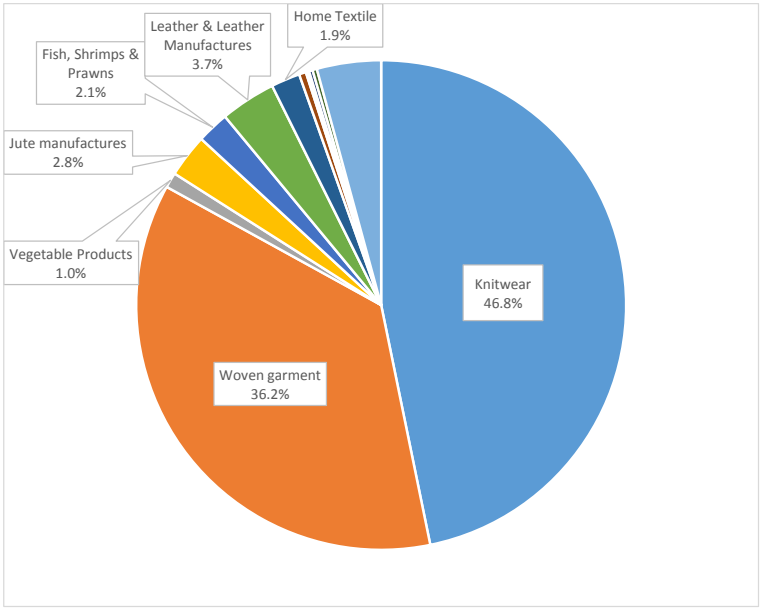
Another useful statistic data which help understand the present status of manufacturing in Bangladesh is the export of each product as summarized in Table 5-6. The total amount of export increased from 153,225 Crore BDT at 2011-2012 to 187,971Crore BDT at 2014-2015 (see the sub-total in the data, which is the total value of export excluding SEZ). The average growth of total export was 7.1% per year.

Knitwear and woven garment account for 46.8% and 36.2% respectively among total earnings from export and are representing the growth of total export. The exports of "vegetable products", "leather & leather manufactures" and "pharmaceuticals" are increasing likewise. In the meanwhile, the export of "raw jute", "terry towel", and "petroleum & petroleum products" has been decreasing. At present, the country's earnings from export are heavily dependent on textile industries including RMG, home textiles etc. and leather related industries including foot ware. For further economic development of Bangladesh, the new industries such as food processing, pharmaceuticals and light industries are expected to gain more shares in the export.

Table 5-6 Trends of Exports in Bangladesh

		2011–2012		2012–2013		2013–2014		2014–2015	
		crore Taka	% of	crore Taka	% of	crore Taka	% of	crore Taka	% of
RMG	Knitwear	70,910	46.3%	72,706	45.7%	82,425	46.2%	87,941	46.8%
	Woven garment	49,238	32.1%	55,563	34.9%	64,201	36.0%	68,104	36.2%
Vegetable Products		844	0.6%	1,030	0.6%	1,424	0.8%	1,894	1.0%
Jute manufactures		5,200	3.4%	5,988	3.8%	5,317	3.0%	5,351	2.8%
Fish, Shrimps & Prawns		4,758	3.1%	3,580	2.3%	4,097	2.3%	3,989	2.1%
Leather & Leather Manufactures		4,265	2.8%	5,399	3.4%	6,864	3.8%	6,890	3.7%
Home Textile		3,608	2.4%	3,316	2.1%	3,862	2.2%	3,589	1.9%
Raw Jute		1,866	1.2%	1,681	1.1%	948	0.5%	856	0.5%
Petroleum & Petroleum Products		972	0.6%	825	0.5%	535	0.3%	295	0.2%
Terry Towel		929	0.6%	193	0.1%	106	0.1%	123	0.1%
Bicycle		407	0.3%	462	0.3%	377	0.2%	443	0.2%
Pharmaeutical Products		391	0.3%	466	0.3%	508	0.3%	537	0.3%
Others		9,837	6.4%	7,902	5.0%	7,891	4.4%	7,959	4.2%
Sub–Total		153,225	100.0%	159,111	100.0%	178,555	100.0%	187,971	100.0%
Export of SEZ		27,086	–	30,549	–	34,820	–	38,515	–
Ground Total		180,310	–	189,660	–	213,375	–	226,486	–

Source: Prepared by the JICA Survey Team using the web site, https://www.bb.org.bd/econdata/export/exp_rcpt_comodity.php, https://www.bb.org.bd/openpdf.php



Source: Prepared by the JICA Survey Team using the information from BBS Websites (https://www.bb.org.bd/econdata/export/exp_rcpt_comodity.php, https://www.bb.org.bd/openpdf.php)

Figure 5-13 Composition of the Share of Each Products (2014-2015)

5.5.2 Roles and directions of manufacturing sector in Bangladesh

The study team conducted interviews with the officers of Ministry of Industries (MOI) and the policy adviser to MOI dispatched by JICA, and also reviewed the government plans such as Vision 2021 and the Seventh Five-Year Plan. The expected roles and directions of manufacturing that can be observed from aforementioned can be summarized as follows.

- Manufacturing is and will remain the driver of industrial growth.
- The main driver of manufacturing growth will be the export market.
- Until 1981, Jute and Jute goods dominated the export sector making up 70%, and then RMG export overtook the traditional export which rose to around 80%.
- The export concentration in RMG makes the economy extremely vulnerable to external changes and export diversification is very much important for the sustainable growth of Bangladesh.

According to the Perspective Plan of Bangladesh 2010-2021 (April 2012), the following industries are indicated as growth generator.

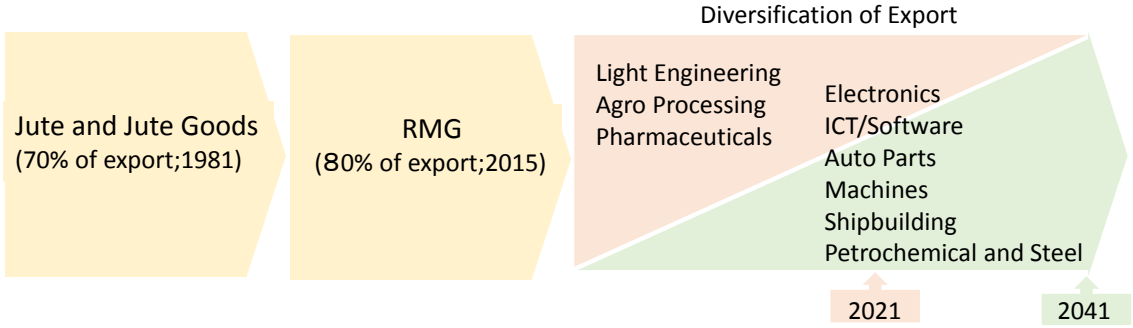
<Likely to be the main growth generator>
- Food processing, Leather and footwear, Pharmaceutical, Ship building, Toys, Ceramics , Furniture

<Likely to be the emergence of new products>
- Auto parts, Electronics, Light engineering

In addition, the Seventh Five-Year Plan FY2016-2020 (Final Draft, 11 November 2015) lists the industries as the growth generator.

<Likely to grow at a much faster rate>
- Footwear and Leather products, light engineering products (bicycle and electronics), pharmaceuticals, jute goods, ocean-going ship

To summarize the aforementioned, this study summarizes the future image of industrial development toward 2041 as illustrated in Figure 5-14.
Up to early-2020s, whereas Bangladesh economy still depends high on conventional industries such as RMG, jute and leather, new industries are expected to grow gradually. The export products are expected to be more diversified, such as light engineering, agro processing products and pharmaceuticals. Afterwards, i.e. towards 2041, the diversification will be further progressed to cover new industries and products with more value added, such as electronics, ICT/software, auto parts, machines and shipbuilding.

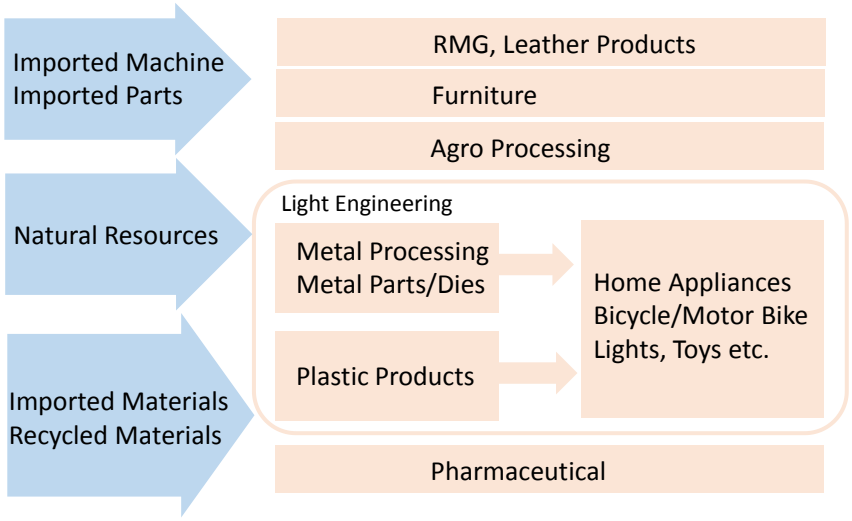


Source: JICA Survey Team

Figure 5-14 Future Image of Industrial Development in Bangladesh Towards 2041

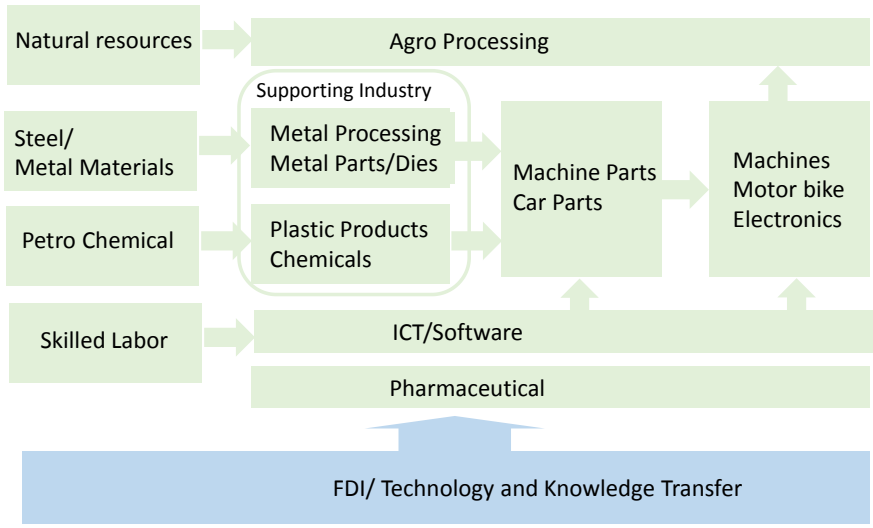
Future image of industrial structure in Bangladesh in early-2020s and 2041 is shown in Figure 5-15 and 16.
Up to early-2020s, Bangladesh industry will continue using imported materials and imported parts & machines as well as the direct use of domestically available natural resources. This means that the value chain of manufacturing from material to product is relatively simple. Here, SMEs (small and medium enterprises) are expected to play an important role. To develop SMEs and to support them to entry into the export market, various support policies should be undertaken.
Towards 2041, Bangladesh industry is expected to provide more multi-layered value chain for itself from raw material to machinery and then to final products, so that it will produce higher value added.

Introducing FDIs and taking advanced technologies and knowledges is indispensable to achieve this. Here, heavy industries like petrochemical and steel making will be integrated into industrial value chain in Bangladesh as well as SMEs. This study also emphasizes that agro processing industry will still remain as an important industry because it utilizes Bangladesh's own natural resources. Agro industry is expected to continue playing an important role because it is appropriate for Bangladesh to sustain huge labor force and secure food supply. Agro industry can be a highly value-added industry through the advancement of value-added processing, as seen in the experience of Thailand.



Source: JICA Survey Team

Figure 5-15 Image of Industrial Structure in Early-2020s



Source: JICA Survey Team

Figure 5-16 Image of Industrial Structure in 2041

5.5.3 Positioning of Bangladesh in the process of industrialization and measures to be taken

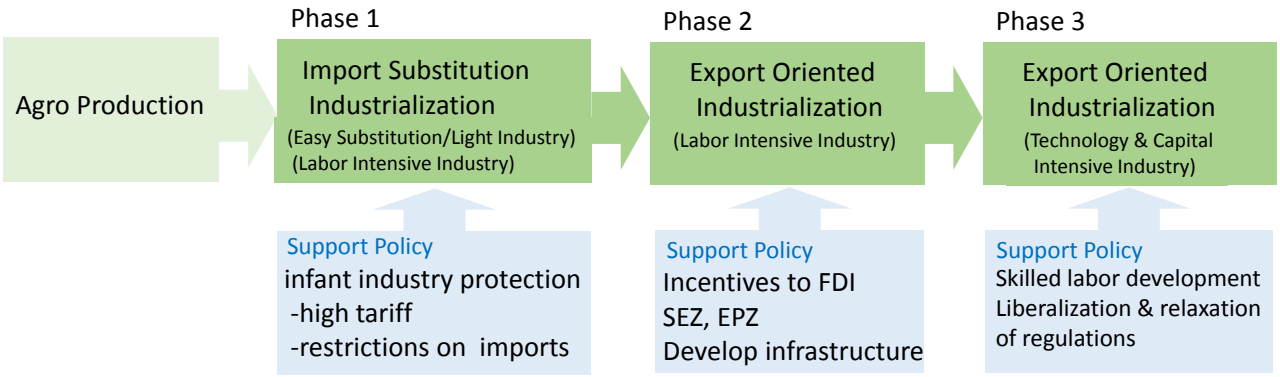
According to some academic researches on economic development in Asian developing countries, it is generally observed that there are three phases of industrialization in these countries as follows.

Phase 1: Import Substitution Industrialization by labor intensive and light industries under infant industry protection policies.
Phase 2: Export Oriented Industrialization by labor intensive industries like textile and footwear industry under export industry development policies.

Phase 3: Export Oriented Industrialization by technology and capital intensive industries like metal processing and machine industry.

The study team considers that this process can also be applicable in Bangladesh. According to the Seventh Five-Year Plan, Bangladesh after independence embraced a predominantly import-substituting trade regime. Around 1990, Bangladesh economy reached a point that protective policy for promoting import-substitution has become an obstacle for further growth and policy change is needed. It means that Bangladesh economy proceeded from Phase 1 to Phase 2 around 1990 and currently Phase 2 is in progress.
According to past studies, Thailand adopted import substitution industrialization policy during 1960s and changed the policy to export oriented industrialization in 1971. As a result, the ratio of trade amount in GDP increased from less than 30% in 1970 to 50% in 1981 and 65% in 1990. Industrialization in Thailand entered into Phase 3 in the middle of 1980s.
Considering the policies taken in Thailand over the period of industrialization, various policies need to be taken in each process of industrialization in the future in Bangladesh as follows

Phase 1: Import Substitution Industrialization
Policies for infant industry protection should be implemented (ex. High tariff, restriction on imports).
Phase 2: Export Oriented Industrialization (Labor Intensive Industry)
Policies on provision of incentives to FDI, construction of Industrial zone such as SEZ for foreign enterprises and development of various infrastructures like port, road, railway, and power supply must be needed.
Phase 3: Export Oriented Industrialization (Technology and Capital Intensive Industry)
In the stage of Phase 3, in addition to the above mentioned policies in Phase 2, skilled labor development and liberalization & relaxation of regulations are needed for realizing the industrialization among international competition.



Source: JICA Survey Team

Figure 5-17 Stages of Industrialization and Necessary Policy Measures

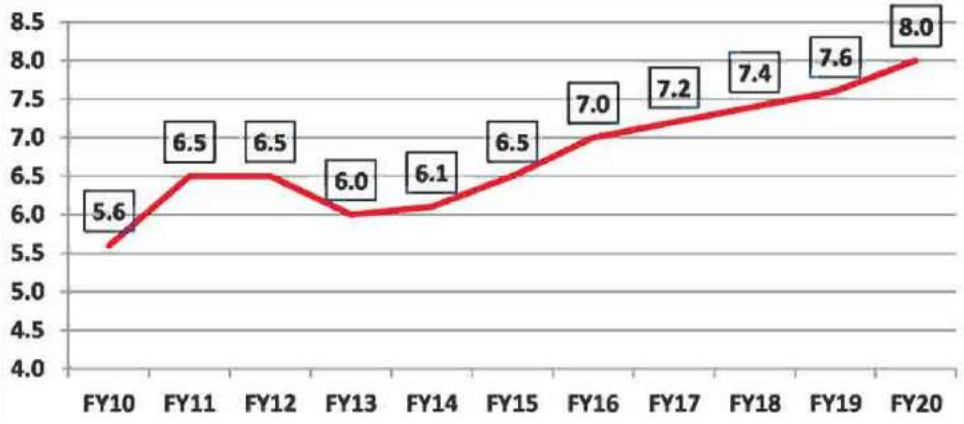
5.6 Projections of GDP in Bangladesh up to 2041

Based on the assumptions discussed in the precious sections, this study projected the GDP growth of Bangladesh up to 2041.

5.6.1 Bangladesh Government's GDP growth target

For the first five years up to 2020, this study refers to the GDP growth target set out in the Seventh Five-Year Plan. The Government of Bangladesh sets the country's growth to be 7.4% p.a. (per annum) during the five-year period (FY2016-FY2020), as shown in Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015
Figure 5-18. The growth rate is expected to increase steadily from 6.5% in FY2015 to 8.0% in FY2020.

The Government sees that the upward trend of GDP growth rate since FY2013 is expected to continue.



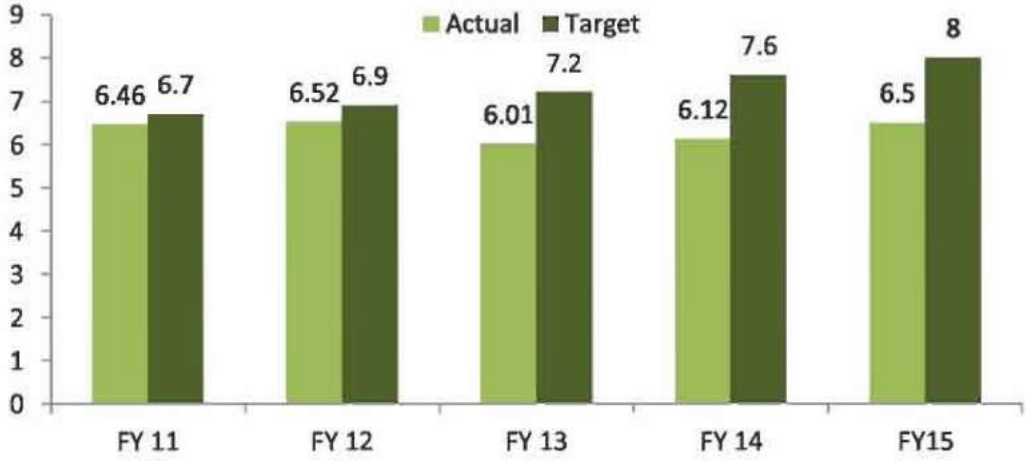
Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

Figure 5-18 Projection of GDP Growth Rate in the Seventh Five-Year Plan

According to the announcement of the Government, the provisional result of GDP growth rate in FY2015-2016 was 7.05%, which attained the first year's target of the Seventh Five-Year Plan that was 7.0%. Considering the improved productivity of national economy and the strengthened international competitiveness, the country's economy is capable of keeping at least higher than 6% growth rate for the upcoming 5 years. However, it appears that achieving 7.4% growth target is not easy.

It has to be noted that in general the "target" is apt to be ambitious. As seen in Table 5-1, the actual growth rate during the period of past five-year plans (from first to sixth) has been underperforming the government plan, though the acceleratedly increasing trend of GDP, up from 3.8% p.a. in 1985-1990 to 6.3% p.a. in 2011-2015, proves that Bangladesh economy took on a track of rapid growth.

For the past five years during the period of Sixth Five-Year Plan (from FY2011 to FY2015), the actual growth rate has been constantly underperforming the target, as shown in Figure 5-19. According to the GOB's review on the achievements of the Sixth Five-Year Plan, which is described in the Seventh Five-Year Plan, the main factors of this gap are the "constrained growth of the service sector," "shortfall in the investment rate, both public and private" and "inability to achieve the projected growth rate in agriculture." They imply, in short, that the delay of economic reforms for inducing further economic growth. The country may not be able to fully reap the opportunity of economic development and the growth rate may continue underperforming the government's expectation unless the economic policies to support the development are not in place as planned.



Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015
Note: the actual performance of growth rate in FY2014-2015 was later amended from 6.5% to 6.6%

Figure 5-19 Comparison between the Government's Projection and Actual Performance during the Period of Sixth Five-Year Plan

5.6.2 Projections of international agencies

Table 5-7 shows the projection of GDP growth rate in Bangladesh with comparison of International Organizations, such as International Monetary Fund (IMF), World Bank and Asian Development Bank (ADB).
These international organization expects Bangladesh's GDP to grow at 6.7%-7.0% in 2016 and afterwards. These projections reflect the recent performance of Bangladesh's economy growth and are considered to be very positive. However, compared to them, GOB's GDP growth target is still more ambitious.

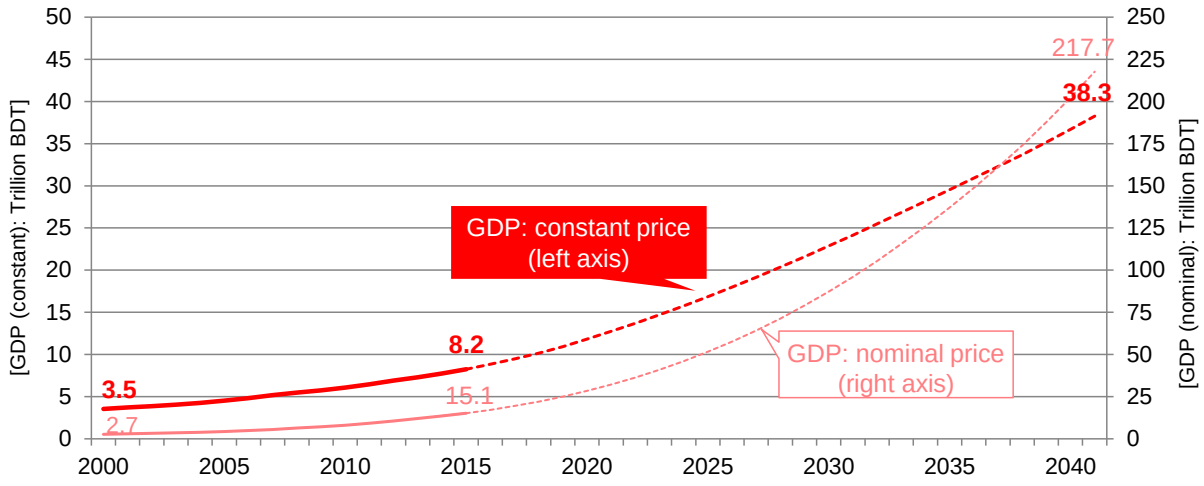
Table 5-7 Projection of GDP Growth Rate in Bangladesh:Comparison with International Organizations (real GDP)

	2015	2016	2017	2018	2019	2020
IMF "World Economic Outlook" (October 2015)	6.5%	6.8%	7.0%	7.0%	7.0%	6.7%
World Bank "Global Economic Prospects" (January 2016)	6.5%	6.7%	6.8%	6.8%	-	-
ADB "Asian Development Outlook 2015" (update: September 2015)	6.5%	6.7%	-	-	-	-
GoB "Seventh Five-Year Plan" (December 2015)	6.5%	7.0%	7.2%	7.4%	7.6%	8.0%

Source: Publications from International Monetary Fund, World Bank and Asian Development Bank

5.6.3 Projection in PSMP2016

The study team initially analyzed that the 7.4% p.a. growth from 2016 to 2020 might be overstretching and that the growth rate between 6.5 and 7.0%, as projected by international organizations, appears to be more realistic. Even if the fundamentals of Bangladesh economy continue to perform well, the recent slowdown of global economy, as typically seen in China, may also affect the economic growth of Bangladesh, considering that the country has been shifting to export-driven economy.
However, considering the consistency with the economic development plan officially made public by the GOB, this study follows the GOB's economic growth target, i.e. 7.4% p.a. from 2016 to 2020, assuming that policy measures to promote the economic growth, as discussed in the previous sections, will be optimally in place.
To follow this, Bangladesh economy in the next five years in early 2020s is expected to grow as high as during the period of Seventh Five-Year Plan and is expected to reach the criteria of upper-middle income countries. Afterwards, the growth rate may become slightly moderate as the economy comes to a certain level of maturity, but GDP will continue to grow steadily.
Figure 5-20 shows the study team's projection of GDP, both in constant and nominal price, up to 2041. Real GDP (constant at 2005 price) as of 2041 is estimated to reach 38 trillion BDT, about 4.6 times of the current level (8.2 trillion BDT). Nominal GDP (current price) is estimated to become about 220 trillion BDT in 2041. The average growth rate from 2016 to 2041 is 6.1% p.a. in real price and 10.8% in nominal price.
Methodologies of the GDP projection are discussed more in detail in the next section.



Source: JICA Survey Team

Figure 5-20 GDP Projection Up to 2041

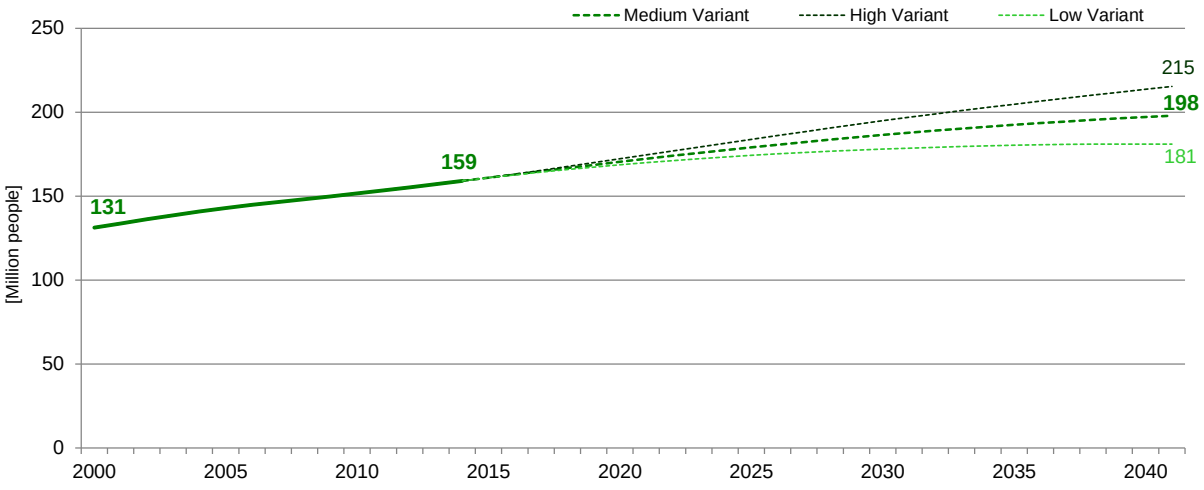
5.7 Methodologies of GDP Projection in this Study

5.7.1 Population

Population projection refers to United Nations' "World Population Prospects 2015" (WPP) as shown in Figure 5-21. WPP provides three scenarios of population growth, "High Variant," "Medium Variant," and "Low Variant" scenarios. In the "Medium Variant" scenario, which was adopted for this GDP projection, the population as of 2041 is expected to reach 198 million.

In Bangladesh, where the population density is high, population is still growing but the growth is getting moderate recently. The growth rate was about 2% around 2000, but it declined to 1.2% in 2014. In the "Medium Variant" scenario, this declining trend is expected to continue and the growth rate in 2041 will be 0.4% in 2041. The average growth rate for the entire period from 2015 to 2041 is 0.8% p.a. Table 5-8 summarizes the population projection and five-year (or six-year) average in each period.

In the "High Variant" scenario, the population growth is rather constant though the growth rate starts declining slightly from 2020s, whereas in the "Low Variant" scenario, the growth rate drops much faster and the total population starts decreasing (i.e. growth rate becomes negative) from 2039.



Source: United Nations "World Population Prospects 2015"

Figure 5-21 Population Projection Up to 2041

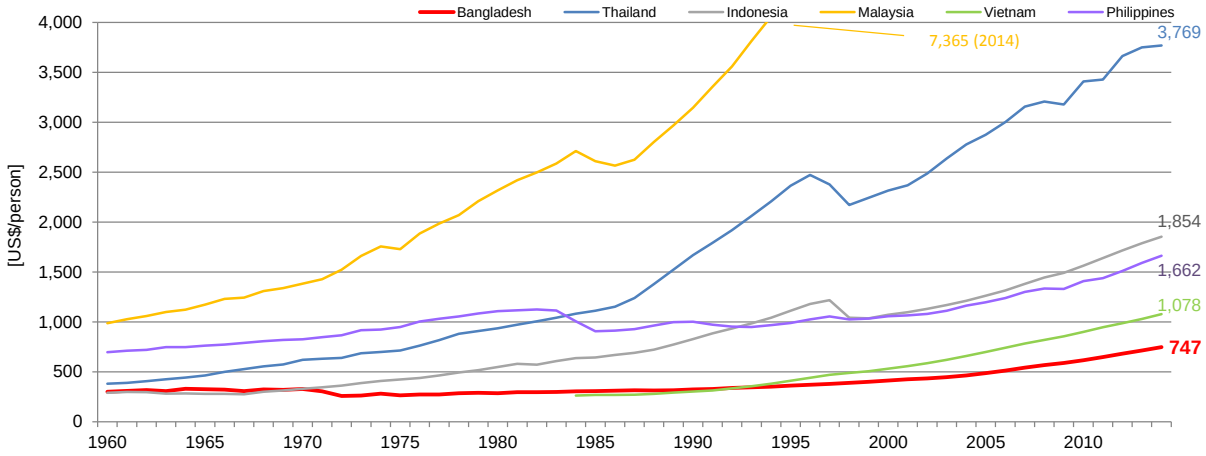
Table 5-8 Population Projection Up to 2041 (Medium Variant Scenario)

	2010	2015	2020	2025	2030	2035	2041
Population (1,000 people)	151,617	153,406	155,257	157,157	159,078	160,996	162,911
Average growth rate (p.a.)	1.2%	1.2%	1.1%	1.0%	0.8%	0.6%	0.5%

Source: United Nations "World Population Prospects 2015"
Note) Average growth rate is the five-year average except in the column of year 2041 that is six-year average.

5.7.2 Economic development scenario

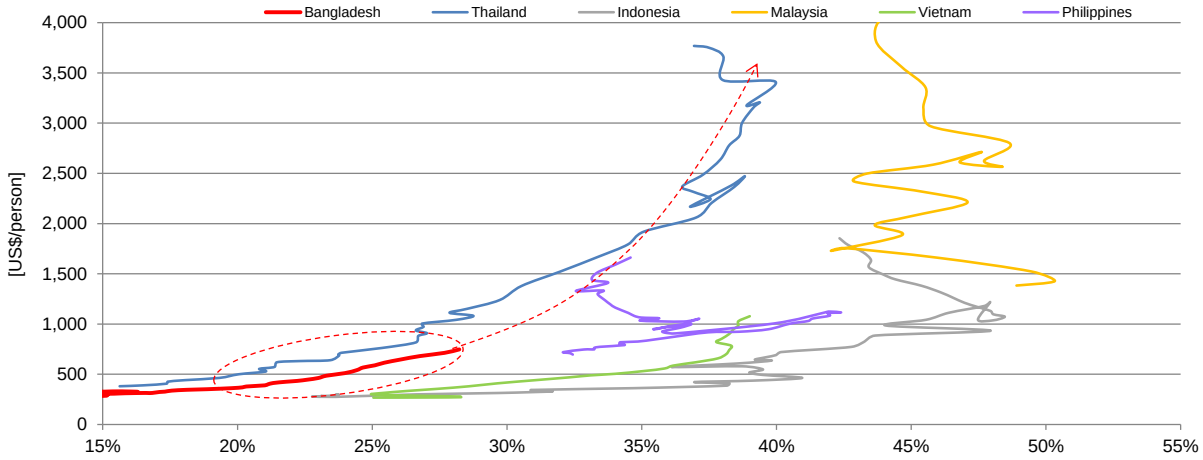
Figure 5-22, likeFigure 5-3, compares the historical trend of GDP per Capita of Bangladesh with that of ASEAN countries, as also discussed in Section 5-3. Bangladesh's real GDP per capita (constant at 2005 price) in 2014 was 48,664 BDT, which is equivalent to 747 USD in 2005 price.
Considering that in ASEAN countries GDP per capita saw a rapid growth after it reached 1,000 USD, Bangladesh, which will reach this threshold soon, is also supposed to have a good potential of accelerated economic growth to follow this trend.



Source: World Bank database

Figure 5-22 Historical Trend of GDP per Capita (real GDP) of Bangladesh and ASEAN Countries

Figure 5-23 plots the relation between the share of industrial sector in GDP (horizontal axis) and the GDP per capita (vertical axis) of Bangladesh and ASEAN countries since 1960. As a general trend, GDP per capita increases along with the growth of the industrial sector's share in GDP up to a certain level, which is supposed to be the stage of initial industrialization, and then GDP continues to grow while the share of industrial sector in GDP become relatively stable, which is considered the economic growth after the country's industrialization comes to a certain level of maturity.
Bangladesh's GDP capita started increasing rapidly when the industrial sector's share exceeded 20%. And this trend curve has been taking a similar track to what Thailand experienced before. Hence this study assumes that Thailand's history of economic development can be a good reference for projecting a future scenario of Bangladesh's economic development.



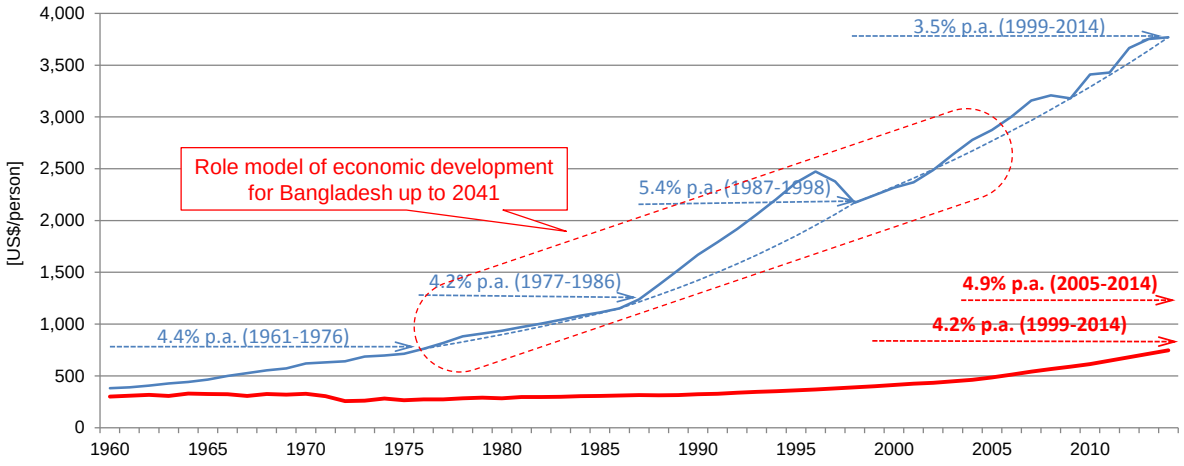
Source: Prepared by the JICA Survey Team using World Bank database

Figure 5-23 Industrial Sector's Share in GDP and GDP per Capita (real GDP) of Bangladesh and ASEAN Countries (1960-2014)

As already discussed above, Bangladesh's GDP per capita (real GDP in 2005 price) as of 2014 was 747 USD, which is almost equivalent to that of Thailand around 1976. Figure 5-24 shows the historical trend of GDP per capita of Thailand as a role model of economic development for Bangladesh. The current status of economic development of Bangladesh can be compared with that of Thailand also from the view point that Bangladesh saw a 4.2% p.a. growth of GDP per capita from 1999 to 2014 (16 years), which is similar to Thailand's growth rate from 1961 to 1976 (16 years) that was 4.4% p.a., and the growth rate from 1977 to 1986 (10 years) that was 4.2% p.a.

Thailand saw a rapider growth of economy afterwards, i.e. from mid-1980s to late-1990. Thought the country suffered an economic slump in late-1990s caused by the Asian Financial Crisis, the average growth rate of GDP per capita from 1986 to1998 was 5.4%, even higher than beforehand and afterwards. From late-1990s up to now, GDP per capita in Thailand has been keeping a 3.5% p.a. growth in average, though there's a fluctuation from year to year.

Assuming that Bangladesh follows the track of Thailand's economic growth in the past, the high growth is expected to continue, especially during the period when the country's GDP per capita reaches around 2,000 USD. Considering the recent rapid growth of Bangladesh economy and the follower's advantage for Bangladesh, this study assumes that the GDP per capita of Bangladesh for 27 years from 2014 to 2041 grows a little faster than that of Thailand for 27 years for 1976 to 2003.



Source: Prepared by the JICA Survey Team using World Bank database

Figure 5-24 Historical Trend of GDP per Capita (real GDP) of Bangladesh (red) and Thailand (blue)

Based on the aforementioned observations, this study assumes the growth rate of GDP per capita up to 2041 as follows.

- From 2016 to 2020:
  Average growth rate 6.2% p.a., which coincides with the government's target of GDP growth rate (7.4% p.a.), will be achieved.
- During 2020s:
  High growth rate continues like the past experience of Thailand achieved a rapid growth in 1980s and 1990s when GDP per capita increased from 1,000 USD to 2,000 USD.
- During 2030s and afterwards:
  Growth rate starts getting slightly moderate as the country's economic development comes to a certain level of maturity.

The result of the study team's projection of GDP per capita is summarized in Table 5-9. GDP per capita as of 2041 is expected to reach about 3,000 USD, about 3.8 times of that in 2015.

Table 5-9 Projection of GDP per Capita Up to 2041 (Real Basis at 2005 Price)

	2010	2015	2020	2025	2030	2035	2041
GDP per capita (USD)	615	787	1,063	1,444	1,883	2,357	2,970
GDP precipitate (BDT)	40,042	51,215	69,245	94,035	122,611	153,446	193,361
Exchange rate (BDT/USD)	65.1						
Growth rate (p.a.)	4.8%	5.0%	6.2%	6.3%	5.5%	4.6%	3.9%

Source: JICA Survey Team
Note: Average growth rate is five-year average except in the column of year 2041 that is six-year average.

The projection of GDP per capita at current price (nominal GDP) is shown in Table 5-10. At current price, GDP capita is expected to reach around 1.1 million BDT, or around 11,000 USD. GDP deflator in Bangladesh, which is currently around 7%, is expected to decline gradually to about 3%. Considering the inflation in Bangladesh, BDT is expected to depreciate against USD and the exchange rate in 2041 will be about 100 BDT/USD.

Table 5-10 Projection of GDP per Capita Up to 2041 (Nominal Basis)

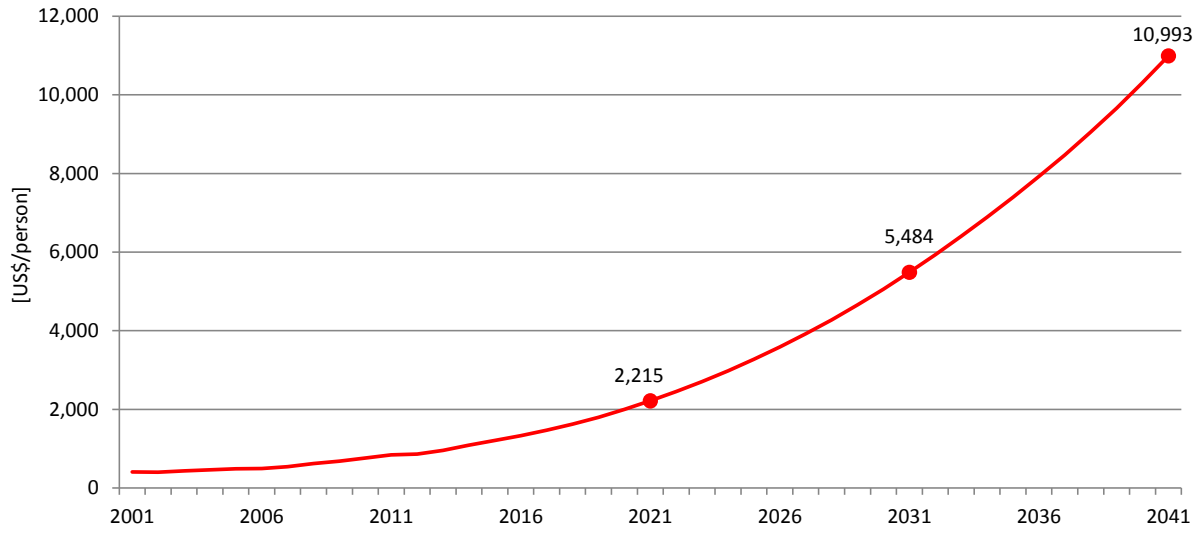
		2010	2015	2020	2025	2030	2035	2041
GDP per capita (USD)		760	1,207	1,998	3,270	5,060	7,396	10,993
GDP per capita (BDT)		52,602	94,015	166,131	287,938	467,860	712,373	1,100,271
Exchange rate (BDT/USD)		69.2	77.9	83.2	88.0	92.5	96.3	100.1
GDP deflator (p.a.)		6.8%	6.9%	5.5%	5.0%	4.5%	4.0%	3.4%
Growth rate (p.a.)	USD	9.4%	9.7%	10.6%	10.4%	9.1%	7.9%	6.8%
	BDT	12.0%	12.3%	12.1%	11.6%	10.2%	8.8%	7.5%

Source: JICA Survey Team
Note: GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

According to the World Bank's country classification (updated: February 2015), low-income, middle income, and high-income economies are defined as follows.

- Low-income economies: Countries with GNI (Gross National Income) per capita of 1,045 USD or less.
- Middle-income economies: Countries with GNI per capita of more than 1,045 USD but less than 12,736 USD.
  (Lower-middle-income and upper-middle-income economies are separated at a GNI per capita of 4,125 USD)
- High-income economies: Countries with GNI per capita of 12,736 USD or more.

This study expects that the GDP per capita of Bangladesh in 2041, about 11,000 USD (see alsoFigure 5-25), almost reaches the definition of "High-income economies", considering that GDP and GNI are not much different. That is, GOB's target to turn Bangladesh into a developed country by 2041 may not be too much unrealistic, though achieving this target may require some optimistic assumptions of economic growth. The criterion of upper-middle economies, i.e. GNI per capita of 4,125 USD, is supposed to be reached in 2020s.



Source: JICA Survey Team

Figure 5-25 Historical Trend and Projection of GDP per Capita (Nominal Base)

5.7.3 GDP projection up to 2041

Multiplying the GDP per capita and the population, the GDP of Bangladesh up to 2041 was forecasted, as already shown in Figure 5-20.
Table 5-11 and Table 5-12 are the summary table of forecasted GDP on real basis (constant at 2005 price) and nominal basis (current price) respectively. Real GDP is expected to continue growing higher than 7% until mid-2020s, then the growth rate will become slightly moderate as the economic development comes to a certain level of maturity.

Table 5-11 Real GDP Projection (constant at 2005 price)

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	93,236	126,630	181,282	258,598	351,109	453,642	587,665
GDP (billion BDT)	6,071	8,245	11,804	16,838	22,862	29,538	38,265
Exchange rate (BDT/USD)	65.1						
Growth rate (p.a.)	6.1%	6.3%	7.4%	7.4%	6.3%	5.3%	4.4%

Source: JICA Survey Team
Note) Growth rate is five-year average except in the column of year 2041 that is six-year average.

Table 5-12 Nominal GDP Projection (current price)

		2010	2015	2020	2025	2030	2035	2041
GDP (million USD)		115,279	194,300	340,576	585,615	943,451	1,423,643	2,175,520
GDP (billion BDT)		7,975	15,136	28,320	51,559	87,237	137,132	217,738
Exchange rate (BDT/USD)		69.2	77.9	83.2	88.0	92.5	96.3	100.1
GDP deflator (p.a.)		6.8%	6.9%	5.5%	5.0%	4.5%	4.0%	3.4%
Growth rate (p.a.)	USD	10.7%	11.0%	11.9%	11.4%	10.0%	8.6%	7.3%
	BDT	13.3%	13.7%	13.3%	12.7%	11.1%	9.5%	8.0%

Source: JICA Survey Team
Note) GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

Table 5-13 and Table 5-14 are the GDP projection expressed in PPP (power purchasing parity). World Bank's database was referred to in setting the conversion factor. In terms of PPP, GDP capita at current price is expected to reach about 32,000 USD in 2041.

Table 5-13 GDP Projection (PPP, constant at 2011 price)

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	371,659	504,770	722,625	1,030,822	1,399,588	1,808,308	2,342,549
GDP per capita	2,451	3,135	4,239	5,757	7,506	9,394	11,837
Conversion factor (BDT/USD)	13.5						

Source: JICA Survey Team

Table 5-14 GDP Projection (PPP, current price)

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	364,141	558,287	978,583	1,682,660	2,710,837	4,090,581	6,250,966
GDP per capita	2,402	3,468	5,741	9,397	14,538	21,250	31,587
Conversion factor (BDT/USD)	21.9	27.1	28.9	30.6	32.2	33.5	34.8

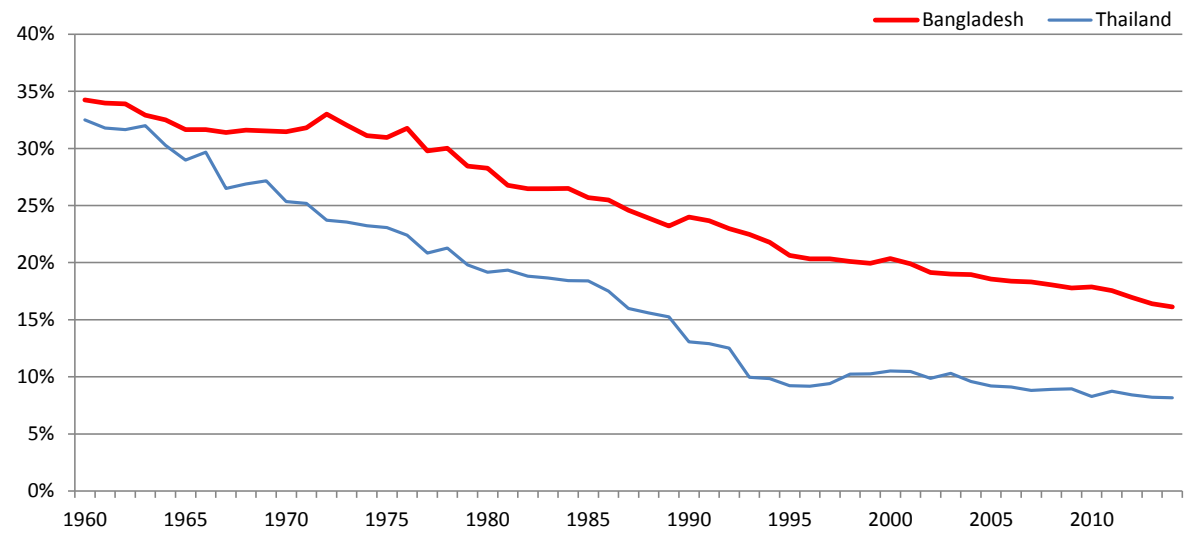
Source: JICA Survey Team

5.7.4 Sectorial breakdown of GDP

This study then estimated the share of GDP broken down by sectorial value added, such as agriculture, industrial and commercial & public services.

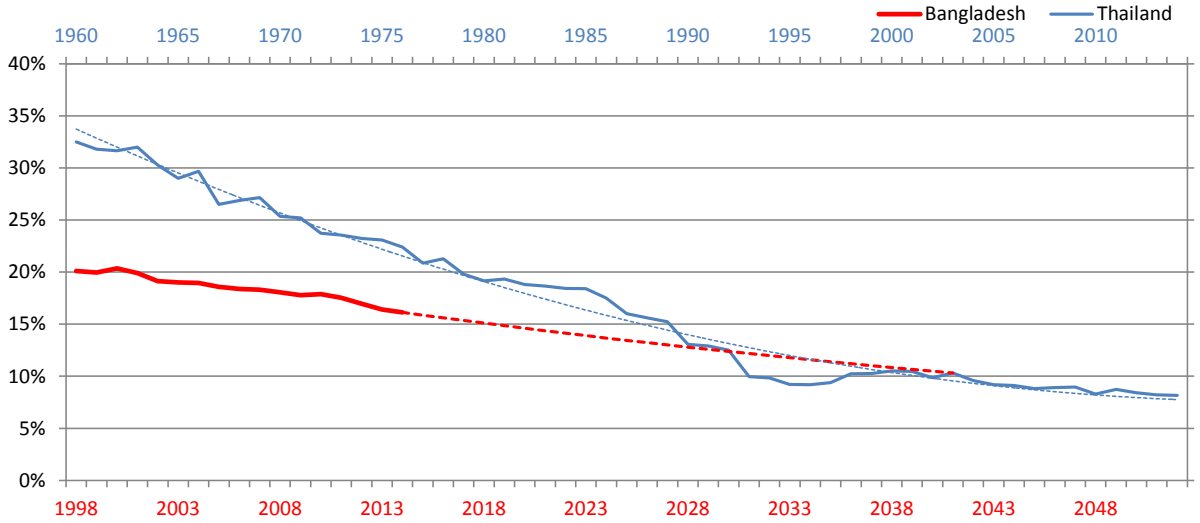
(1) Agriculture

Figure 5-26 compares the historical trend of agricultural sector's share in total GDP between Bangladesh and Thailand. Both in Bangladesh and Thailand, the share of agricultural sector's value added has been declining constantly.
Thailand saw a rapider decrease of agricultural share in the national economy until mid-1990s, but since then it has been keeping a relatively constant share around 8-10%. The trend that agricultural sector still retains certain share in Thailand's total GDP supports the argument that agriculture has been modernized to shift from self-sufficiency to more value-added products and gained competitiveness for export.
Bangladesh has been following the trend of Thailand, though the pace of decline is slower. Hence this study expects that the share of agriculture in GDP will continue to decline but will retain about 10% even as of 2041, as shown in Figure 5-27.



Source: World Bank database

Figure 5-26 Share of Agriculture in GDP: Bangladesh (red) and Thailand (blue)

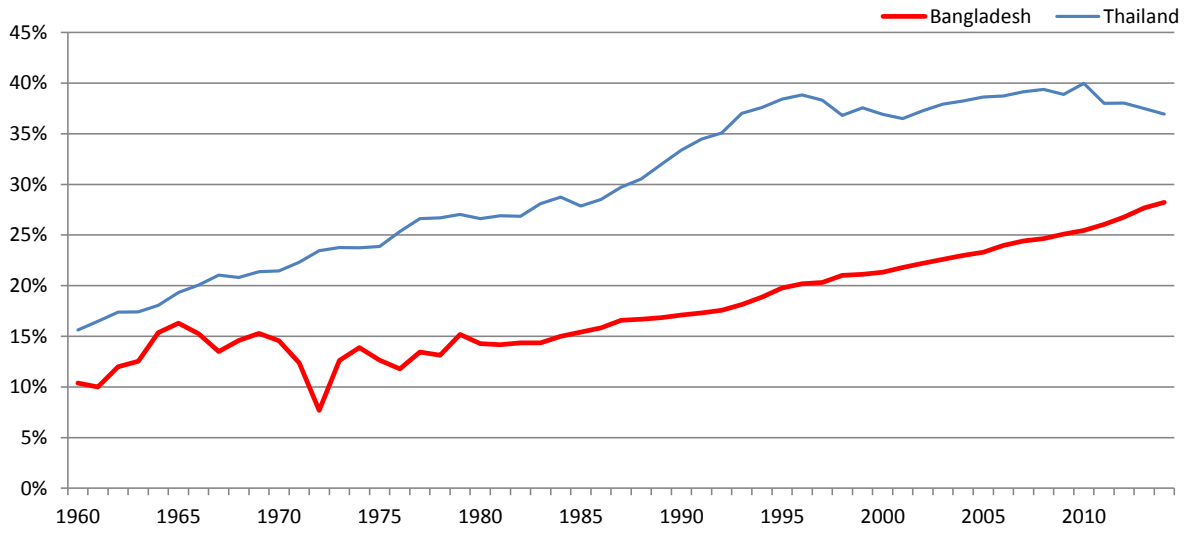


Source: JICA Survey Team

Figure 5-27 Share of Agriculture in GDP: Bangladesh (red) and Thailand (blue)

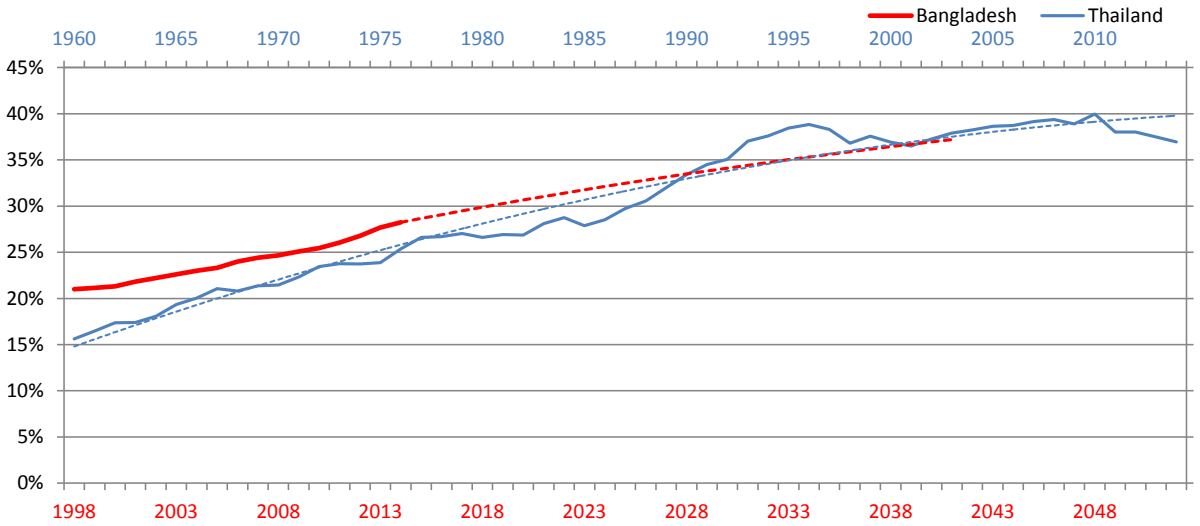
(2) Industry

Figure 5-28 compares the historical trend of industrial sector's share in total GDP between Bangladesh and Thailand. In Bangladesh, the share of industrial sector's value added started increasing from early-1980. Since then the country has been on a track of industrialization.
In Thailand, the share of industrial sector in GDP also saw a continuous increase until mid-1990, and since then it has been relatively constant between 35% and 40%. This is considered that the country's industrialization came to a certain level of maturity.
This study assumes that Bangladesh follows the past trend of Thailand and that the industrial sector's share in GDP is expected to increase up to 37% in 2041 as shown in Figure 5-29.



Source: World Bank database

Figure 5-28 Share of Industrial Sector in GDP: Bangladesh (red) and Thailand (blue)

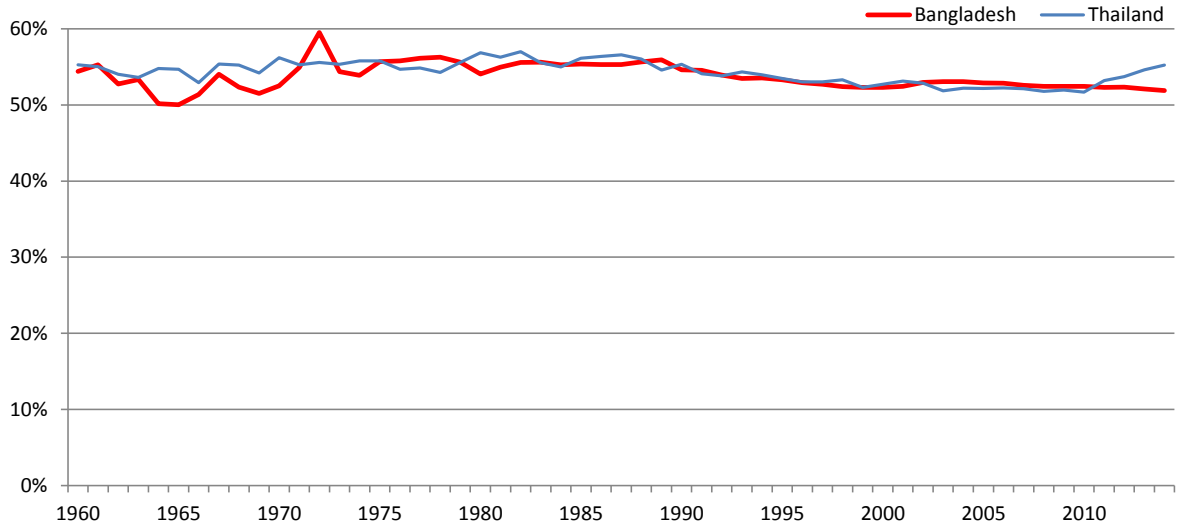


Source: JICA Survey Team

Figure 5-29 Share of Industrial Sector in GDP: Bangladesh (red) and Thailand (blue)

(3) Commercial & public services

Figure 5-30 compares the historical trend of commercial & public services' share in total GDP between Bangladesh and Thailand. Both countries saw a relatively stable share between 50% and 60% and a slightly declining trend has been observed in Bangladesh. This study assumes that this trend is expected to continue.

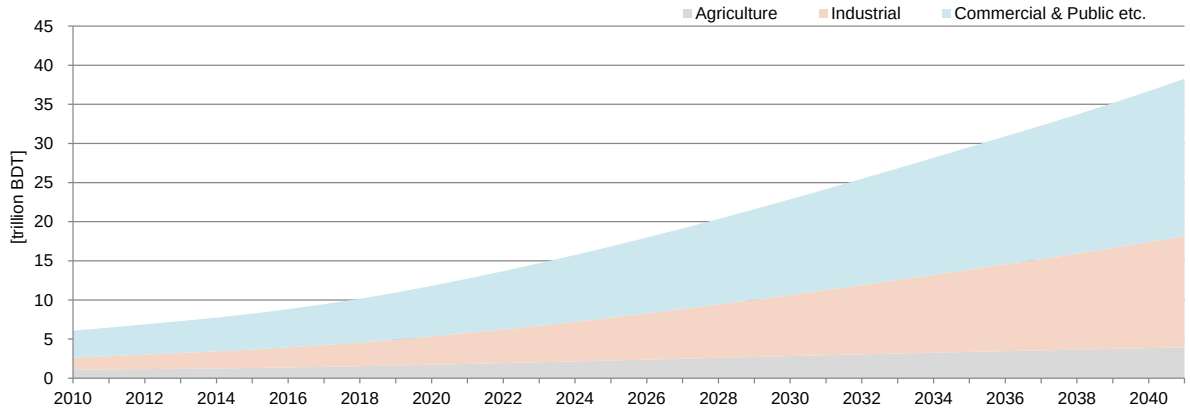


Source: World Bank database

Figure 5-30 Share of Commercial & Public Services in GDP: Bangladesh (red) and Thailand (blue)

(4) Summary

Figure 5-31 shows the study team's projection of sectorial breakdown of GDP (constant at 2005 price) up to 2041. As of 2041, agriculture, industry, and commercial & public services are expected to grow to 3.9 trillion BDT, 14.2 trillion BDT, and 20.1 trillion BDT, respectively.



Source: JICA Survey Team

Figure 5-31 Sectorial Breakdown of GDP Projection (Real GDP, constant at 2005 price)

5.7.5 Projection of "High-growth Scenario" and "Low-growth Scenario"

Besides the projection of GDP growth in section 5.7.3 as the "Base Scenario", this strudy also projected a "High-growth Scenario" and "Low-growth Scenario".
This study assumed that, in all of these scenarios, Bangladesh economy will continue growing in accordance with the economic scenario discussed in section, but this study considered that the trend of long-term economic development may vary depending on the strength of economic reform policies etc. To be specific, all these scenarios assumed that the GDP growth target up to 2020 that is stipulated in the Seventh Five-Year Plan will be achieved, but after 2020s when the growth rate becomes gradually moderate in the course of maturity of economic development, the pace of declining growth rate is relatively slow in the "High-growth Scenario" whereas in the "Low-growth Scenario" the pace of declining growth rate is relatively rapid.
As a result, whereas the "Base Scenario" assumed that the average growth rate of GDP (real price) from 2036 to 2041 becomes 4.4% p.a., the "High-growth scenario" assumed 5.0% p.a. and the "Low-growth Scnerio" assumed 4.0% p.a. GDP projection in the "High-growth Scenrio" are shown in (real price) and (nominal price), and that in the "Low-growth Scenario" are shown in (real price) and (nominal price) respectively.

Table 5-15 Real GDP Projection (constant at 2005 price) – High-growth Scenario

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	93,236	126,630	181,282	259,889	357,613	472,273	633,087
GDP (billion BDT)	6,071	8,245	11,804	16,922	23,286	30,751	41,223
Growth rate (p.a.)	6.1%	6.3%	7.4%	7.5%	6.6%	5.7%	5.0%

Source: JICA Survey Team
Note: Growth rate is five-year average except in the column of year 2041 that is six-year average.

Table 5-16 Nominal GDP Projection (current price) – High-growth Scenario

		2010	2015	2020	2025	2030	2035	2041
GDP (million USD)		115,279	194,300	340,576	588,540	960,930	1,482,112	2,343,672
GDP (billion BDT)		7,975	15,136	28,320	51,817	88,853	142,764	234,568
Growth rate (p.a.)	USD	10.7%	11.0%	11.9%	11.6%	10.3%	9.1%	7.9%
	BDT	13.3%	13.7%	13.3%	12.8%	11.4%	9.9%	8.6%

Source: JICA Survey Team
Note: GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

Table 5-17 Real GDP Projection (constant at 2005 price) – Low-growth Scenario

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	93,236	126,630	181,282	257,740	346,830	441,597	559,104
GDP (billion BDT)	6,071	8,245	11,804	16,782	22,583	28,754	36,405
Growth rate (p.a.)	6.1%	6.3%	7.4%	7.3%	6.1%	4.9%	4.0%

Source: JICA Survey Team
Note: Growth rate is five-year average except in the column of year 2041 that is six-year average.

Table 5-18 Nominal GDP Projection (current price) – Low-growth Scenario

		2010	2015	2020	2025	2030	2035	2041
GDP (million USD)		115,279	194,300	340,576	583,671	931,953	1,385,843	2,069,790
GDP (billion BDT)		7,975	15,136	28,320	51,388	86,174	133,491	207,156
Growth rate (p.a.)	USD	10.7%	11.0%	11.9%	11.4%	9.8%	8.3%	6.9%
	BDT	13.3%	13.7%	13.3%	12.7%	10.9%	9.1%	7.6%

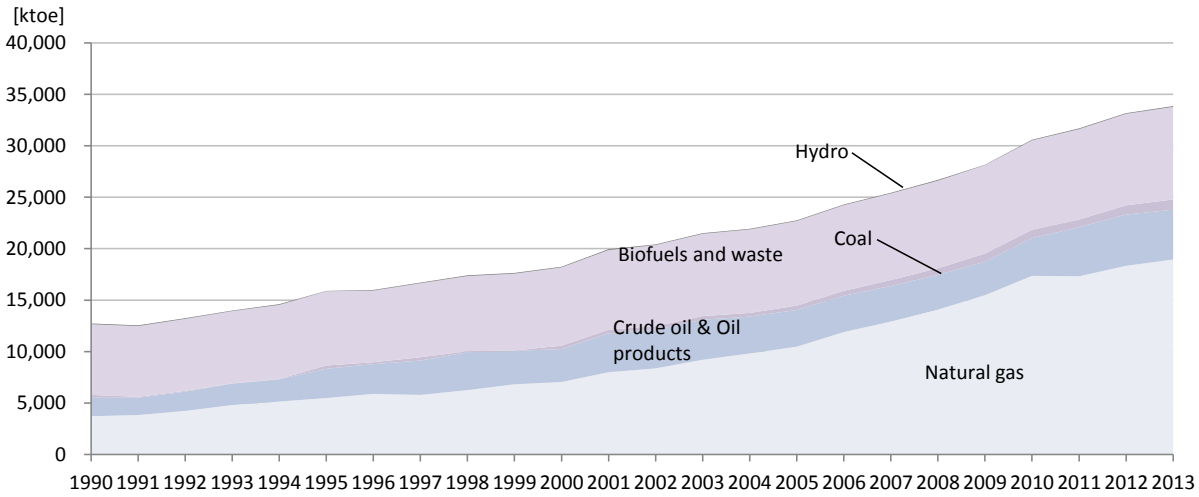
Source: JICA Survey Team
Note: GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

Chapter 6 Prospects of Energy Supply and Demand

6.1 Overview of Energy Supply and Demand Balances of Bangladesh

6.1.1 Historical trend of primary energy supply

A main issue regarding the energy supply and demand in Bangladesh is that, whereas the energy demand has been growing and is expected to continue growing rapidly, domestic production of natural gas that accounts for more than half of the country's energy demand is coming to saturation hence the country will be faced with the necessity of structural changes of energy supply and demand.
Figure 6-1 illustrates the trend of primary energy supply in Bangladesh. The ratio of natural gas in the total supply of primary energy increased from 29% in 1990 to 57% in 2010, which means that the increase of energy demand during that period was mainly met by the increase of natural gas supply. However, from 2011 the domestic production of natural gas did not increase much and the gap from the increasing demand was mainly covered by crude oil & oil products.

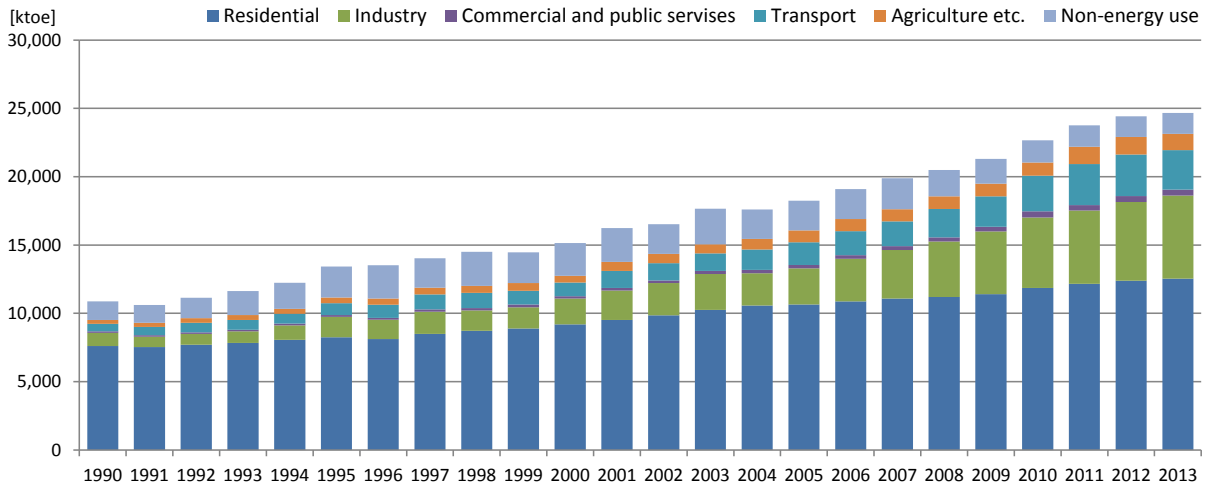


Source: IEA statistics

Figure 6-1 Historical Trend of Total Primary Energy Supply in Bangladesh (1990-2013)

6.1.2 Historical trend of final energy consumption and sectorial breakdown

Figure 6-2 shows the historical trend of final energy consumption and its sectorial breakdown. The total final energy consumption increased by 2.2 times (3.6% p.a.) from 1990 to 2013. The growth became moderate from 2012 to 2013, but this is considered a temporary effect caused by natural disaster like cyclone and so on, and the increasing trend is expected to continue.
Looking at the sectorial breakdown of the final energy consumption, the residential sector has been taken more than half and is still growing gradually. However, the increase of this sector during the same period was 1.6 times (2.1% p.a.), which is lower than that of the total and its share has been decreasing. In the meanwhile, the industrial sector, the commercial & public services sector, and the transport sector increased by 6.3 times (8.3% p.a.), 3.8 times (6.0% p.a.), and 5.3 times (7.5% p.a.) respectively during the same period, and they all outperformed the total energy consumption. Above all, the industrial sector and the transport sector saw a high growth in the past.



Source: IEA statistics

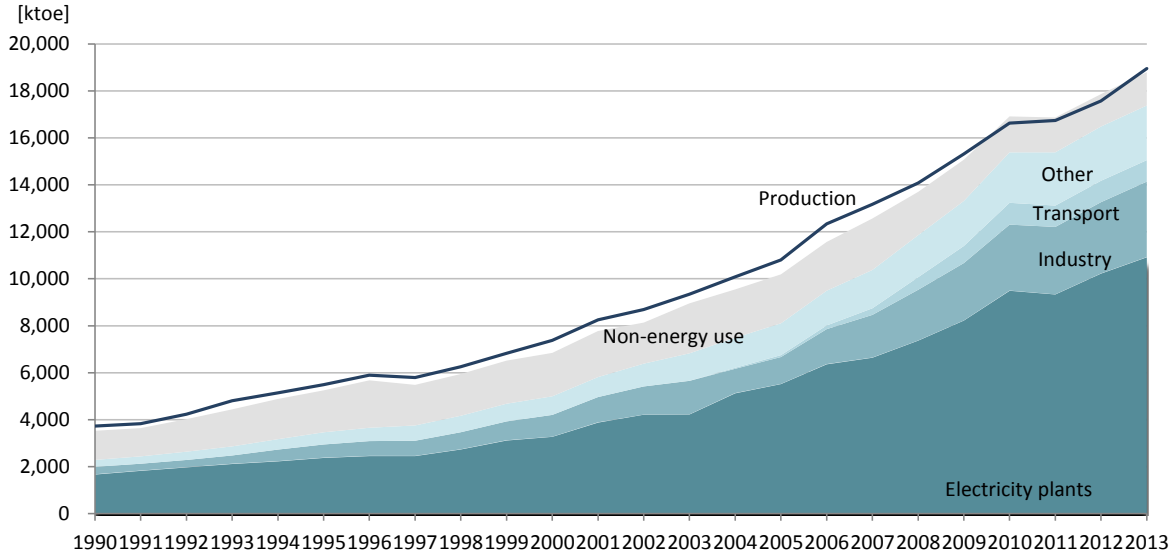
Figure 6-2 Historical Trend of Total Final Energy Consumption in Bangladesh (1990-2013)

6.1.3 Historical trend of supply and demand for each fuel type

The historical trend of energy supply and demand in Bangladesh is analyzed for each type of fossil fuel such as natural gas, coal and oil (crude oil and oil products).

Figure 6-3 shows the historical trend of domestic production of natural gas and the consumption broken down by main sectors. The line chart in the figure indicates the domestic production of each year. In the stacked area chart, "Electricity Plants" indicates the volume of fuel input for power generation. From here the thermal loss from thermal power generation, in-house consumption of power plants, and transmission and distribution losses are deducted before being delivered to final consumption. The electrical energy used for final consumption is less than half of the energy input.

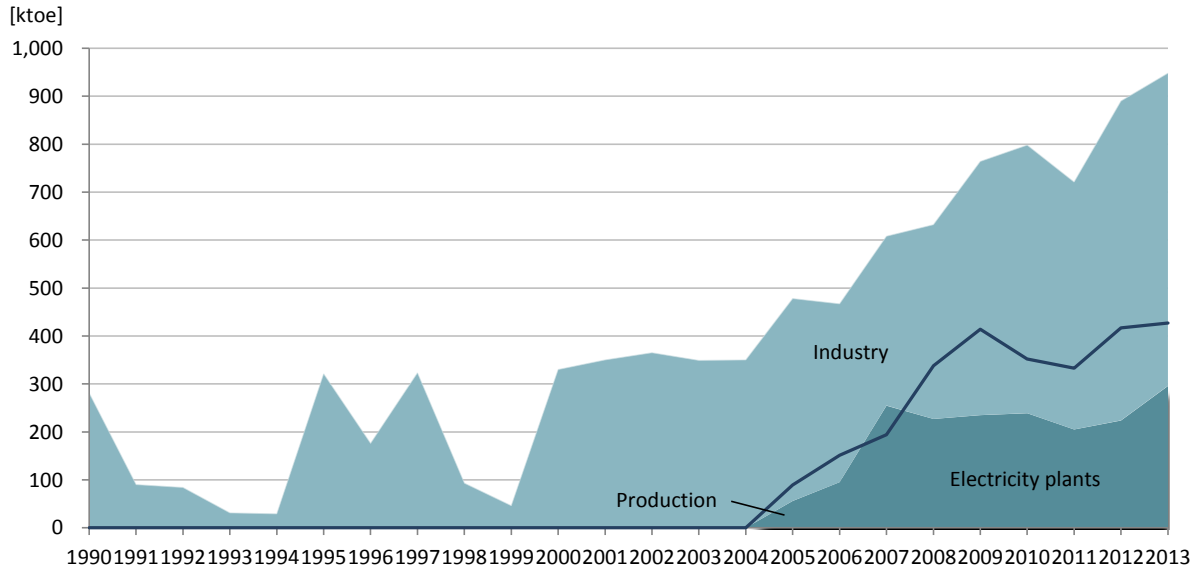
In Bangladesh, the demand of natural gas is almost 100% supplied from domestic production, and this is why the amount of production and consumption has been almost balanced. The share of power generation has been constantly about 50% of total consumption of natural gas in recent years. In the meanwhile, the share of industrial and transport sectors has been increasing, whereas the share of non-energy use (such as raw material of chemical fertilizer) has been decreasing.



Source: IEA statistics

Figure 6-3 Historical Trend of Natural Gas Supply and Demand (1990-2013)

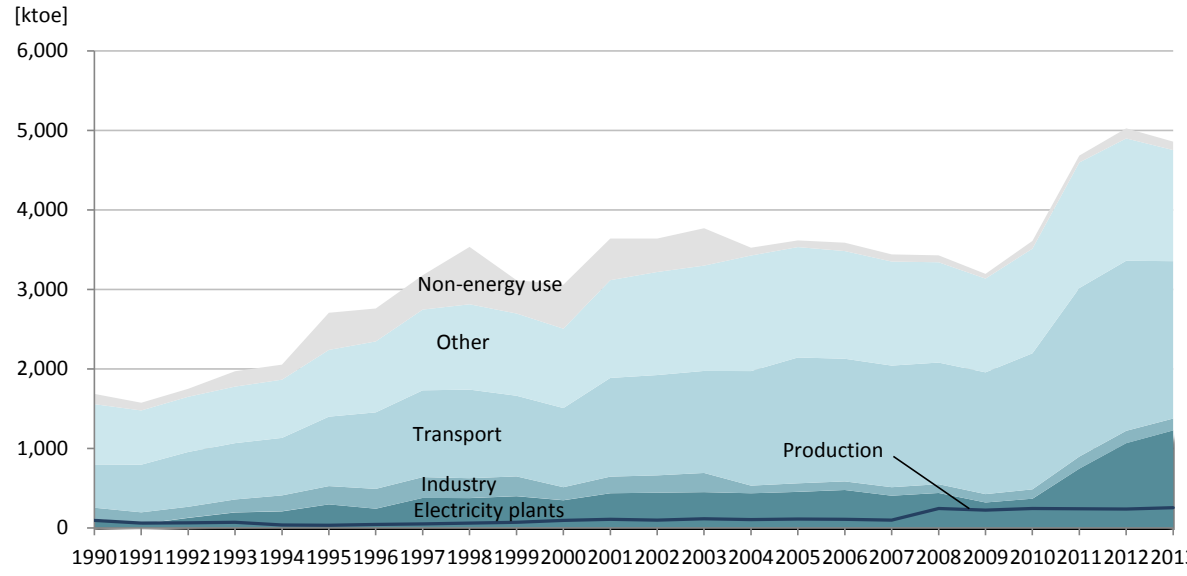
In the same way, Figure 6-4 shows the domestic production of coal and the consumption broken down by main sectors. In the statics, domestic production of coal in Bangladesh first appears in 2005, and since then the trend of consumption for power generation has been taking a similar trend as that of production. This means that the use of imported coal and domestic coal has been roughly segregated, i.e. imported coal for industrial use and domestic coal for power generation.
In the future, as the domestic production of natural gas is coming to saturation, the consumption of coal including import is expected to increase not only in volume but also in types of use. Expanding the utilization of imported coal as the energy source for power generation, as represented by "Matarbari Ultra Super Critical Coal-Fired Power Project" sponsored by JICA, is supposed to gain importance.



Source: IEA statistics

Figure 6-4 Historical Trend of Coal Supply and Demand (1990-2013)

Figure 6-5 shows the historical trend of domestic production of petroleum (crude oil and oil products) and the consumption broken down by main sectors. In Bangladesh, domestic production of petroleum is far less than that of natural gas, and the country's demand mostly depends on imports. This graph shows that the consumption of petroleum for power generation has been increasing rapidly since 2011, but that the amount of domestic production has not increased during that period, which implies that the dependence of power generation on imported petroleum has been progressed.
However, because procuring imported oil for power generation is costly not only compared to domestic production of natural gas but also compared to procuring coal (both domestic production and import) in general, it is recommended that the increased dependence of power generation on imported oil should be confined to a temporary expedient so that the insufficiency of natural gas for power generation should be covered by other primary energy sources such as coal.

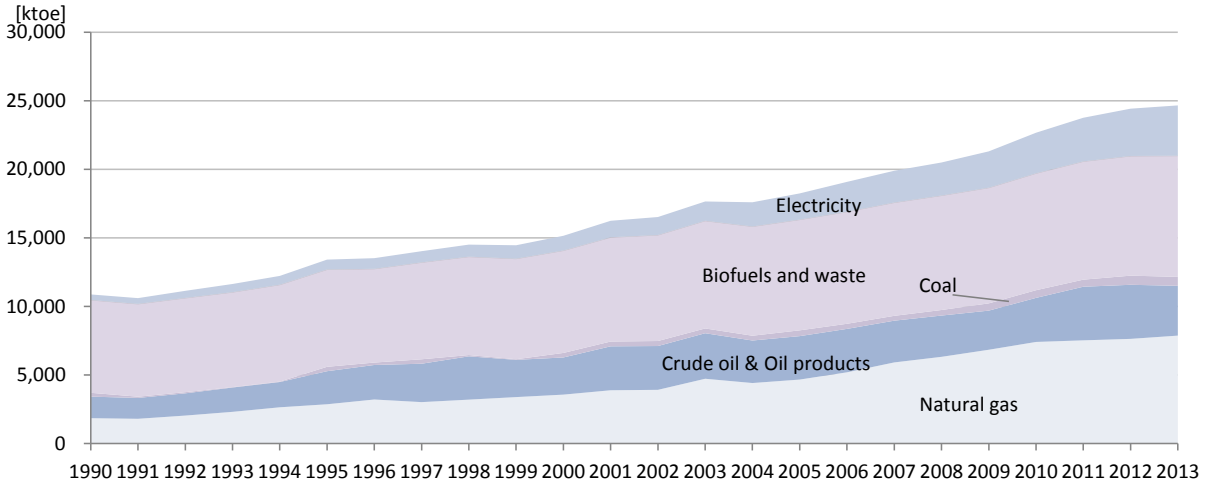


Source: IEA statistics

Figure 6-5 Historical Trend of Oil (Crude Oil & Oil Products) Supply and Demand (1990-2013)

6.1.4 Historical trend of final energy consumption for each sector

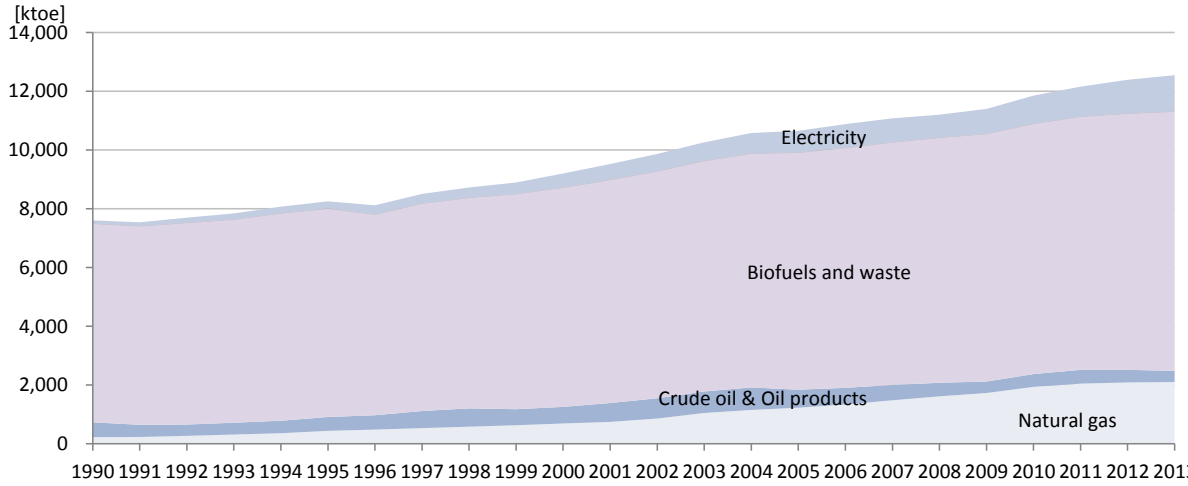
The historical trend of final energy consumption for each sector and its breakdown by the modes of energy supply are analyzed. First, Figure 6-6 illustrates the trend of total final energy consumption in Bangladesh broken down by the modes of supply.
"Biofuels and waste", which is consumed almost exclusively by the residential sector accounts for the largest share, but its share has been gradually declining due to the modernization of energy supply to the residential sector (shift to electricity and gas). The increase of oil consumption has become moderate since 2000s, which is mainly due to the electricification of residential sector and the shift of transport sector energy demand from oil to CNG. On the other hand, the share of electricity and natural gas in total energy demand has been increasing and especially the share of electricity, though it still accounts for only about 15% of total final energy consumption, has seen a rapid increase.



Source: IEA statistics

Figure 6-6 Total Final Energy Consumption Broken Down by Modes of Supply (1990-2013)

Then the breakdown of the final energy consumption by the modes of energy supply is analyzed for each sector. The breakdown of residential sector energy consumption by modes is shown in Figure 6-7. "Biofuels and waste" takes an overwhelmingly large share, and this is due to the fact that considerable number of unelectrified villages and households still exist mainly in rural area. Driven by the progress of household electrification, the share of electricity has been increasing, but the limited share of electricity and natural gas in the total energy consumption implies that even the electrified households more or less rely on conventional energy sources such as firewood.

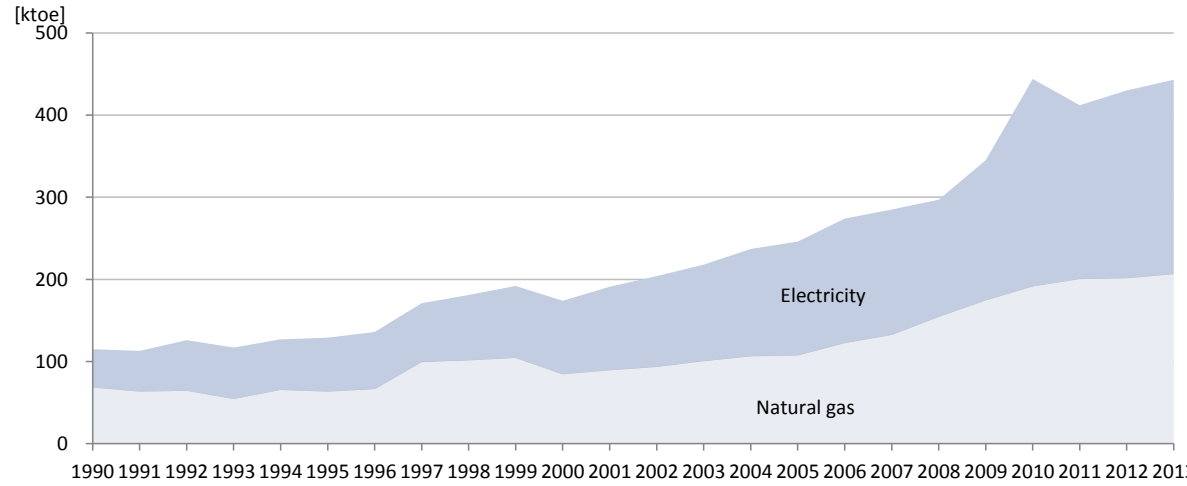


Source: IEA statistics

Figure 6-7 Historical Trend of Residential Sector Energy Consumption (1990-2013)

Figure 6-8 shows the breakdown of final energy consumption of commercial and public services sector by the modes of energy supply. According to the statistics, the share of this sector in total final energy consumption is small, i.e. less than one-twentieth of that of the residential sector and less than one-tenth of that of the industrial sector. The main reason is supposed to be that large commercial facilities and office buildings are still underdeveloped in Bangladesh but there is also a possibility that the statistical categorization of energy consumption is not accurate thus it may not reflect the actual status of energy consumption.

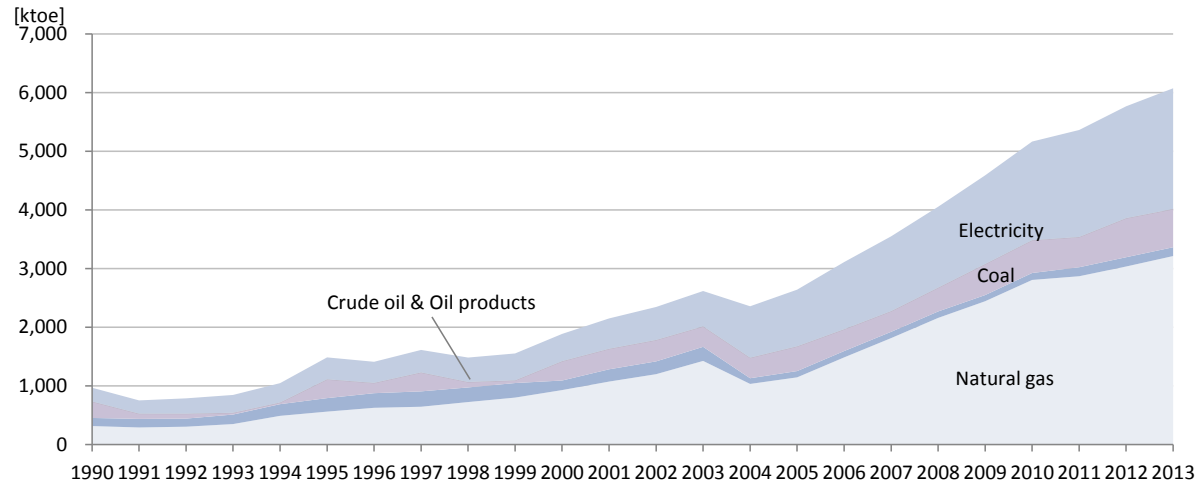
The share of electricity and gas in this sector has been nearly 50:50 since 2000, but recently the increase of electricity supply outstrips that of gas supply.



Source: IEA statistics

Figure 6-8 Historical Trend of Commercial/Public Services Sector Energy Consumption (1990-2013)

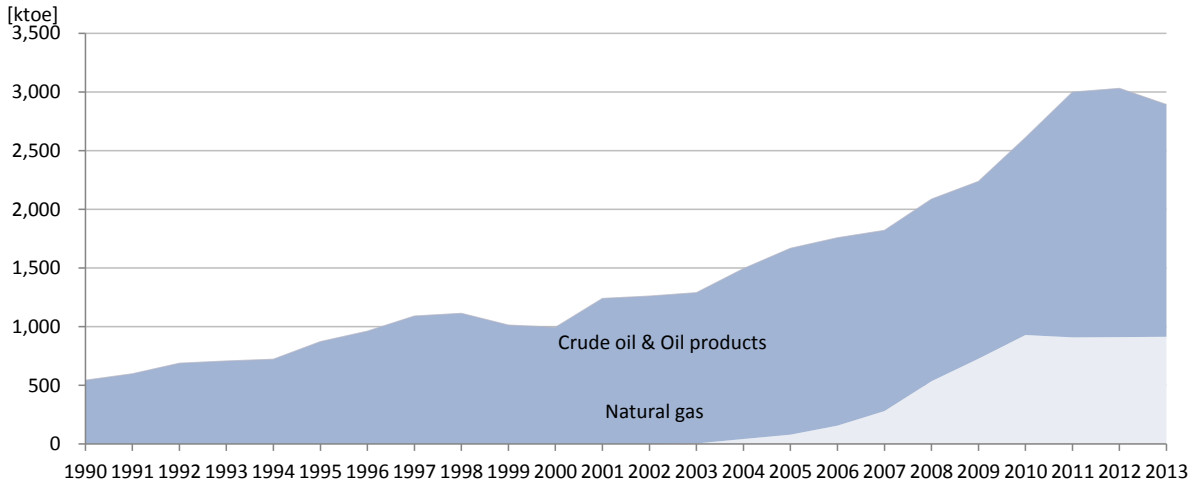
Figure 6-9 shows the breakdown of final energy consumption of commercial and public services sector by the modes of energy supply. The gas consumption takes up more than half of the energy consumption but recently electricity supply also sees a rapid increase.



Source: IEA statistics

Figure 6-9 Historical Trend of Industrial Sector Energy Consumption (1990-2013)

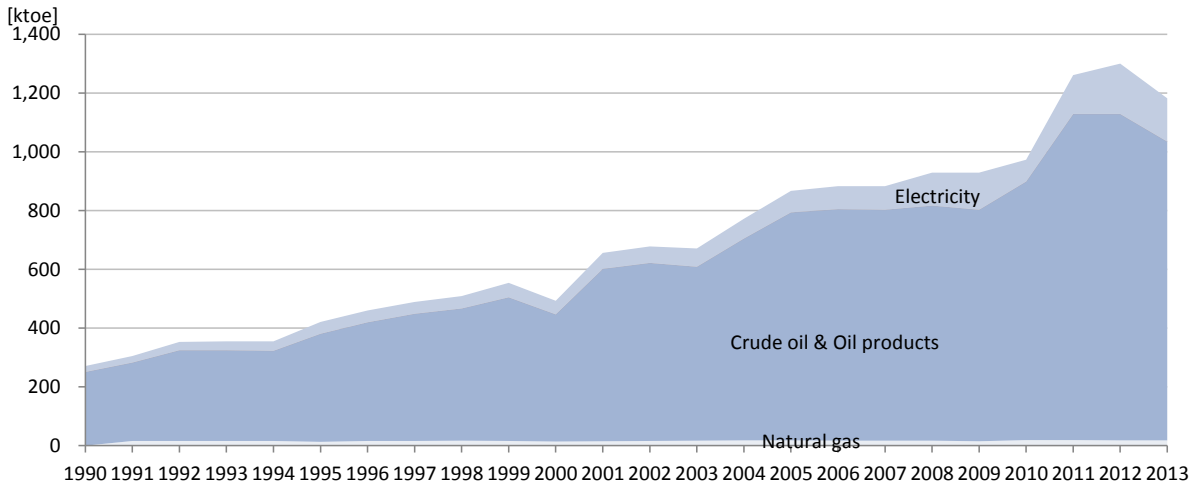
Figure 6-10 shows the breakdown of final energy consumption of transport sector by the modes of energy supply. It is observed that, reflecting the policy of Bangladesh government to promote the diffusion of CNG vehicles, the increase of energy demand of this sector is mainly covered by natural gas. However another trend can also be seen from 2011 when the increase of natural gas consumption became moderate and instead the consumption of oil products increased.



Source: IEA statistics

Figure 6-10 Historical Trend of Transport Sector Energy Consumption (1990-2013)

Figure 6-11 shows the breakdown of final energy consumption of other sectors such as agriculture by the modes of energy supply. Oil products account for an overwhelmingly large share. The share of electricity in the total final energy consumption is still only about 10% of the total final energy consumption but this share is gradually gaining.



Source: IEA statistics

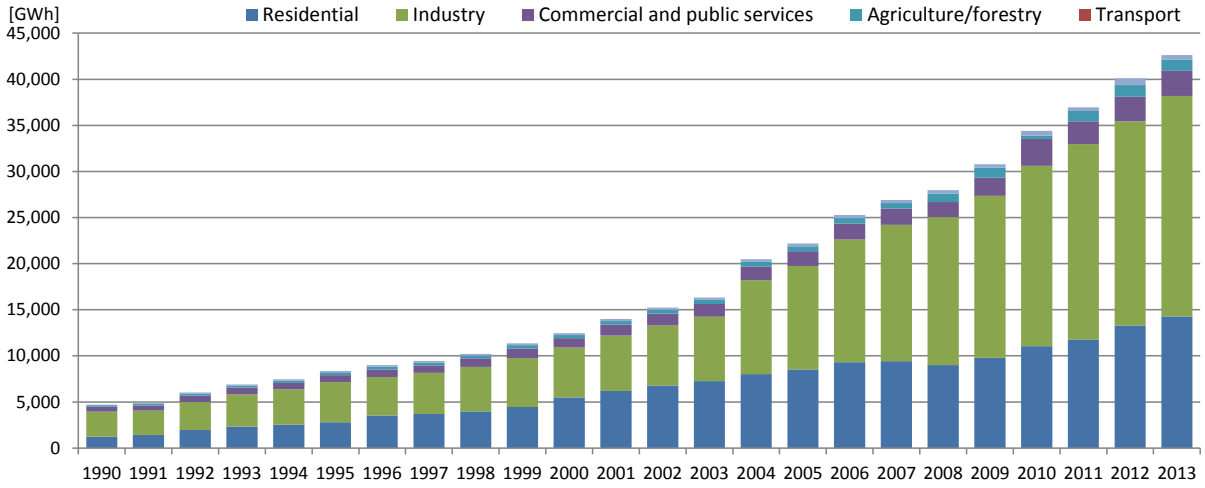
Figure 6-11 Historical Trend of Other Sectors (e.g. Agriculture) Energy Consumption (1990-2013)

6.1.5 Historical trend of electricity consumption and sectorial breakdown

The historical trend of electricity consumption in Bangladesh broken down by sectors, which is available from IEA statistics, is shown in Figure 6-12. From 1990 to 2013, the total electricity consumption increased by 9.1 times (10.1% p.a.), which is far higher than that of the total final energy consumption (see Figure 6-2: 2.2 times, 3.6% p.a.)

Looking at each sector, the industrial sector, which accounts for more than half of the total, increased by 8.8 times (9.9% p.a.) during that period, and the residential sector by 11.7 times (11.3% p.a.). These two sectors' growth rate is much higher than these sectors' growth rate in total final energy consumption, which means that the electrification of energy consumption i.e. shift to electricity supply from other modes of energy supply, is in progress.

On the other hand, the electricity consumption of commercial/public services sector increased by 5.1% (7.3% p.a.) during that period, which is lower than that of other sectors. In addition to that, the gap between the growth rate of this sector's electricity consumption and that of the sector's total energy consumption (3.8 times, 6.0% p.a.) is relatively small compared to other sectors, which means that this sector's shift to electricity supply is relatively dull. This is probably because most of the energy supply to the commercial/public services sector was established from scratch in the form of modern energy supply system consisting of electricity and gas.



Source: IEA statistics

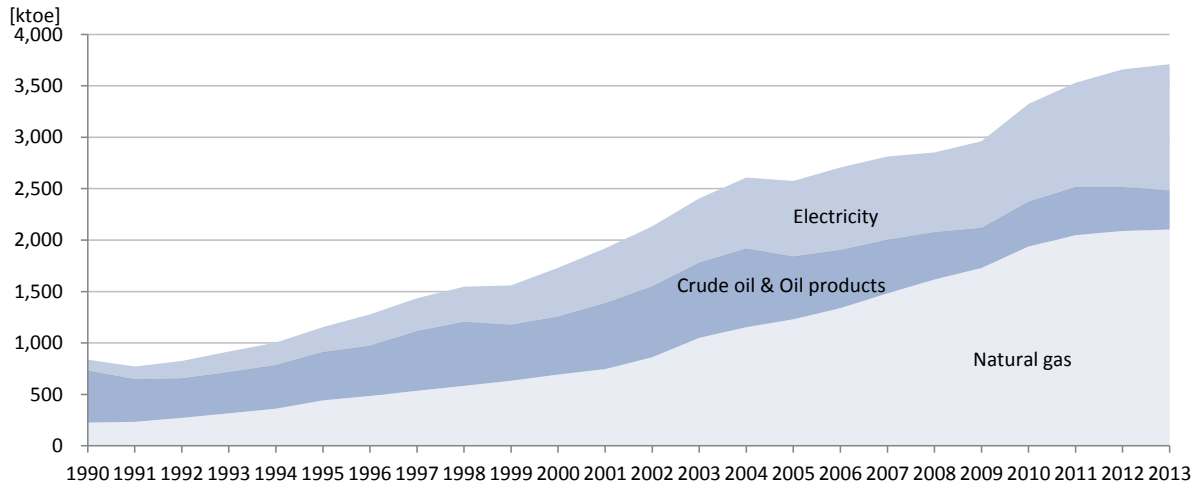
Figure 6-12 Historical Trend of Electricity Consumption in Bangladesh (1990-2013)

6.2 Civilian Sector (Residential and Commercial/Public Services)

6.2.1 Current status of energy demand

(1) Residential Sector

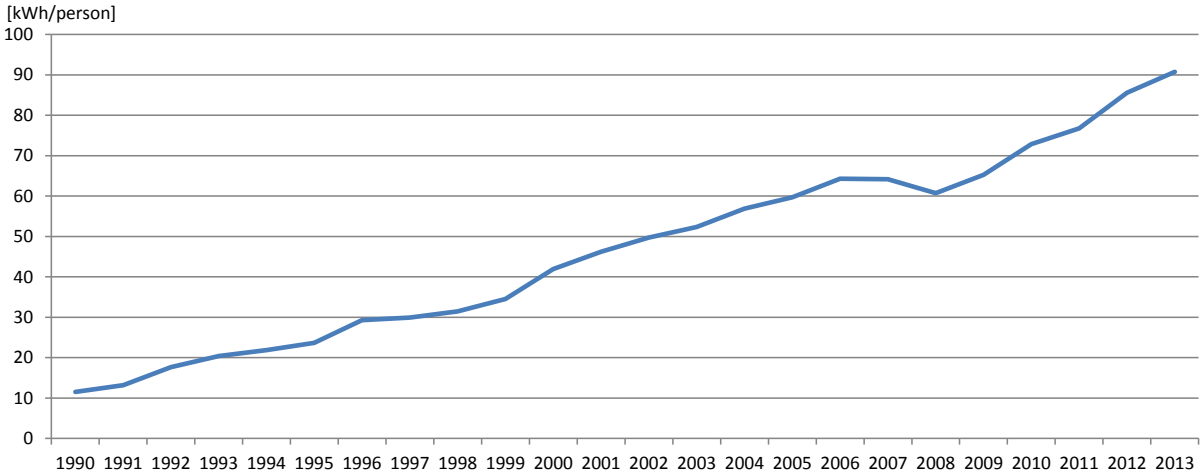
As observed in Figure 6-7, "Biofuels and waste", which is supposed to be mainly non-commercial energy source, accounts for a large share in the energy consumption of the residential sector. The historical trend of other modes of energy supply to end-consumption, i.e. electricity, gas, and oil products is shown in Figure 6-13. Among these three sources, oil products (e.g. kerosene) accounted for more than half as of early 1990s but as the supply of electricity and gas is getting diffused, consumption of these energy sources increased rapidly whereas the consumption of oil products started to decline. From 2011 to 2012 the growth of natural gas consumption became moderate and electricity consumption increased considerably.



Source: IEA statistics

Figure 6-13 Trend of Residential Sector Energy Consumption (excluding Biofuels and waste)

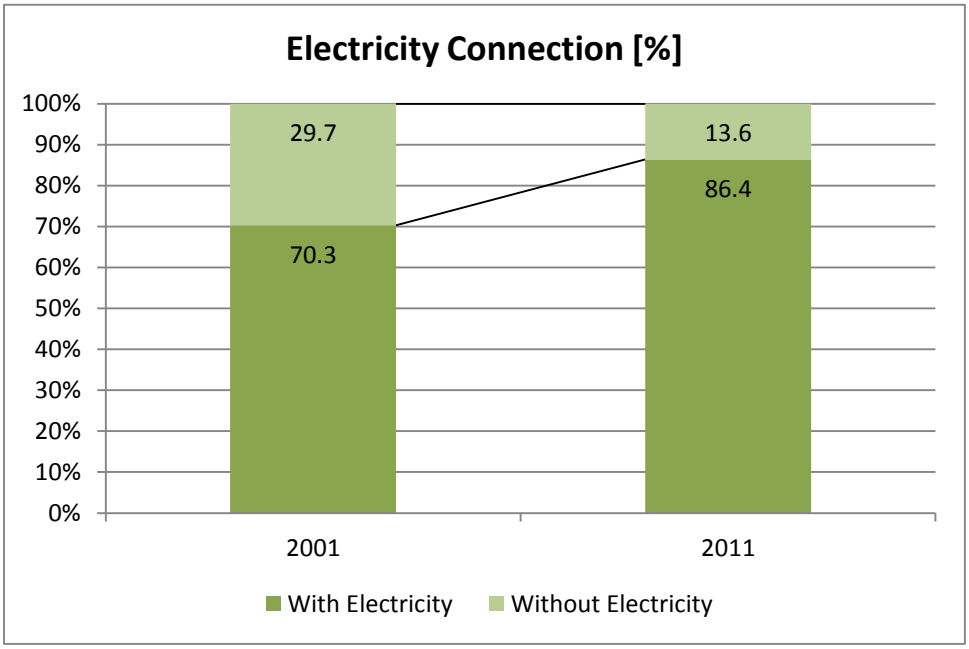
Figure 6-14 shows the historical trend of electricity consumption of residential sector divided by population. The electricity consumption per capital increase by about eight times in twenty-three years from 11.5 kWh/person in 1990 to 90.8 kWh/person in 2013, though this number decreased from 2012 to 2013. This implies not only the progress of electrifying the unelectrified villages and households but also the increase of energy consumption of the already electrified households as well as the shift of energy consumption from other sources to electricity as the background of this rapid increase.



Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

Figure 6-14 Historical Trend of Residential Sector Electricity Consumption per Capita

One of the statistical data that deals with household electrification is the "Population & Housing Census" conducted by the Bangladesh Bureau of Statistics (BBS). According to this survey, household electrification saw an improvement from 70.3% in 2001 to 86.4% in 2011. However, judging from the objective of this census, the "Electricity connection" appears to include not only the grid-connected electricity supply but also the electrification with stand-alone solar home system (SHS). Therefore this 86.4% household electrification may be overestimated if we define "electrification" to be the status of a household where electricity is accessible without quantitative limitations.



Source: Population & Housing Census-2011, Bangladesh Bureau of Statistics

Figure 6-15 Household Electrification Rate (2001 and 2011)

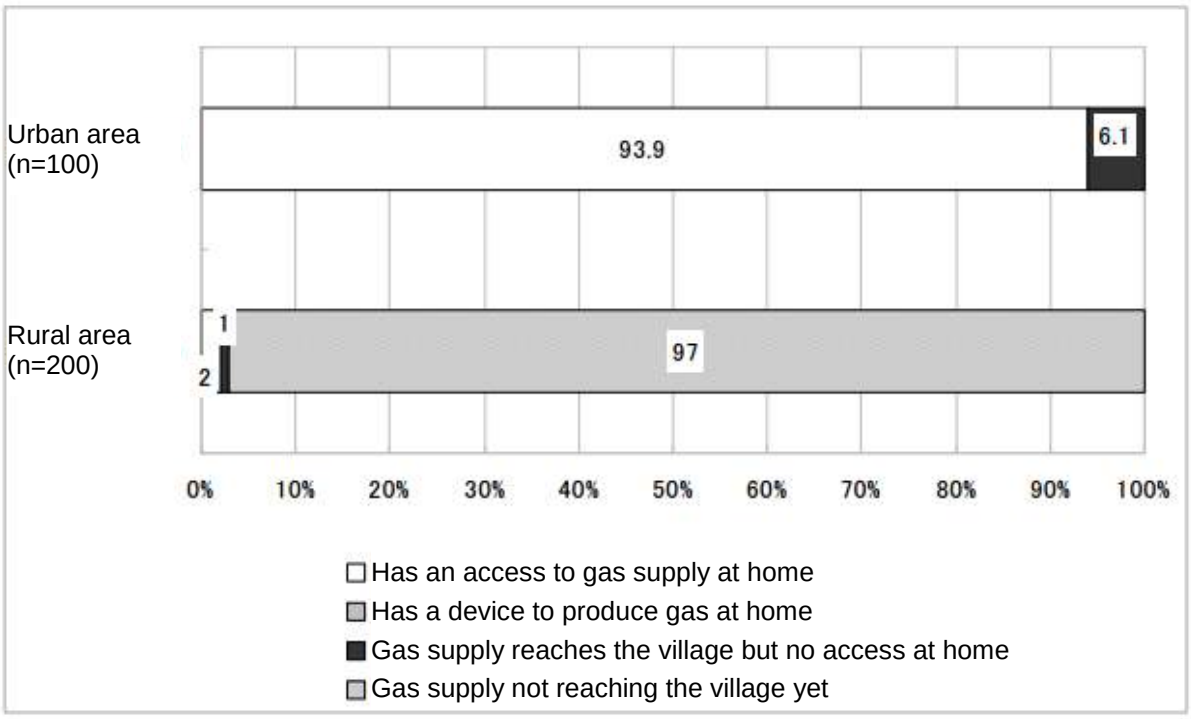
Another statistical survey published by BBS, which is called "Household Income & Expenditure Survey (HIES)", presents that the nation-wide household electrification rate as of 2010 was about 55%. This result significantly deviates from "86% in 2011" as seen in the census data, and there is a possibility that the definition of electrification may be different between them, such as whether to include SHS electrification or not. This survey classifies the status of household electrification not only into administrative divisions but also into rural/urban categorization. Whereas the household electrification in urban area has already reached 90%, the electrification rate in rural area is still only 42%, which implies a huge gap in energy supply infrastructure between urban and rural areas.

Table 6-1 Household Electrification Rate for Each Administrative District

	National	Barisal Div.	Chittagong Div.	Dhaka Div.	Khulna Div.	Rajshahi (Former) Div.	Rajshahi Div.	Rangpur Div.	Sylhet Div.
National	55.26	40.12	60.34	67.34	54.13	41.73	51.88	30.07	47.22
Rural	42.49	31.62	48.84	47.36	45.55	36.17	46.94	24.44	39.09
Urban	90.10	82.33	92.31	96.15	83.83	72.85	75.53	68.68	88.94

Source: Household Income & Expenditure Survey (HIES) 2010, Bangladesh Bureau of Statistics

There is also a survey on the status of household's access to gas supply. According to the study report that summarizes the results of inquiry survey that was conducted on 300 households in Bangladesh between 6th December 2010 and 14th January 2011, 93.9% of households in urban area had an access to gas supply while only 2% of households in rural area had an access, and here again a huge gap in energy supply infrastructure between urban and rural areas can be observed.



Source: JETRO (Japan External Trade Organization) "Study Report on the Potential Needs of BOP Business in Bangladesh: Energy Sector", March 2011

Figure 6-16 Status of Access to Gas Supply in Urban and Rural Areas

According to the results of inquiry survey on the energy consumption in rural area of Bangladesh that was conducted by the World Ban Group in 2004, biomass energy was mainly for cooking and firewood was the most consumed energy source and accounted for 41% of biomass energy for cooking in terms of weight. As for the lighting, grid electricity and kerosene were widely used, and only grid electricity served for cooling.

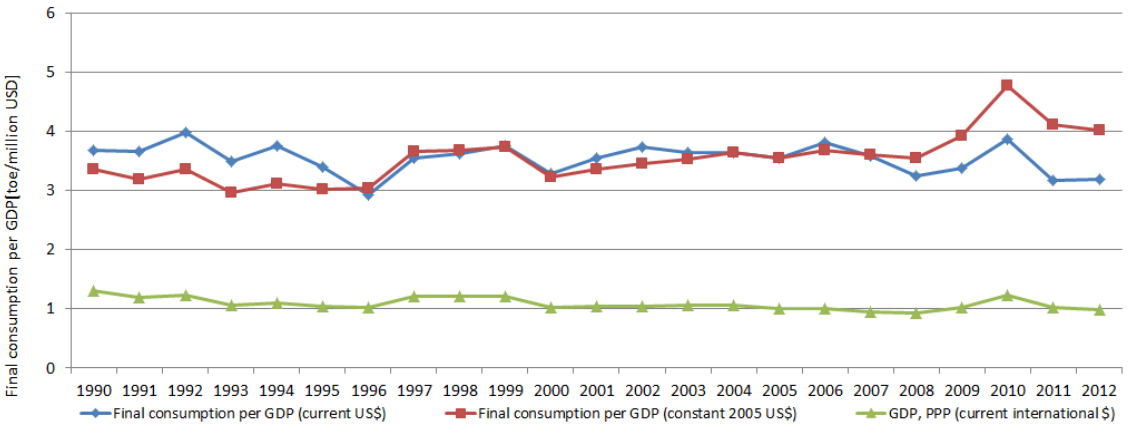
Table 6-2 Annual Energy Consumption per Capita in Rural Area (surveyed in 2004)

Energy Sourcce		Heating			Cooling	Lighting	Amusement	All Uses
		Cooking	Parboiling	Others				
Biomass								
Fuelwood	kg	1064.84	28.60	92.77	-	-	-	1,186.21
Tree leave	kg	470.67	29.99	0.85	-	-	-	501.51
Crop residue	kg	538.86	164.41	2.72	-	-	-	708.18
Dump cake/stick	kg	503.68	16.07	4.16	-	-	-	523.90
Non-Biomass								
Kerosene	liter	1.76	-	0.07	-	27.16	-	28.98
Grid electricity	kWh	0.25	-	4.00	49.50	80.74	9.34	143.83
Dry-cell batter	piece	-	-	-	-	-	-	15.01
Candle	piece	-	-	-	-	15.86	-	15.86
LPG/LNG	liter	0.05	-	-	-	-	-	0.05
Natural gas	Tk	9.59	-	-	-	-	-	9.59
Storrage cell	kWh	-	-	-	-	0.14	0.41	0.55

Source: M. Asaduzzaman et al. (2010) "Restoring Balance; Bangladesh's Rural Energy Realities", World Bank Working Paper No.181.

(2) Commercial/Public Services Sector

The final energy consumption of the commercial/public services sector has also been increasing by 3.8 times (6.0% p.a.) from 1990 to 2013. Looking at the energy consumption per GDP, the ratio against PPP-based GDP sees an almost flat line, implying a possibility of strong correlation.



Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

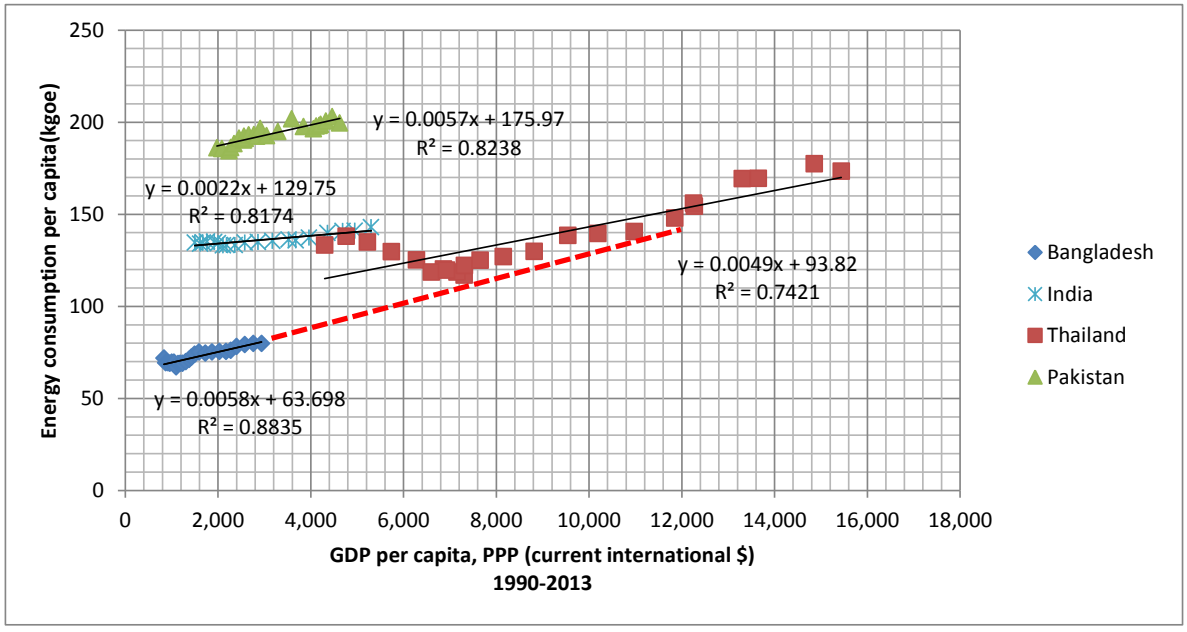
Figure 6-17 Final Energy Consumption per GDP in Commercial Sector

6.2.2 Key factors that affect future prospects of energy demand

There are three key factors that affect future prospect of energy demand in the residential sector. The first factor is population growth. The population is expected to grow steadily, reaching to nearly 200 million people with half of the population residing in the urban area and the other half in the rural area by 2041. Currently there is a significant difference in energy demand between urban and rural households. However such difference will be diminished by 2041, when households in the whole country will enjoy a good standard of living. The second factor is the market penetration rates of electric appliances such as refrigerators, washing machines, ACs and microwave ovens. Presuming that 100% electrification will be achieved by 2021, those appliances will be acceleratedly introduced. At the same time, it is noted that policies will be in place to promote energy efficient home appliances such as ACs, refrigerators, fans and LEDs. The third and last factor is availability of gas supply. It is pointed out that newly built households will have limited access to gas supply, therefore LPG filling the gap of demand and supply.
In the commercial sector, the key factors are growth of the tertiary industry and expansion of office buildings.

6.2.3 Projection of energy consumption

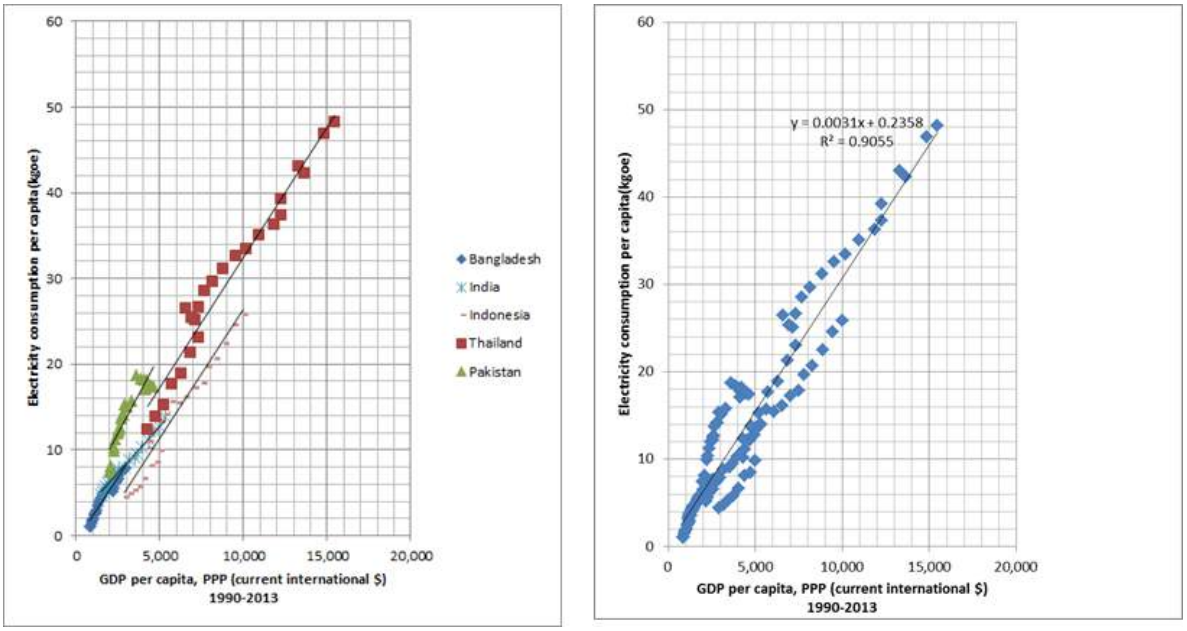
Projection of energy demand in the residential sector is made in the following manner. Firstly, overall energy demand is estimated to grow according to the historical annual growth rate (1990-2013), i.e. 2.2%. As shown in the figure below, there is a rough correlation between energy consumption per capita and GDP per capita. Therefore, energy demand in the Bangladeshi residential sector is expected to grow constantly.



Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

Figure 6-18 Energy Consumption and GDP in Residential Sector

Secondly, demand for electricity is estimated drawing upon other countries' experiences. As shown in the figure below, it is widely discussed that electricity consumption per capita has a strong correlation with GDP per capita. Therefore approximation formula (y = 0.0031x + 0.2358) is applied to GDP growth of Bangladesh to project electricity demand.



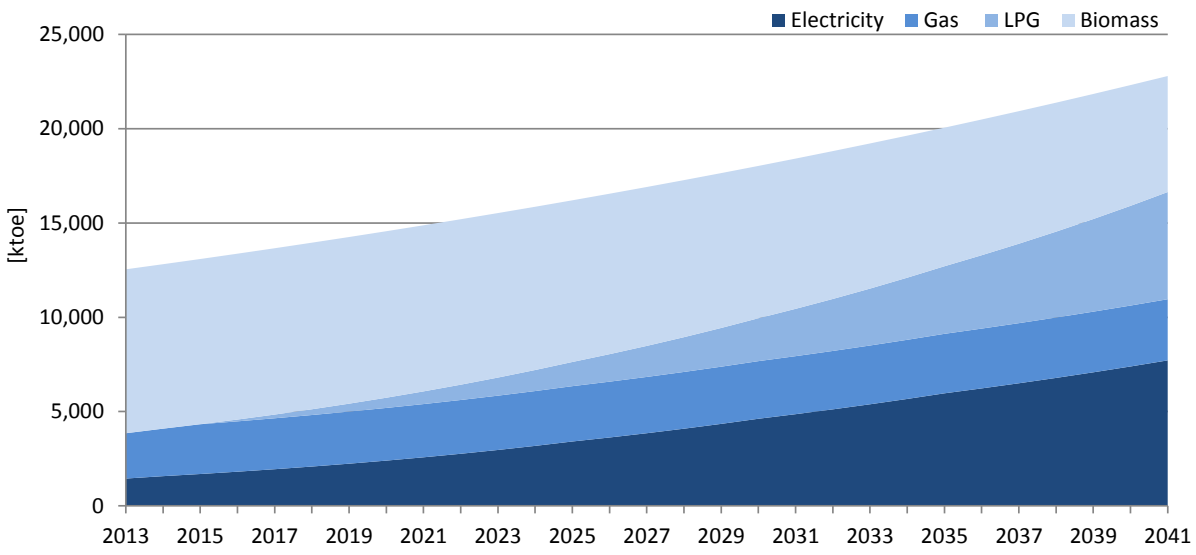
Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

Figure 6-19 Electricity Consumption and GDP in Residential Sector

Thirdly, gas demand is estimated. Unlike case of electricity, other countries' experiences show that there is little correlation between gas consumption and GDP growth. As the existing prospects of gas consumption in Bangladesh, Petrobangla's "Five Year Gas Supply Strategy (2015-2019)" estimates that gas demand in the residential sector will grow at 4.8% annually. However, such growing demand is unlikely to be met due to shortage of gas supply. It is thought to be rational to estimate that gas supply only grows in proportion to population growth, which means that gas consumption per capita remains constant from 2015 on. It is assumed that LPG will fill the gap of gas demand and supply.

Fourthly and lastly, the remaining portion, derived from "Overall energy demand in the residential sector – Electricity – Natural Gas – LPG," is categorized as "others" of which main source is biomass (both solid and gas).

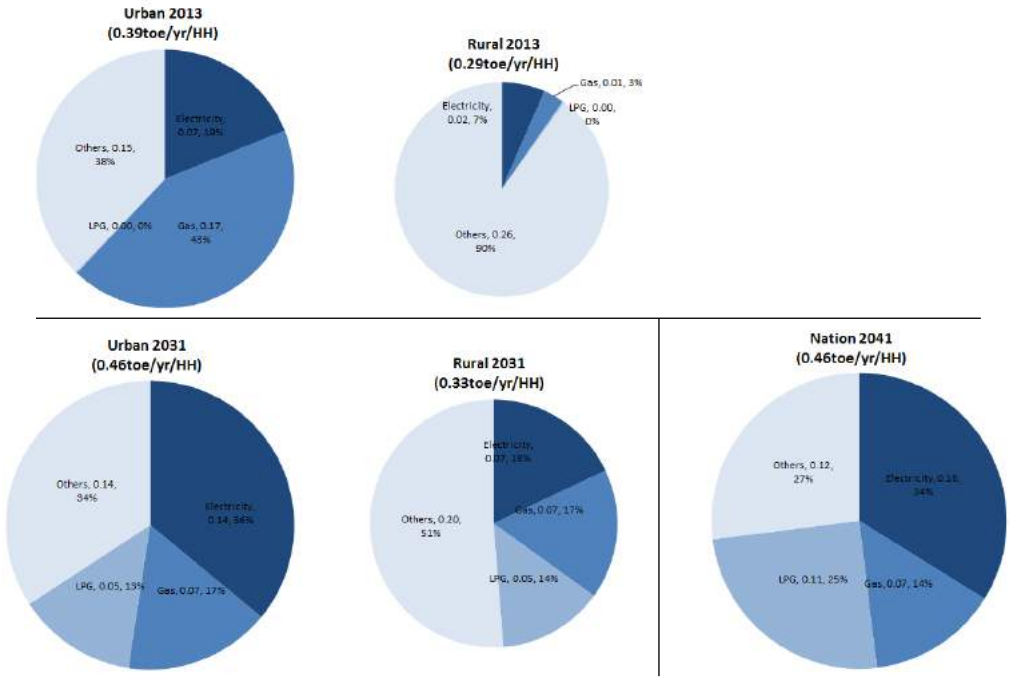
Figure 6-20 shows the projection of energy demand in the residential sector.



Source: JICA Survey Team

Figure 6-20 Energy Demand Projection in Residential Sector

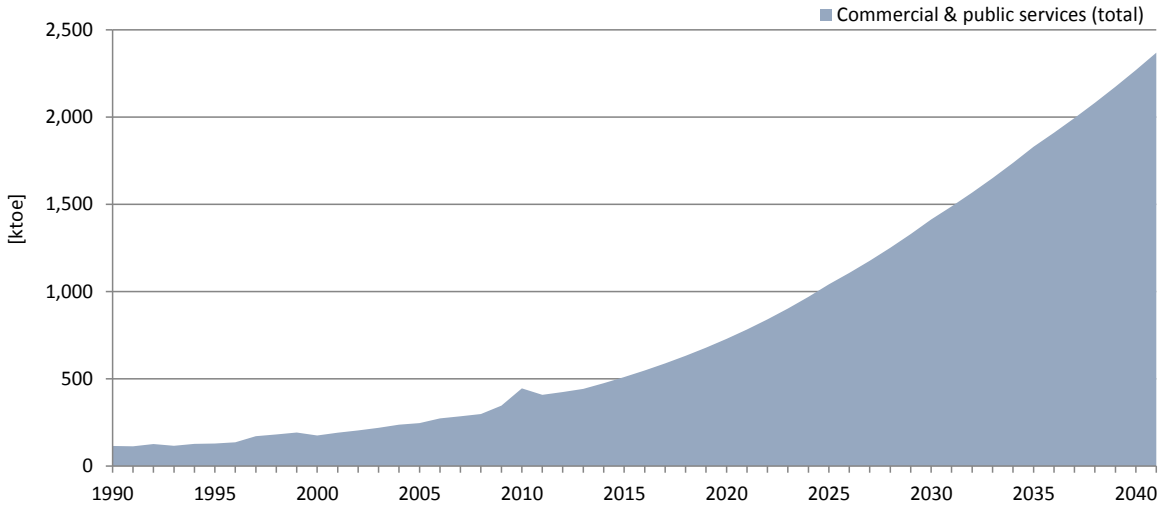
Differences of energy consumption patterns in urban and rural households are shown in some snapshots of year 2013, 2031 and 2041. With the improvement of living standard in rural area, the difference of energy consumption between urban and rural areas is expected to be diminished by 2041.



Source: JICA Survey Team

Figure 6-21 Energy Consumption Pattern of Urban and Rural Households

In the commercial sector, its activities are expected to grow continuously. Energy demand is expected to increase in line with GDP growth. It is noted that various Energy Efficiency and Conservation (EEC) policies and programs will be implemented in buildings, resulting in 25% energy reduction compared to Business as Usual.



Source: JICA Survey Team

Figure 6-22 Energy Demand Projection in Commercial & Public Services Sector

6.3 Industrial Sector

6.3.1 Current status of energy demand

(1) Positions of Industrial Sector in Bangladesh

The industrial sector roughly consists of manufacturing and mining. This study mainly focuses on manufacturing in discussing energy demand of the industrial sector. As seen in Figure 6-23 and Table 6-3, which is the sectorial breakdown of GDP of Bangladesh in 2014 (provisional, real base), whereas manufacturing accounts for 19.45% of the country's total GDP, the share of mining is only 1.64% and is less than one-tenth of that of manufacturing. Though the statistical data to provide breakdown of energy consumption between manufacturing and mining is not available, the share of mining in the energy consumption is supposed to be much less than that in GDP because the energy supply for producing crude oil and natural gas, which represents the mining industry in Bangladesh, is mainly self-contained.

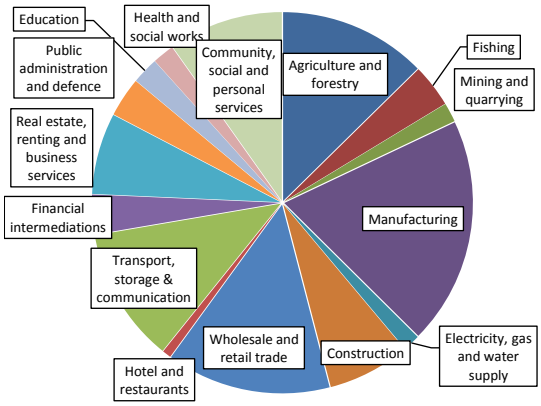


Figure 6-23 Sectorial Composition of GDP in 2014

Table 6-3 Sectorial Composition of GDP in 2014

Industries	GDP (million Tk)	Percentage
Agriculture and forestry	939,115	12.64
Fishing	274,537	3.69
Mining and quarrying	121,880	1.64
Manufacturing	1,445,438	19.45
Electricity, gas and water supply	108,746	1.46
Construction	524,380	7.06
Wholesale and retail trade	1,046,268	14.08
Hotel and restaurants	55,701	0.75
Transport, storage & communication	857,244	11.54
Financial intermediations	252,168	3.39
Real estate, renting and business services	516,092	6.95
Public administration and defence	252,030	3.39
Education	169,309	2.28
Health and social works	137,964	1.86
Community, social and personal services	729,554	9.82
Total	7,430,426	100.00

Source: Bureau of Statistics, "GDP of Bangladesh at 2013-2014(p)"

The growth rate of manufacturing sector for the past five years has outperformed that of total GDP, which indicates that manufacturing in Bangladesh has been growing rapidly.

Table 6-4 Growth Rate of Manufacturing and Total GDP (real base)

	2010	2011	2012	2013	2014
Manufacturing	6.65%	10.01%	9.96%	10.31%	8.68%
Total GDP	5.57%	6.46%	6.52%	6.01%	6.12%

Source: Bureau of Statistics, "GDP of Bangladesh at 2013-2014(p)"

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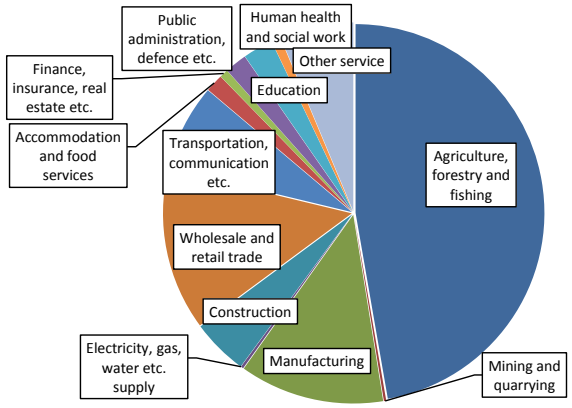


Figure 6-24 Sectorial Share of Employment (2010)

Source: Bangladesh Bureau of Statistics "Labor Force Survey 2010"

Table 6-5 Sectorial Share of Employment (2010)

Industries	Employees (000)	Percentage
Agriculture, forestry and fishing	25,727	47.57
Mining and quarrying	109	0.20
Manufacturing	6,737	12.46
Electricity, gas, water etc. supply	123	0.23
Construction	2,617	4.84
Wholesale and retail trade	7,557	13.97
Transportation, communication etc.	4,038	7.47
Accommodation and food services	832	1.54
Finance, insurance, real estate etc.	399	0.74
Public administration, defence etc.	1,030	1.90
Education	1,402	2.59
Human health and social work	430	0.80
Other service	3,431	6.34
Total	54,084	100.00

Whereas the share of manufacturing in the total employment is 12.4% the share in GDP is 19.45% (or 17.20% in 2010, when is the Labor Force Survey was conducted), which means that the manufacturing's value added per capita outperforms that of the average of all sectors. Assuming that there is no constraint on the liquidity of population migration, the trend of population influx from rural area to urban area to provide human resources to the manufacturing is expected to continue.

(2) Status of Energy Demand for Each Industrial Subsector

It needs to be noted that, even within the manufacturing sector, characteristics of energy demand may vary among subsectors, but at present no relevant statistic data exist in Bangladesh concerning the status of each subsector's energy consumption. Therefore, there's a limitation with quantitative analysis of each subsector's energy consumption using the data that are publicized by the government of Bangladesh.
This study therefore referred to past literature on the status of energy consumption of manufacturing in Bangladesh, such as the study report for grasping the status of each subsector's energy consumption. Literatures that were mainly referred to are the study report of JICA's "Bangladesh Energy Saving Master Plan Formulation Project" (2015) as the reference for energy supply to each subsector, and ADB's "Bangladesh: Industrial Energy Efficiency Finance Program" (Project Number: 45916, May 2014) as the reference for the current status of each industrial subsector. In addition, the information on the status of installing captive power generators in Bangladesh, which is publicized by Bangladesh Bureau of Statistics (BBS), is also referred to for supplementing the aforementioned.

1) Textile and Garment

In the textile and garment industry, both electricity and thermal energy are used in the process of manufacturing. General characteristics of electricity supply are as follows.

1. State Electricity Grid/State Utility: Almost every factory is connected to the grid of distribution companies. Voltage level of electricity supply varies among 33 kV, 11 kV, and 0.4 kV.
2. Captive Power Generation Utilizing Natural Gas: It is generally observed that electricity generation from on-site generators is utilized for sustaining factory production.
   According to existing literature, 80% of factories have their own captive power plant. The textile sector alone has a captive generation capacity of 1,100 MW, while the country as a whole has a total generation capacity of about 8,525 MW as of December 2012.
3. Diesel Generators: As a source of back up supply.
4. Thermal energy: Used for steam generation and hot water.

Since the most common steam generators are gas powered, there is frequent interruption in the production of steam whenever gas pressure reduces. Currently, new gas connections to industrial facilities have been halted due to the demand-supply gap. New facilities are therefore utilizing diesel-fired boilers, furnace oil boilers, compressed natural gas (CNG) boilers, etc. Some factories have started to use exhaust gas boilers (EGB) to get steam from generator, boiler and furnace exhaust; based on the ADB report, however, utilization of such technologies is less than 50%.
It needs to be noted that there's a commonly observed practice in many factories that the electricity demand mainly rely on captive generation from natural gas whereas the power supply from grid is used as back-up. This is due to the fact that the tariff of gas supply for captive power is set lower than electricity tariff, i.e. electricity supplied by distribution companies to factories is at the rate of 6.95 BDT/kWh while the cost of electricity generation from captive power is about 3 BDT/kWh, even without utilizing waste heat recovery. This is why most industrial facilities prefer using captive power generation.

2) Steel-making and Re-rolling

Main sources of energy for iron and steel industry in Bangladesh are electricity, natural gas and HSD (high speed diesel). In fact, this subsector is the largest consumer of natural gas in Bangladesh. In general, induction furnaces use electricity from grid as their source of energy supply, whereas natural gas use is predominantly in re-rolling mills.
Most of the iron and steel factories are connected with the grid at 33 kV or 11 KV voltage level. Many iron and steel manufacturers also generate electricity through gas-fired captive power generation for sustaining factory production. The captive generation is said to be cheaper than electricity supply from distribution companies by up to 30%. HSD is predominantly kept as a source of stand-by captive power generation.

3) Cement

The source of energy supply for cement factories in Bangladesh is electricity, which is utilized to drive motors in several production processes. This electricity is either drawn from the grid or generated from onsite captive power generators using natural gas.
Factories usually have grid connection at 33 kV level. Though many factories prefer to have their own gas connection and generate electricity from natural gas, only 20% of the units have their own captive power plant. In terms of energy conversion, captive power generation is less efficient than grid electricity, as the typical efficiency of a captive power plant is only 30%. Therefore the captive power generation is not a preferred option in terms of energy economics though captive power generation may be less costly because of the government's energy price policy.

4) Glass, Sanitary and Tiles

Almost every factory has a connection to the grid at 33 kV or 11 kV. However, electricity supply mainly relies on captive power generation and grid connection is used mainly as backup power when gas supply is interrupted or is of low pressure. Natural gas is also used as the fuel for kilns, and since the natural gas in Bangladesh does not contain Sulphur, ceramic products in Bangladesh is said to have a bright color.
New gas connections have been suspended since March 2009, causing the stagnation of establishing new factories. Because of the restrictions in new connections of gas supply, some new companies use CNG or HSD (High Speed Diesel) as substitute. HSD is also used as the fuel for back-up power generation for lighting.
The ceramics industry is characterized by the fact that its manufacturing process is vulnerable to low voltage electricity and low gas pressure, and this is said to be the main reason for the recent trend of lowered quality and the slump in export. Ceramic tableware processes requires uninterrupted power and gas supply so that the 360°C temperature is maintained constantly for 24 hours, and drops in

temperature needs to take at least 12 hours for recovery which causes a huge loss in production. Stable supply of electricity and gas is indispensable.

5) Chemical, Chemical Fertilizer, Pulp & Paper

Many factories in chemical, plastics and pulp & paper industries rely on electricity generation through captive power generators for sustaining factory production. About 55% of factories are said to have their own captive power plant. Factories that have both electricity and gas connections use grid electricity as backup power when gas supply is interrupted or of low pressure. HSD is used only as the fuel of backup generation for emergency lighting purposes only.
The fertilizer industry is very much reliant on natural gas as it is not only the source of energy supply but also the main raw material in the production of urea, which is one of main elements of fertilizer.
Electricity supply quality is poor and the factories frequently suffer five to six hours of load shedding in summer in Dhaka area, where SMEs in the plastics sector are located. Productivity is badly affected by shortage or fluctuations in electricity supply. Firms that have gas connections for captive power generation enjoy relatively better conditions of power supply, but after early 2009, when the government stopped new gas supply connections, firms have experienced difficulties with their planned expansion projects.

6) Jute Mills and Agro Processing

Jute mills in Bangladesh mainly use electricity for energy supply and the factories have a connection to the grid at 11 kV or 0.4 kV.
Agro processing plants usually use captive power generation as the energy source for sustaining factory production. 50% of the factories have their own captive power plant, and use gas or diesel as fuel sources. Some factories that do not have gas connection or that only receive low pressure gas utilize diesel for production and lighting. Since diesel oil is costly, the production cost of these factories is apt to be high.

7) Brick

According to the academic article published by Bangladesh University of Professionals (BUP) titled “Securing the Environment: Potentiality of Green Brick in Bangladesh” (BUP Journal, Volume 1, Issue 1, September 2012, ISSN: 2219-4851), bricks manufacturers in Bangladesh usually fire coal in fixed chimney kiln (FCK) and bull's trench kiln (BTK). It is said that 23 tons of coal is consumed for making 2 crore BDT of bricks. Kilns such as FCK and BTK have problems not only with their low energy efficiency, but also with their environmental burden of PM2.5 and CO2. These factories have become one of main reasons of atmosphere pollution in Dhaka are in dry season, because they mainly work in dry season.
Currently, government has been providing support for diffusing new manufacturing technology called “Green brick”, which only consumes 7.8-8 tons of coal for making 2 crore BDT of bricks.

8) Fishery Products (Frozen Foods)

According to the study report published by USAID called “Bangladesh Industrial Energy Efficiency Opportunities Assessment Task 1: Industry Profile – Sectors Selection Report” (March 2012”, main energy-consuming appliances at fishery food processing factories are chillers, freezing plants and frozen storage.
The source of energy supply for these fish processing plants is electricity from the grid. Because the power supply from the grid is not stable, these plants also have diesel based captive power generators as back-up.

6.3.2 Key factors that affect future prospects of energy demand

(1) Balance between Grid Electricity and Captive Power (Natural Gas) in Relation to Tariff Policy

As seen in the previous section, the current status of industrial sector energy demand is reviewed for each subsector, referring to the existing study reports. It was observed that, while there are characteristics of energy supply and demand unique to each subsector, a common issue in the industrial sector was also identified, that is, the price of natural gas for captive power generation is set at a very low level thus the cost of captive power generation is less expensive than the cost of power purchase from the grid, despite that the energy conversion efficiency is lower than grid power. According to the existing literature, there are many factories that use the electricity from the grid not because it's economically rational but because they wanted to use captive power generation but gave it up due to the gas suppliers' rejection of new connection.

As the domestic gas production is expected to deplete and the dependence on imported LNG will increase, keeping the gas price at a very low level compared to international price level is not desired in terms of national economy. Therefore, on mid- and long-term basis, electricity and gas prices will be rebalanced and both prices will be adjusted to an appropriate level so that a considerable portion of industrial sector energy consumption will naturally shift from captive power generation to grid power supply. In terms of primary energy supply, this means that certain part of natural gas supply will shift to other sources of power generation such as coal.

However, the current status is that the capacity of grid power supply is not sufficient to meet the power demand in Bangladesh hence it will take years to come for the grid power supply to cover the total power demand including the part that is currently fed by captive power. Therefore, rebalance between electricity and gas prices will occur gradually in accordance with the increased capacity of electricity supply and the shift between energy sources will also occur gradually likewise.

In addition, though the electricity price is relatively higher compared to gas price, the current level of electricity price is not sufficient for BPDB to recover the cost of power procurement from power generating companies, as explained in Chapter 19 and afterwards. And it may also need to be considered that drastic increase of electricity and gas prices at once may increase the negative impact on the national economy of Bangladesh. The revision of price policy will be progressed gradually, also from this point of view. Discussion on energy price will be made more in detail in Chapter 19 and afterwards.

In the meanwhile, there are also cases that the manufacturers in ceramics prefer captive power generation also because they need high quality of power supply in the production process but the power supply from the grid is not reliable enough. These subsectors may still choose captive power generation because of supply reliability even when gas price is raised to outperform the power supply from the grid. For motivating them to purchase electricity from the grid, not only increasing the gas price but also improving the quality of power supply to a sufficiently reliable level is needed.

(2) Structural Changes of the Industrial Sector Triggered by Economic Development

This study referred to the existing literature for obtaining basic information on the status of energy consumption in each sector in Bangladesh. However, it was confirmed that only very limited statistic data to serve for the analysis of industrial sector energy demand exist in Bangladesh. In fact, the aforementioned past literatures also obtained very few statistic data and relied a lot on their own estimation for analysis.

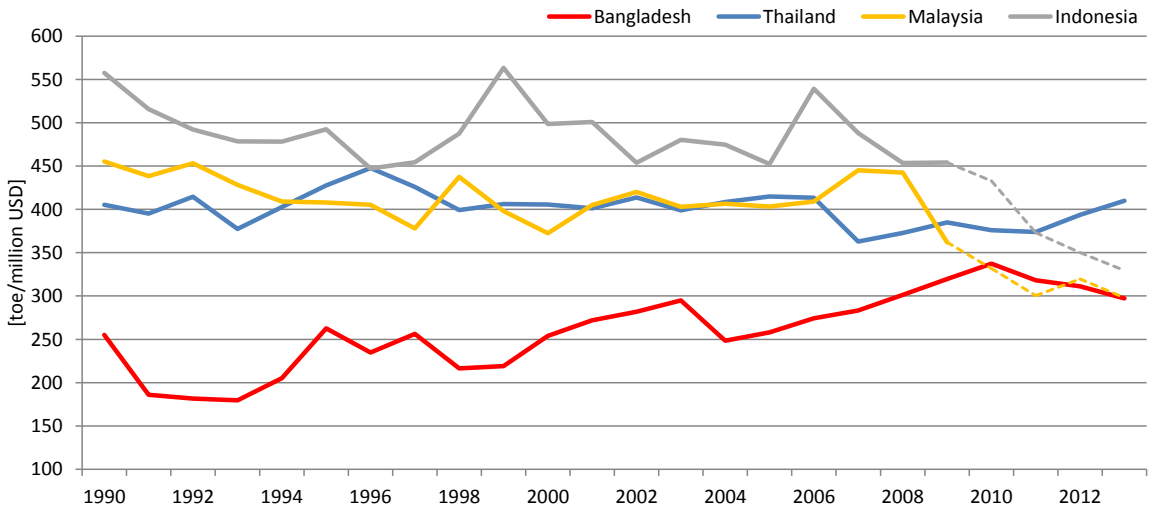
In this study, the JICA Survey Team also interviewed relevant stakeholders in Bangladesh such as Ministry of Industries and various business organizations that represent the main industries. However, it turned out that, though only some fragmented information about the energy consumption in each subsector was obtained and that information was basically consistent with the analysis of existing literature, no new statistic data to serve for quantitative analysis was available.

In formulating the prospects of industrial sector's energy consumption, detailed analysis with breakdown by subsectors and energy sources is effective for short-term projection (e.g. in five years,

in ten years). However, because it was confirmed that no other statistical data than those obtained in the past studies are available, the methodology of energy demand forecast by analyzing the each subsector and energy source in detail would have limitations.
In addition, if the period of energy demand forecast is relatively short, making a future projection in detail based on the current industrial structure as precondition is effective, but because this study aims at making a long-term projection of energy demand up to 2041, the industrial structure of Bangladesh is expected to change drastically, as discussed in Chapter 5. In other words, the effect of changes in industrial structure itself is expected have more impact on the future prospects of energy consumption of the entire industrial sector rather than the effect of each subsector's trend.
This study therefore adopted a methodology to analyze how the industrial sector's energy consumption of a country changes with the progress of economic development, referring to the experiences of other countries, and then to grasp the prospects of energy consumption of the industrial sector in Bangladesh nationwide.

6.3.3 Projection of energy consumption

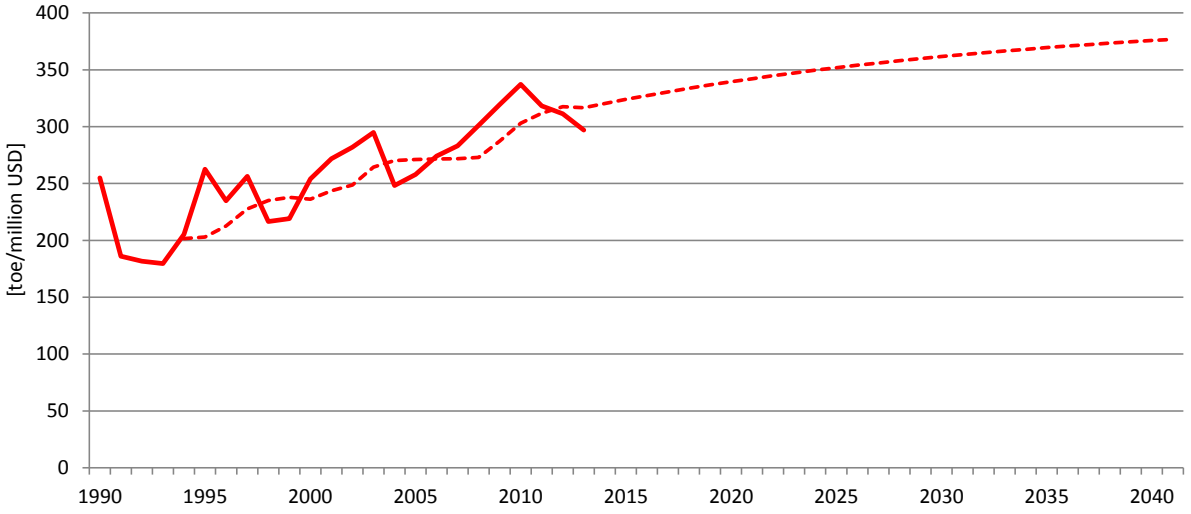
In order to analyze the prospects of industrial sector's energy consumption in Bangladesh, this study calculated the industrial sector's energy intensity, i.e. energy consumption divided by the sectorial valued added (= GDP) of manufacturing (constant price). This ratio indicates how much energy (toe) is consumed for the industrial sector to yield a value of 1 million USD.
If this ratio is constant, GDP elasticity of energy consumption is 1. If this ratio increases from the previous year(s), it means that the industrial sector consumed more energy than before for yielding a same economic value, if the GDP increased during this period, the growth rate of energy consumption was much higher than that of GDP. That is, GDP elasticity in this period was higher than 1. If this ratio decreases from the previous year(s), vice versa, i.e. GDP elasticity in this period was lower than 1
Figure 6-24 shows the historical trend of industrial sector's energy intensity in Bangladesh, in comparison with Thailand, Malaysia and Indonesia. Whereas this ratio has been relatively constant around 400 toe/million USD in Thailand, Malaysia and Indonesia, this ratio is relatively low in Bangladesh, but it has seen a gradually increasing trend.



Source: Prepared by JICA Survey Team based on World Bank database and IEA statistics
Note) Declining trend of energy consumption in Malaysia and Indonesia from 2010 is considered a statistical error

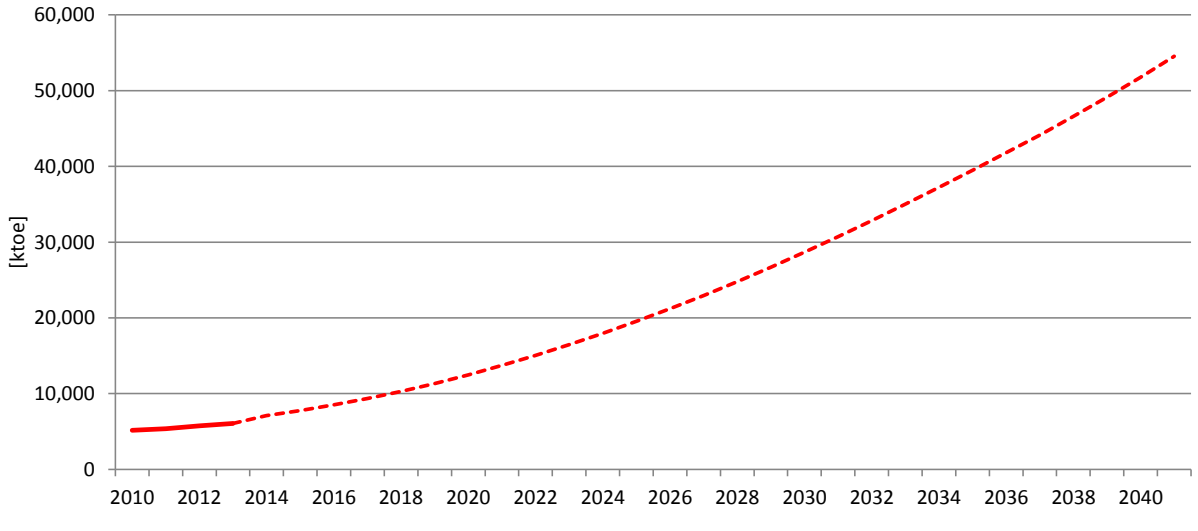
Figure 6-24 Industrial Sector's Energy Consumption per Sectorial Value Added

One of the possible reasons why the ratio of industrial sector's energy consumption to sectorial GDP is creeping up (GDP elasticity higher than 1) in Bangladesh is that the economic development (=industrialization) of this country is still at an early stage and that a shift from labor-intensive industries to energy-consuming industries is in process.
Referring to the historical trend of some ASEAN countries as benchmark, this study assumes that the gradually increasing trend of industrial sector's GDP intensity will continue to increase up to 400 toe/million USD, as shown in Figure 6-25. By multiplying the prospects of this ratio by the projection of sectorial value added (GDP), this study expects that the energy consumption of the industrial sector will reach about 54,500 ktoe in 2041, about eight times increase from 2014, as shown in Figure 6-26. The main drive of the rapid increase of the sectorial energy consumption is the rapid growth of the economy itself, but is also accelerated by the expected increase of the energy intensity.



Source: JICA Survey Team

Figure 6-25 Projection of Industrial Sector's Energy Consumption per Sectorial Value Added



Source: JICA Survey Team

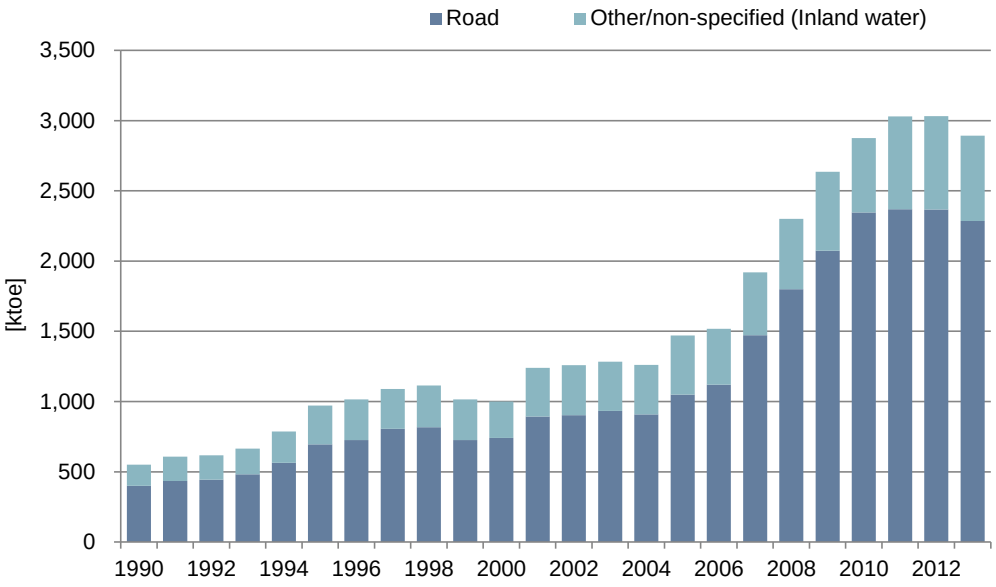
Figure 6-26 Projection of Industrial Sector's Energy Consumption

6.4 Transport Sector

6.4.1 Current status of energy demand

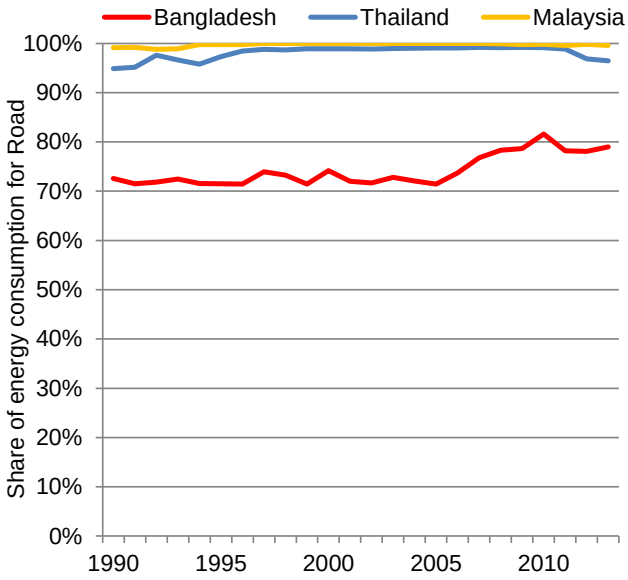
(1) Structure of Transport Sector in Bangladesh

The historical trend of energy consumption of transportation sector is shown in Figure 6-27. It grew more than five times in 23 years, from 544 ktoe in 1990 to 2,893 ktoe in 2013, and especially saw a high growth in late-2000s. Though the growth appears to stop in 2010s, this is considered merely a statistical error considering the recent progress of motorization of the country, and the trend of rapid growth is supposed to continue.
Looking at the breakdown of energy consumption by the type of transport, road transport accounts for about 80% of the total sectorial energy consumption, and the share has been creeping up as seen in Figure 6-28.
The reason why the share of road transport is relatively small compared to other countries (such as Thailand and Malaysia where its share is higher than 90%) is that Bangladesh has the large inland waterway networks and water transport has a relatively large share in total transport, though the share in sectorial energy consumption has been slightly decreasing, reflecting the progress of motorization. Development of river bridges is expected to accelerate the trend that water transport gives way to road transport.



Source: IEA Energy Balances

Figure 6-27 Historical Trend of Transport Sector's Energy Consumption in Bangladesh

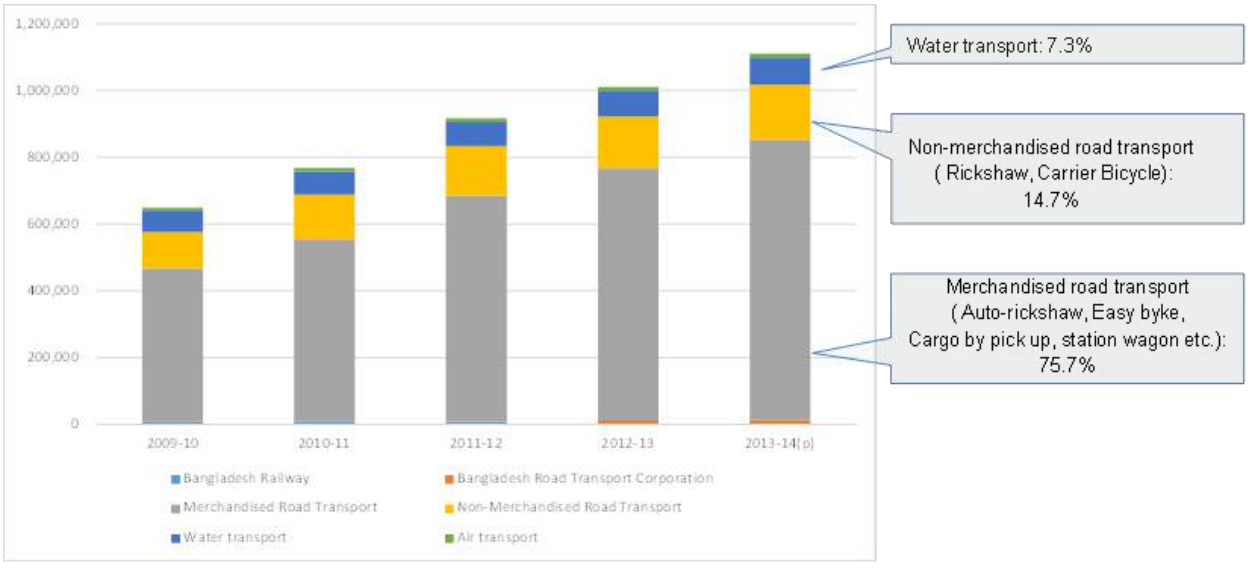


Source: IEA Energy Balances

Figure 6-28 Share of Road Transport in Transport Sector's Energy Consumption

Figure 6-29 shows the trend of modal share in transport sector in terms of economic value. More than 90% of value added in transportation sector is from road transport whereas the remaining parts are water transport and air transport, and railway.

Road transport can be broken down into non-merchandised road transport, such as rickshaw and carrier bicycle, merchandised road transport, such as automobiles. The merchandised road transport can be further broken down into passenger transport and cargo transport. At the moment, auto-rickshaw/tempo, easy bike and cargo (by pickup, station wagon etc.) mainly contributes to the value added of merchandised road transport in Bangladesh.



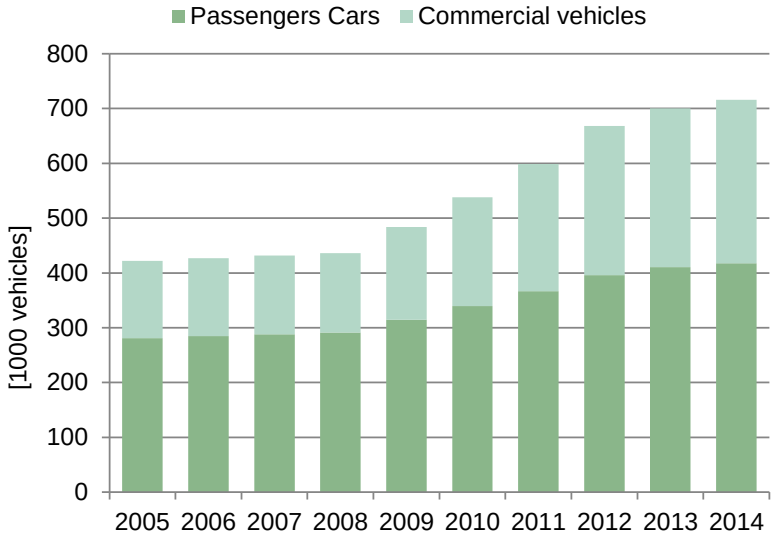
(Unit: million BDT at current price)

Source: Prepared by JICA Survey Team based on BBS "Bangladesh National Accounts Statistics"

Figure 6-29 Value Added of Transport Sector with Modal Breakdown

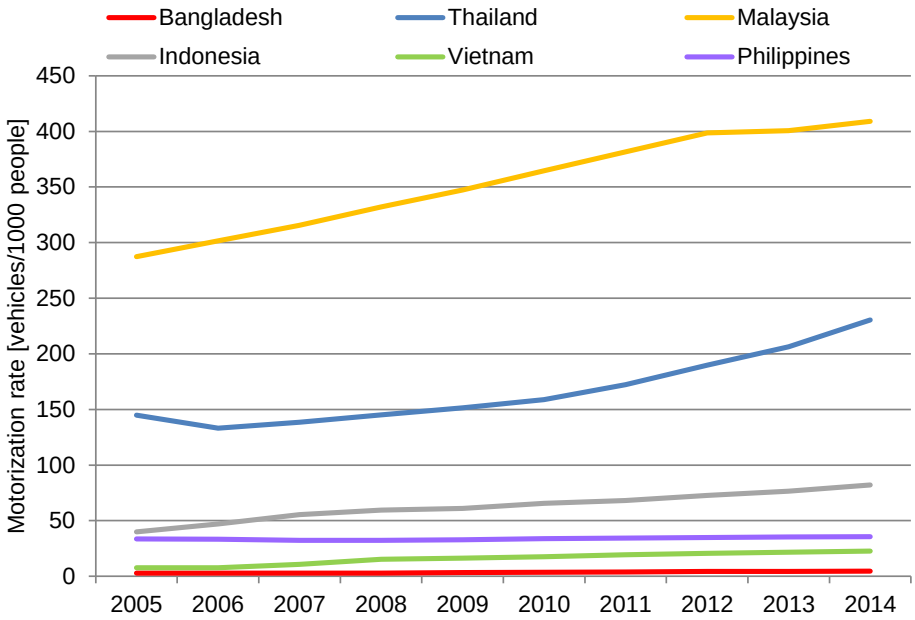
(2) General Trend of Motorization

According to International Organization of Motor Vehicle Manufacturers (OICA), the number of vehicles owned in Bangladesh has increased from 422,000 in 2005 to 716,000 in 2014, 1.7 times (6.1% p.a.) in 9 years (see Figure 6-30). However, the current level of motorization in Bangladesh, which can be expressed as the number of vehicles per 1,000 people, is still very low compared to that in ASEAN countries (see Figure 6-31).



Source: Prepared by JICA Survey Team based on World Bank database and OICA statistics

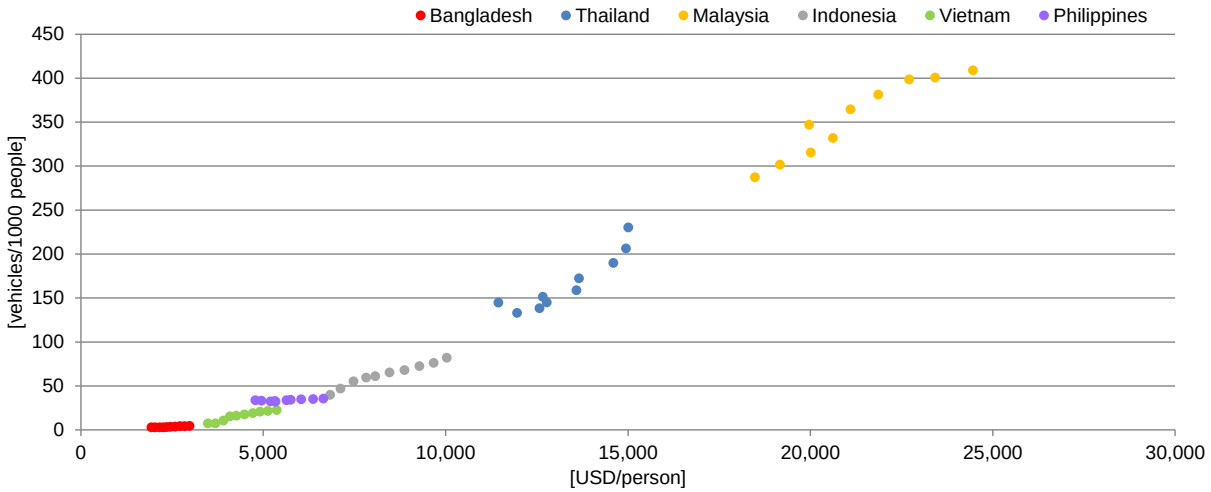
Figure 6-30 Number of Vehicles Owned in Bangladesh



Source: Prepared by JICA Survey Team based on World Bank database and OICA statistics

Figure 6-31 Motorization Rate of Bangladesh and ASEAN Countries

The extent of car ownership can be explained by the status of economic development of each country. As seen in Figure 6-32, there's a strong correlation between GDP per capita (PPP basis) and motorization rate in ASEAN countries (Thailand, Malaysia, Indonesia, Vietnam and the Philippines). The correlation takes an S-shaped curve, i.e. the slope becomes steep when the country's GDP per capita exceeds 5,000 USD, and after taking an almost linear correlation, the slope becomes moderate when the GDP per capita reaches 20,000 USD.
As Bangladesh economy has not reached the level to trigger massive motorization, the motorization rate (vehicles per 1000 people) is still very low. But when the economic development comes to a certain level, motorization rate increases rapidly. This study expects that this rapid motorization will start around mid-2020s when GDP capita reaches 5,000 USD (see Figure 6-32).



Source: Prepared by JICA Survey Team based on World Bank database and OICA statistics

Figure 6-32 Historical Trend of GDP per Capita (PPP) and Motorization Rate

Table 6-5 is the number of registered motor vehicles in each year in Bangladesh, according to the Road Transport Authority. Main reasons for the difference from the numbers in Figure 6-30 (about 716,000 as of 2014) are the inclusion of other types of motor vehicles such as motorcycle and the possibility of vehicles that were registered in the past but are no longer in use. The total number of motor vehicles that are registration at the end of 2010 was about 1.5 million and it grew to 2.5 million as of 29th February 2016, about 1.6 times increase.
Currently the increase of motor cycles is the most conspicuous. Motor cycles not only account for more than half of total number of registration, but also it saw a rapid increase that was almost doubled during that period.
Private passenger cars accounts for the second largest share in total car registration and the number increased from about 220 thousands in 2010 to 292 thousands in February 2016. An important point to be noted about private passenger car is that the regional distribution of car registration. Out of 292 thousands in total Bangladesh, 227 thousands are registered in Dhaka. That is, most of the private passenger cars exit in Dhaka area whereas the diffusion in other areas is still far behind.

Table 6-5 Number of Registered Motor Vehicles in Bangladesh

<Bangladesh> <Dhaka>

Sl. No	Type of Vehicles	Upto-2010	2011	2012	2013	2014	2015	29-Feb-16	Grand Total	Grand Total
1	Ambulance	2793	219	181	243	338	480	78	4332	2487
2	Auto Rickshaw	126763	20423	23545	15697	19897	20000	1999	228324	8435
3	Auto Tempo	14266	175	626	395	500	1095	136	17193	1664
4	Bus	27778	1761	1439	1107	1488	2391	577	36541	24565
5	Cargo Van	3522	489	282	687	608	399	64	6051	5727
6	Covered Van	5658	2354	1421	2271	2869	2354	416	17343	13742
7	Delivery Van	17063	1004	774	894	1176	1719	281	22911	16725
8	Human Hauler	6520	1152	715	385	225	1142	501	10640	4371
9	Jeep(Hard/Soft)	32286	2134	1569	1314	1870	3601	777	43551	28926
10	Microbus	66379	4051	3044	2537	4313	5224	1062	86610	63959
11	Minibus	25644	276	249	148	256	323	73	26969	10068
12	Motor Cycle	759257	114616	101588	85808	90685	240358	41467	1433779	390062
13	Pick Up (Double/Single Cabin)	32240	10460	7625	6553	9554	10257	1512	78201	54116
14	Private Passenger Car	219830	12950	9224	10472	14699	21062	3910	292147	226645
15	Special Purpose Vehicle	6371	396	226	227	172	296	78	7766	1078
16	Tanker	2706	317	195	226	362	324	64	4194	1536
17	Taxicab	44380	75	172	51	374	88	4	45144	36466
18	Tractor	20600	5200	3494	1885	1522	1699	423	34823	22066
19	Truck	82871	7327	4335	5129	8136	6330	958	115086	48258
20	Others	1317	7	1	1080	1595	2073	572	6645	3498
TOTAL		1498244	185386	160705	137109	160639	321215	54952	2518250	964394

Source: Bangladesh Road Transport Authority (http://www.brta.gov.bd/statistics.html)

In comparison to that, auto rickshaws exist mostly outside of Dhaka area. Out of the 228 thousands registration countrywide, only 8,435 are registered in Dhaka. This implies that in Dhaka area, where the economic level is relatively high, ownership of private passenger cars has already outstripped the usage of auto rickshaws, whereas in other areas auto rickshaws are still dominant in passenger transport. This is in line with the fact that out of the total number of the registered taxicabs, which is currently 45 thousands, about 80% are registered in Dhaka. That is, diffusion of taxicab, which is basically used by a single or a few passengers, is advanced in Dhaka area now but it will also substitute auto rickshaws, which is basically for shared use, in other areas with the development of economic level.

This study therefore projects that the registration of auto rickshaws may still continue to increase outside of Dhaka area for years to come, but will be gradually replaced by passenger cars like in Dhaka area. It means that there is a huge potential for private car ownership to increase rapidly especially in rural area.

In addition, considering the continuous migration of residents from rural areas to urban areas, the car ownership in Dhaka area is considered to increase further. The traffic congestion in Dhaka is still a serious problem but this can be worsened unless appropriate policy measures for mitigating this are not in place.

6.4.2 Key factors that affect future prospects of energy demand

(1) Long-term Policy on Transport Sector

In Bangladesh, some long-term policies on the transport sector were developed, as described below. However, it seems that these past literatures did not care much about the energy usage of the sector, much less to energy efficiency.
In addition, there obviously is not any regular statistics or information on the energy use in transport sector. Developing database on energy use of this sector is needed for grasping the status correctly and for making policy direction for rationalizing energy use and improving energy efficiency.

1) Road Master Plan (2009)

Road Master Plan was developed in response to the direction provided by the National Land Transport Policy and was intended to be the guideline for the investment in the road infrastructure over the next twenty years.
In this Master Plan, a comprehensive investment program was set to:

- Protect the value of RHD's (Road and Highways Department's) road and bridge assets;
- Improve the connectivity of the road network;
- Enhance and develop the strategic road network to meet economic and traffic growth target;
- Improve the Zila Road network to enhance connectivity to the country's growth centers;
- Improve road safety and reduce road accidents;
- Provide environmental and social protection; and
- Outline the institutional improvements required for RHD to deliver the above.

2) The National Integrated Multimodal Transport Policy (2013)

The National Integrated Multimodal Transport Policy, 2013 was prepared in order to redress the imbalance by an overemphasis on road subsector on development started taking place from the beginning of 1990. This policy is to address all modes of transport in an integrated way so that future investment can take account of the best mode in each case to meet overall government objectives including environment issues and safety.
The primary objective of the Multimodal Integrated Transport Policy is to emphasize the roles of rail, inland water transport, aviation alongside road transport in order to ensure the development of the overall transport network. The objectives of the Integrated Multimodal Transport Policy are to:

- Reduce cost of transport goods, so as to make goods and services within Bangladesh less costly;
- Aid export competitiveness, through lower transport costs;
- Improve safety;
- Reduce accident rate;
- Take advantages of Bangladesh's geographical position to trade in transport services and induce efficiency in transport sector;
- Reduce the worst environmental effects of transport;
- Ensure that transport meets social needs in terms of cost accessibility to all sectors of society;
- Improve integration of the overall transport network and foster measures to make interchange between modes easier;
- Reduce the need for travel by better land use planning;
- Use transport as means to assist poverty reduction;
- Improve fuel and energy security; and
- Increase alternative options for passenger and freight transport.

(2) Thailand's Case as a Good Practice for Reference

1) Comparison of Transport Sector Data

This study considers that the case of Thailand to deal with the issues pertaining to the transport sector can be a good reference for Bangladesh. Table 6-6 compares the data regarding the transport sector in Bangladesh and Thailand. In Thailand the number of motor vehicle with 4 or more wheels per 1000 people is 198 units, around 50 times of that in Bangladesh.

Table 6-6 Comparison of Transportation Related Data between Bangladesh and Thailand

		unit	Bangladesh	Thailand	year
motor vehicle	number of motor vehicle (4wheel or more)	1000unit	570	13,213	2012
	number of motor vehicle per 1000people	unit	4	198	
	number of motor cycle	1000unit	1,161	19,169	
road	road length of main roads	km	20,735	51,855	Thailand:2006, Bangladesh:2003
	main road density in terms of population	km/1000people	1.5	3.7	
rail	rail lines	km	2,835	5,327	2012
	passenger	million people*km	7,305	7,504	
	cargo	million ton*km	710	2,455	
air	passenger; international line	million people*km	565	8,204	2011
	passenger; domestic line	million people*km	4,630	59,159	
	passenger; total	million people*km	5,195	67,363	
waterway	Container port traffic	TEU: 20 feet equivalent units	1,571,461	7,702,476	2013

Source: Prepared by JICA Survey Team based on the data of Japan Statistics Office and WB

2) Measures for Mitigating Traffic Congestion

Bangkok, the capital of Thailand, is infamous for its traffic jams like Dhaka. According to the World Bank, the average vehicle speed during rush hours is 17.2 km/h in the morning and 24.2 km/h in the evening. Table 6-7 shows the main measures taken and considered in Thailand to mitigate traffic congestion. By introducing measures for mitigating traffic jam the following effects are expected.

- increase of the average vehicle speed;
- reduction of lost time for transportation;
- reduction of fuel consumption and fuel cost;
- reduction of CO2 emission;
- reduction of exhausted toxic gas;
- reduction of stress of drivers;
- reduction of traffic accidents;

Table 6-7 Measures Taken in Bangkok for Mitigating Traffic Congestion

Categories	Main Measures
Mordal Shift	construction of urban railways (METRO etc.)
	introduction of Bus Rapid Transit
	introduction of Park & Ride System
Road Development	widening of a road
	develop ring road
	construction of flyover
Regulation	road pricing
	time dispersion(staggered commuting, flex time etc.)
Provision of Road Information by ICT	Smart Traffic Sign
	Traffic Signal Control

Source: JICA Survey Team

3) Introducing Eco Car Program

Thailand started the 'Eco-car program' in 2007 that offered preferential tax treatment to car manufacturers producing Eco-car. There were various requirements such as a fuel consumption of 20 km or more per liter, compliance with the European exhaust gas regulations "EURO 4", etc. Various benefits like 8 years exemption from corporation tax were provided to the approved manufacturers of "eco-cars". Also, for purchasers (consumers), a goods tax rate of 17% was introduced as a preferential tax treatment (please see table below).
The second stage of 'eco-car program' started in 2014 which requested a fuel consumption of 20 km or more per liter, compliance with the European exhaust gas regulations "EURO 5", etc. The conditions were that production must commence before year end 2019, and the production from the fourth year and beyond must be 100,000 vehicles or more p.a. (please see table below).
For the first Eco car program five Japanese manufacturers, i.e. Nissan, Honda, Mitsubishi, Suzuki and Toyota were approved. And for the second Eco car program, besides the aforementioned five manufacturers, five other manufacturers from America and Europe were newly approved.

Table 6-8 Outline of Eco car Project Conducted in Thailand

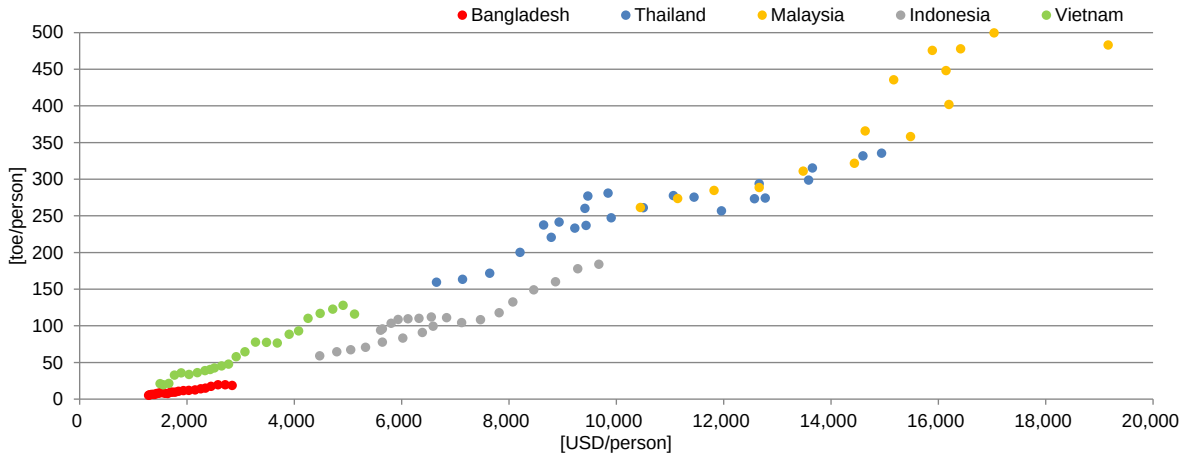
	eco car program	2nd eco car program
start year	2007	2013
main requirement	1300cc or less(gasolin car) 1400cc or less(diesel car) fuel consumption 20km/l or more clear the standard of EURO4 CO2 emission 120g/km or less	1300cc or less(gasolin car) 1500cc or less(diesel car) fuel consumption 23.3km/l or more clear the standard of EURO5 CO2 emission 100g/km or less start production by 2019
main benefit to manufacture	income tax free for maximum 8 years import tax free for production machine	income tax free for 6 years etc. import tax free for production machine
benefit to consumer	consumption tax 17% (30% for passengers car for 2000cc or more)	consumption tax 14%

Source: JICA Survey Team

6.4.3 Projection of energy consumption

As discussed in the Section 6.4.1 , the car ownership starts increasing acceleratedly when the country's GDP per capita (PPP) reaches around 5,000 USD. Because the increased car ownership directly affects the energy consumption, the transport sector's energy consumption is expected to see a rapid growth from mid-2020.
Figure 6-33 shows the relation between GDP per capita (PPP basis) and transport sector energy consumption per capita in Bangladesh and ASEAN countries (Thailand, Malaysia, Indonesia, Vietnam and the Philippines). Like the case of motorization rate (see Figure 6-32), the overall trend of these countries is tracing an S-shaped curve, though it is not as clear as the motorization rate. That is:

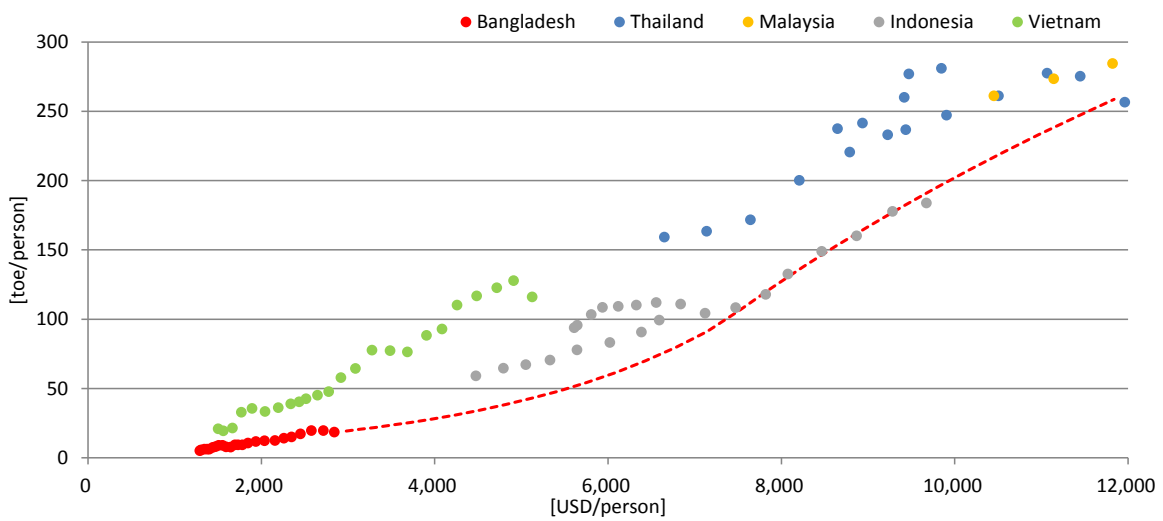
- Energy consumption increases acceleratedly when the economic development comes to a certain level and the car ownership (motorization) increases rapidly, and
- The growth rate of energy consumption becomes moderate when the economic development reaches a certain level of maturity so that the growth of car ownership slows down whereas the regulation on combustion becomes stricter, and that the advanced public transport system is deployed especially in the urban area.



Source: Prepared by JICA Survey Team based on World Bank database and IEA energy balances

Figure 6-33 Historical Trend of GDP per Capita (PPP) and Transport Sector's Energy Consumption per Capita in Bangladesh and ASEAN Countries

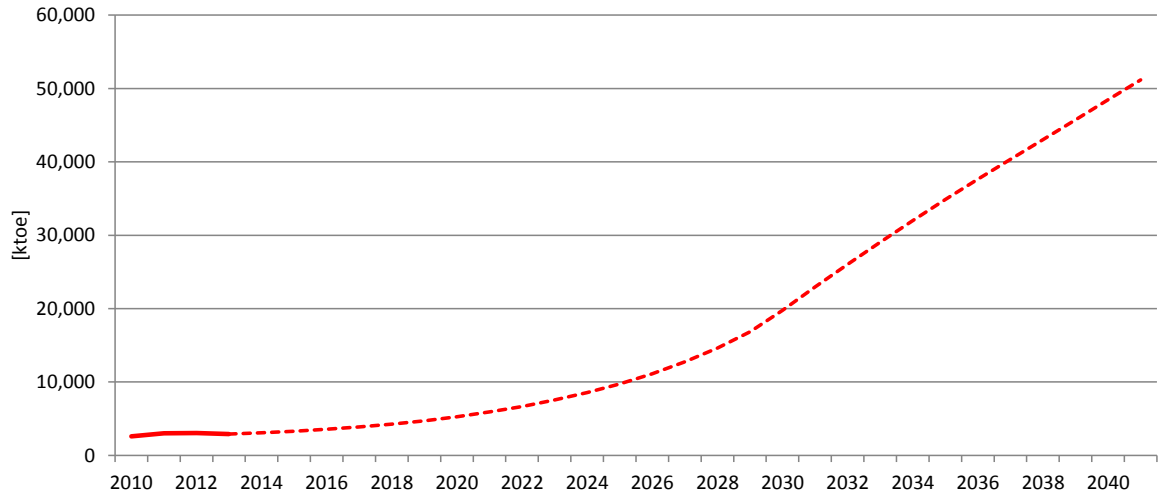
According to this figure, especially the historical trend of Indonesia and Thailand that the transport sector's energy consumption per capital starts growing steeply when GDP capita reached around 5,000-6,000 USD and the growth becomes moderate when it exceeds 8,000 USD, this study considers that the car ownership increases rapidly during that period.
Assuming that Bangladesh will also follow this track, transport sector's energy consumption per population will increase rapidly from mid-2020s to early 2030s in accordance with the accelerated car ownership, as shown in Figure 6-34.



Source: JICA Survey Team

Figure 6-34 Projection of Transport Sector's Energy Consumption per Capita

Multiplying the projection of energy consumption per capita by the projected population (see Chapter 5), the transport sector's energy consumption in Bangladesh is expected to reach around 51,000 ktoe in 2041, about 18 time of the current level (2,893 ktoe in 2013), as shown in Figure 6-35. Rapid increase of energy consumption can be seen from mid-2020s, though the government's plan of public transport (e.g. MRT in Dhaka area) is taken into account.



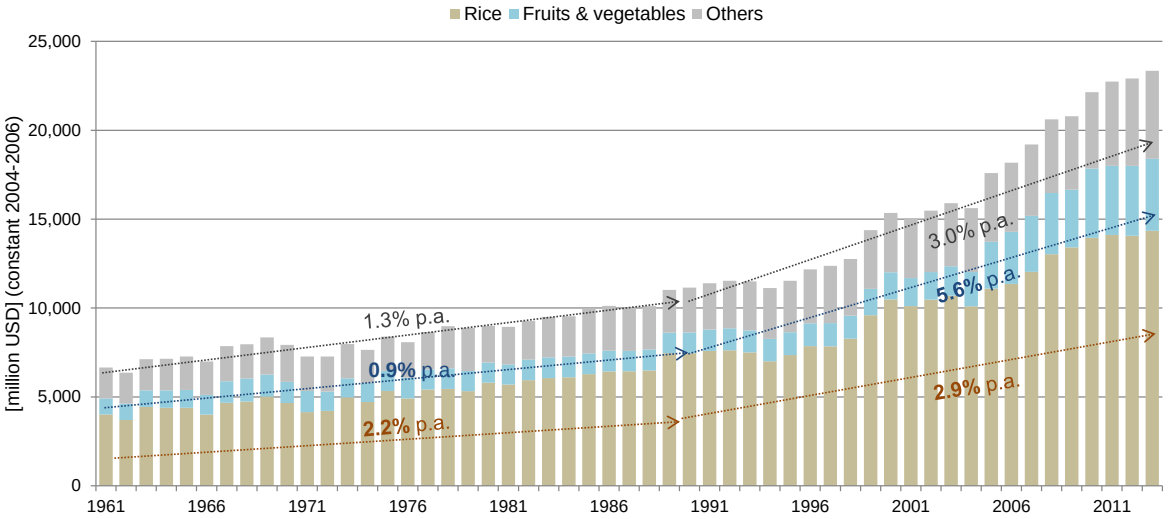
Source: JICA Survey Team

Figure 6-35 Projection of Transport Sector's Energy Consumption

6.5 Agricultural Sector

6.5.1 Current status of energy demand and key factors that affect future prospects

Figure 6-36 shows the historical trend of agricultural production in Bangladesh according to the United Nation's Food and Agriculture Organization (FAO). In Bangladesh, rice has been the major agricultural product and its share in total agricultural production has been constantly around 60% or more since 1960s.
For thirty years from 1961 to 1990, the total agricultural production increased by 1.7 times, i.e. 1.8% p.a. During that period, rice grew by 1.9 times (2.2% p.a.), fruits and vegetables by 1.3 times (0.9% p.a.) and others by 1.4% (1.3%), which indicates that rice was main driver for the growth of the country's agricultural production.
For twenty-three years from 1991 to 2013, the total agricultural production increased by 2.1 times (3.3% p.a.). The fact that the average growth rate was higher than that in previous period despite the migration from agriculture to industry driven by industrialization is considered due to the improved productivity. During this period, rice grew by 1.9 times (2.9% p.a.), whereas fruits and vegetables by 3.5 times (5.6%) and others by 2.0 times (3.0% p.a.). This indicates that the growth of fruits and vegetables replaced rice as the main driver for the production growth.
As a general trend, agricultural sector changes its structure by shifting from primitive self-sufficiency centering on grain production (rice, wheat etc.) to diversification with more value-added products, such as fruits, vegetables and dairy products. This reflects the people's preference for variety of foods with the improvement of economic standard and the shift to value added products for export driven by the improved productivity.

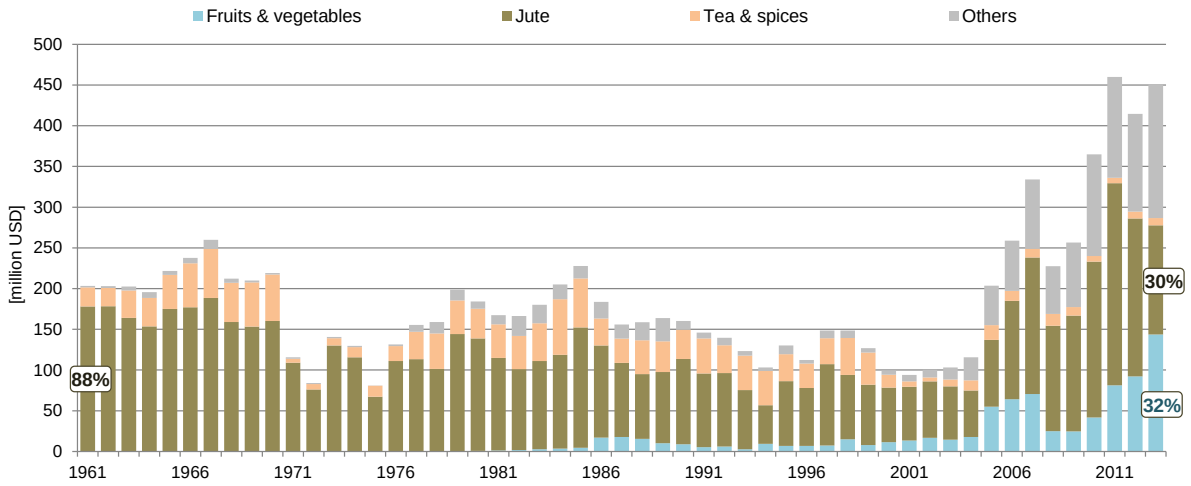


Source: FAO Statistics

Figure 6-36 Historical Trend of Agricultural Production (Turnover) in Bangladesh

Figure 6-37 shows the historical trend of agricultural products export. Until recently jute has been the main export product of Bangladesh and it accounted for 88% of total agricultural products export. In 1970, though the share of jute in total agricultural products export was still high, the export amount itself started declining, and later, along with the growth of other products, its share also started declining, down to about 30% in 2013. Export of tea leaves, which used to be the second largest agricultural product after jute, also started declining from 1990s and its export in 2013 was less than 10% of that in 1961.
In the meanwhile, the export of fruits and vegetables started expanding from mid-2000s, after a dip in late-2000 which is considered due to the Global Financial Crisis, it again started growing rapidly. In 2013, they accounted for 32% of total agricultural products export. The export value of fruits and

vegetables has increased by 16 times in 23 years (12.8% p.a.) from 9 million USD in 1990 to 144 million USD in 2013.



Source: FAO Statistics

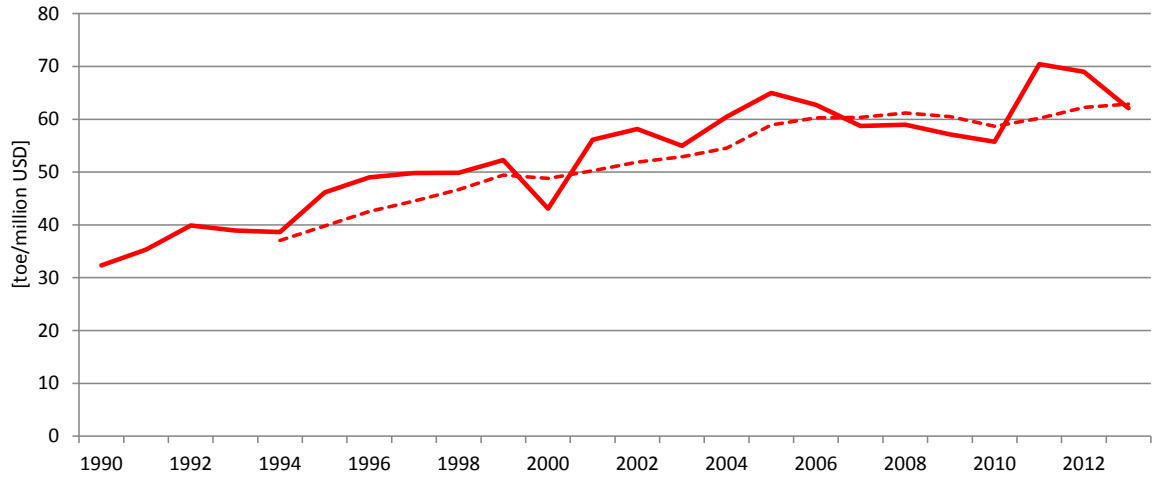
Figure 6-37 Historical Trend of Agricultural Products Export in Bangladesh

It needs to be noted that these value-added products generally require more care for preserving quality and freshness. In order to achieve this, a modernized storage system needs to be established so that these products are conserved and transported in an appropriate temperature, along with the logistic system to enable quick transport and packaging, and marketing system to support them.
In order to achieve this and to enhance the international competitiveness of export products, development of infrastructure is inevitable, especially that for electricity supply, which is also pointed out by a World Bank report[21].

6.5.2 Projection of energy consumption

Figure 6-38 shows the historical trend of agricultural sector's energy consumption in Bangladesh divided by the sectorial value added of agriculture (constant price), along with its five-year moving average (indicated as a dotted line). Like the analysis on the industrial sector, this is a ratio of energy consumption to sectorial valued added (= GDP) to analyze how much energy (toe) is consumed for the sector to yield of 1 million USD
Though there's an increase and decrease from year to year, a gradually increasing trend can be observed. This is probably because the agricultural production is shifting to more value-added products and more energy needs to be consumed for producing a same value in the sector as discussed in the previous section.
However, this creeping trend is has been moderate since mid-2000s, probably because the increasing value-added is high enough to cover the increasing energy consumption.

[21] World Bank "High-value Agriculture in Bangladesh: An Assessment of Agro-business Opportunities and Constraints" (2008)

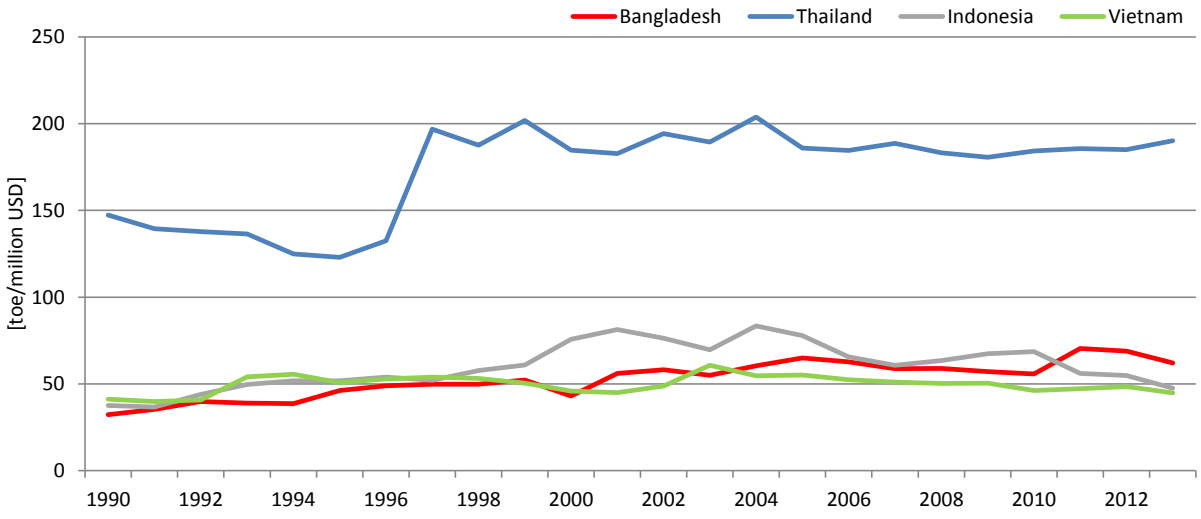


Source: Prepared by JICA Survey Team based on World Bank database and IEA energy balances
Note) Dotted line is the five-year moving average

Figure 6-38 Agricultural Sector's Energy Consumption per Sectorial Value Added

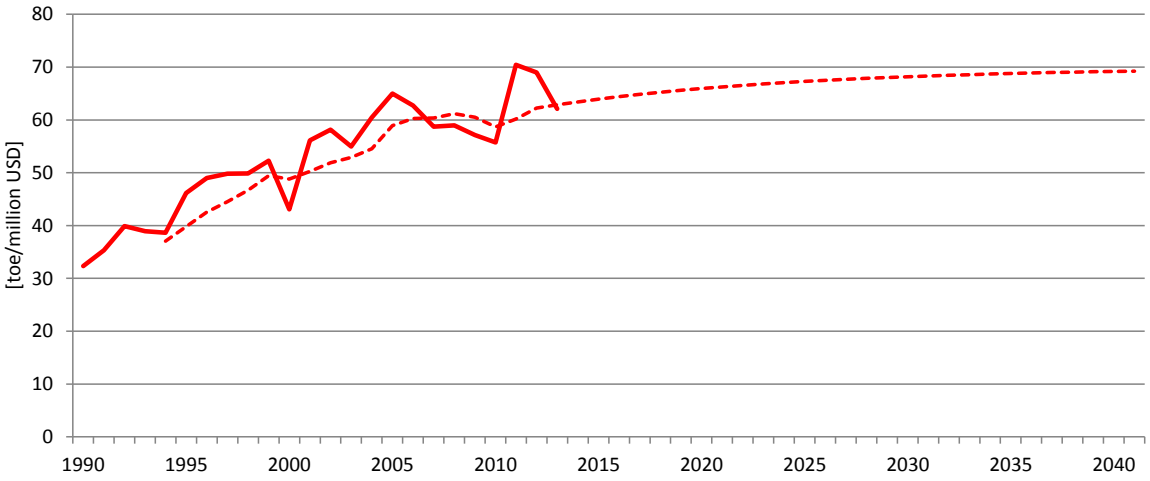
Figure 6-39 compares this historical trend with ASEAN countries (Thailand, Indonesia and Vietnam). The historical trend in Indonesia and Vietnam is similar to that in Bangladesh, ranging mostly between 50 and 70 toe/million USD since 2000s.

Considering that the historical trend in Thailand has been much higher than the other three countries, the reliability of statistic data needs to be doubted, at least in terms of international comparison. However, referring to the performance in Indonesia and Vietnam, this study assumes that a creeping trend of agricultural sector's energy intensity will continue until moderately it reaches to toe/million USD, as shown in Source: JICA Survey Team
Figure 6-40.



Source: Prepared by JICA Survey Team based on World Bank database and IEA energy balances

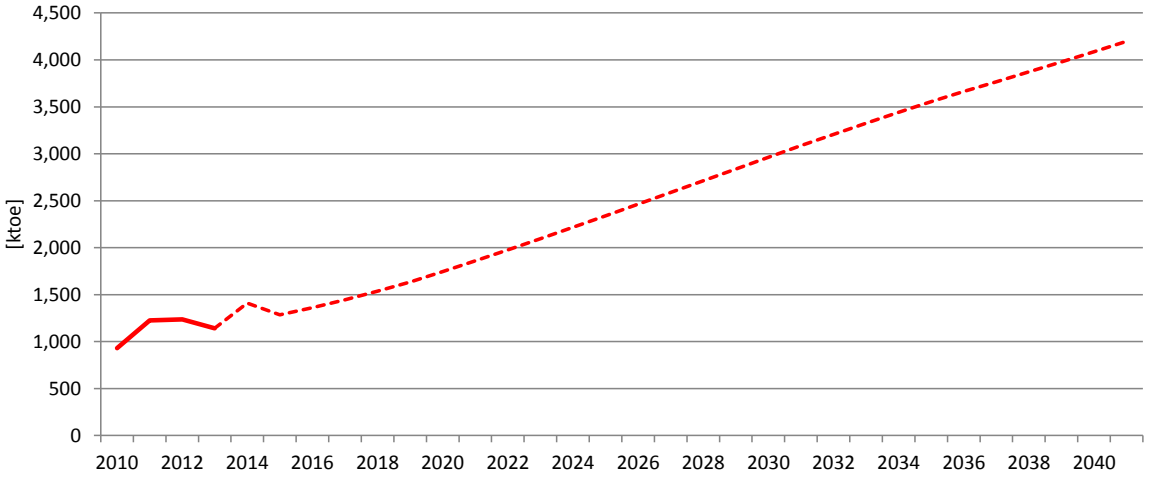
Figure 6-39 Agricultural Sector's Energy Consumption per Sectorial Value Added (Comparison with ASEAN Countries)



Source: JICA Survey Team

Figure 6-40 Projection of Agricultural Sector's Energy Consumption per Sectorial Value Added

Agricultural sector's energy consumption will reach around 4,200 ktoe in 2041, about four times increase from 2013, as shown in Figure 6-41.



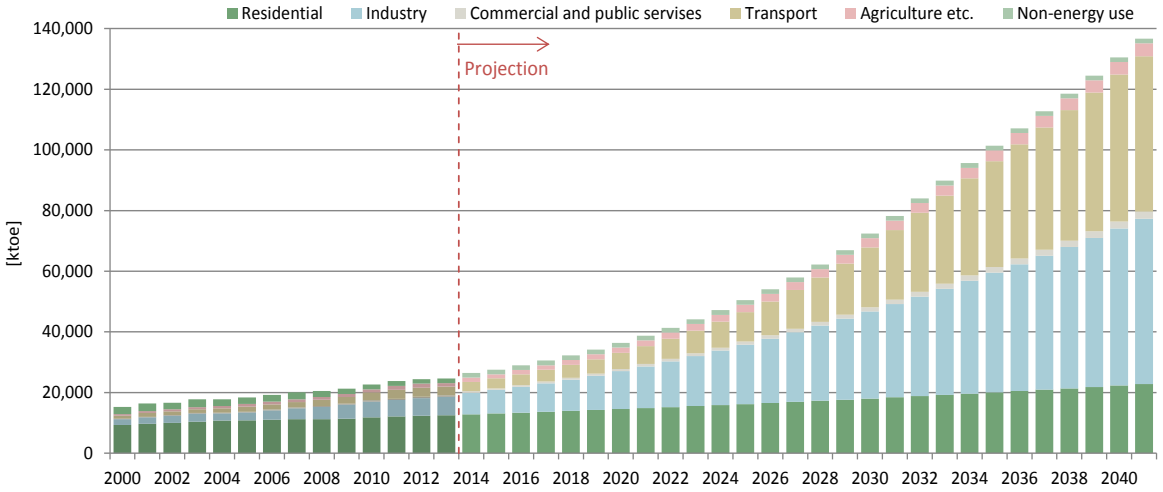
Source: JICA Survey Team

Figure 6-41 Projection of Agricultural Sector's Energy Consumption

6.6 Total Energy Supply & Demand Balance Up to 2041

6.6.1 Projection of total final energy consumption

The projection of final energy consumption in the BAU (business as usual) scenario, which is the sum of energy consumption of each sector as explained in the previous sections of this chapter, is shown in Figure 6-42 and Table 6-9.
In this BAU scenario, industrial sector, which is expected to grow by 7.8% p.a. from 2014 to 2041, will become the largest sector of energy consumption. Transport sector, which is expected to grow by 11.0% p.a., will consume almost as much energy as the industrial sector.
In the meanwhile, residential sector, which accounted for about half of the total energy consumption, will see a relatively moderate growth and its share in the total energy consumption is expected to decline.



Source: JICA Survey Team

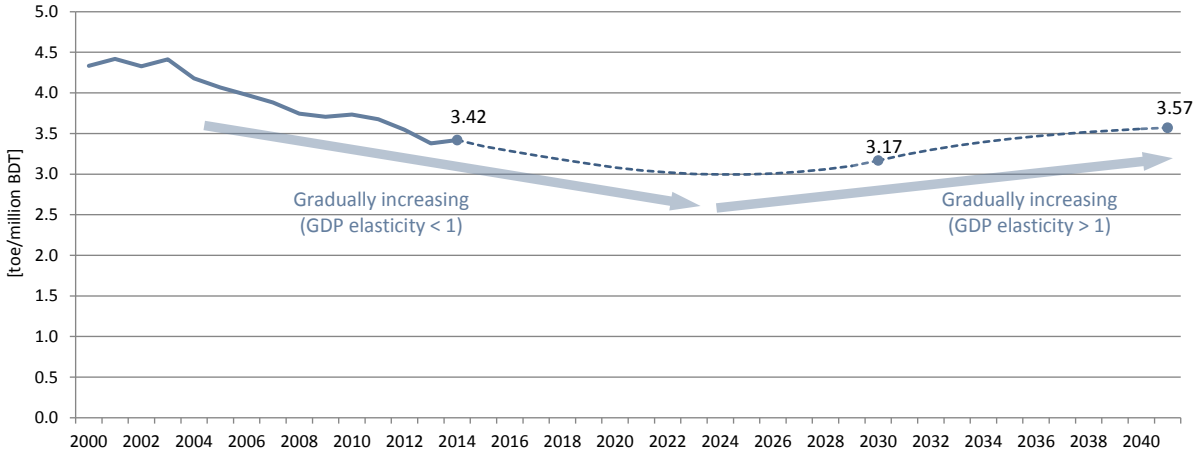
Figure 6-42 Projection of Total Final Energy Consumption – BAU Scenario

Table 6-9 Projection of Total Final Energy Consumption – BAU Scenario

Sectors	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Residential	12,815	(48%)	**22,797**	**(17%)**	**2.2% p.a.**
Industrial	7,116	(27%)	**54,525**	**(40%)**	**7.8% p.a.**
Commercial & Public Service	475	(2%)	**2,369**	**(2%)**	**6.1% p.a.**
Transport	3,080	(12%)	**51,187**	**(37%)**	**11.0% p.a.**
Agriculture	1,409	(5%)	**4,197**	**(3%)**	**4.1% p.a.**
Others	47	(0%)	**47**	**(0%)**	**0.0% p.a.**
Non-energy use	1,534	(6%)	**1,534**	**(1%)**	-
Total	**26,475**	**(100%)**	**136,655**	**(100%)**	**6.3% p.a.**

Source: JICA Survey Team

The total final consumption (TFC) is expected to grow by 5.1 times from 2014 to 2041, i.e. 6.3% p.a. increase. The projection of GDP growth during the same period is 6.1%, hence the GDP elasticity of energy consumption during the projection period, which is the ratio of energy consumption's growth rate divided by GDP growth rate, is slightly higher than 1 (about 1.03).
Figure 6-43 is the historical trend and projection of energy intensity, which is the ratio of total final energy consumption divided by GDP (real base). When the country's GDP is continuously growing, its GDP elasticity becomes lower than 1 when the energy intensity decreases, and the GDP elasticity becomes higher than 1 when the energy intensity increases.
Since 2000s, Bangladesh has seen a declining trend of energy intensity, i.e. GDP elasticity of energy consumption has been lower than 1, and this trend is expected to continue until mid-2020s due to the moderate growth of residential sector energy consumption that currently accounts for about half of the total energy consumption. Energy intensity will decrease from 3.42 toe/million BDT in 2014 to around 3 toe/million BDT (-12% down from 2014) during that period.
However, the energy intensity will start increasing afterwards, i.e. GDP elasticity becomes higher than 1. This is because the industrial sector and the transport sector, which are expected to grow higher than GDP, will account for a larger share in the total energy consumption. Energy intensity will increase to 3.17 toe/million BDT in 2030 (-8% down from 2014), and then 3.57 toe/million BDT in 2041 (4% up from 2014). As a result, GDP elasticity of the entire projection period (from 2014 to 2041) will become higher than 1.



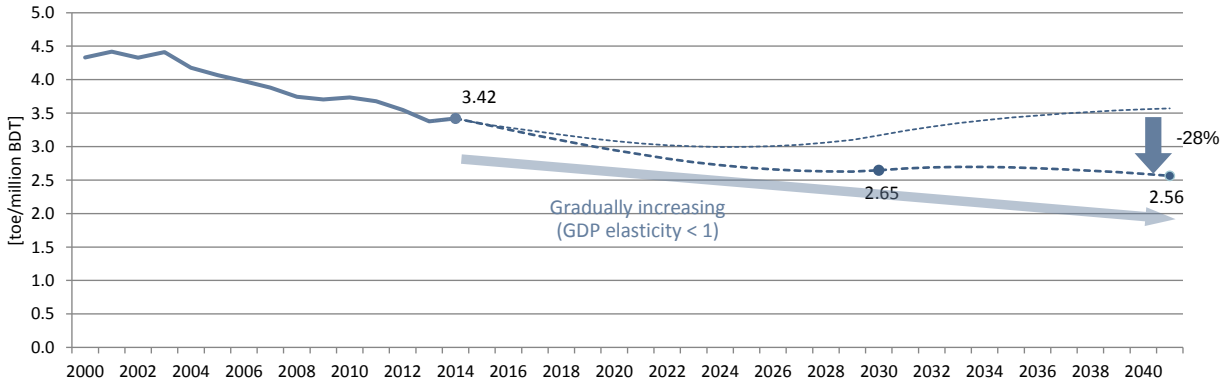
Source: JICA Survey Team

Figure 6-43 Historical Trend and Projection of Energy Intensity – BAU Scenario

Following the projection of BAU scenario, this study forecasted an "energy efficiency scenario", expecting that energy efficiency measures are to be implemented in Bangladesh for mitigating the rapid increase of energy consumption. Referring to "Energy Efficiency and Conservation Master Plan up to 2030" (EECMP), which was published by Sustainable and Renewable Energy Development Authority (SREDA) and Power Division in March 2015 with the technical assistance by JICA, this study expects that the following targets will be achieved by implementing the measures as specified in EECMP.

- 2.65 toe/million BDT in 2030 (down -23% from 2014);
- 2.56 toe/million BDT in 2041 (down -25% from 2014);

In this case, the energy intensity is expected to decrease continuously, though the pace may become moderate. GDP elasticity of the projection period will become lower than 1.



Source: JICA Survey Team

Figure 6-44 Historical Trend and Projection of Energy Intensity - Energy Efficiency Scenario

The aforementioned reduction of energy intensity appears to be different from the energy efficiency target of EECMP, which declares that "approx. 20% reduction of primary energy consumption per GDP can be achieved by 2030 (and) 15% reduction of primary energy consumption per GDP is to be achieved" by 2021. This discrepancy is due to the different definition of energy intensity. For example, energy intensity in EECMP does not include the whole energy consumption of the transport sector and biofuel consumption of the residential sector. Using the same definition as that of EECMP, the energy intensity as of 2030 is 2.46 toe/million BDT, down 20% from 3.06 toe/million BDT in 2014, that is, energy efficiency target has not been changed from EECMP. In the same definition, the energy intensity in 2041will decline to 2.36 toe/million BDT, which is 23% decrease from 2014. [22]

In order to achieve the aforementioned energy efficiency target, the total energy consumption needs to be reduced by 16% as of 2030, and by 28% as of 2041. The sector-wise target of energy efficiency to achieve this is shown in Table 6-10. EECMP set the reduction of energy consumption against BAU scenario in residential sector and industrial sector at 23.0% and 16.8% respectively as of 2030. Because this study's projection of energy consumption in both sectors is more conservative than EECMP, the reduction of energy consumption against BAU scenario in 2030 is adjusted to 21% for residential sector and 15% for industrial sector.
Energy efficiency target for transport sector was not covered in EECMP, but, as discussed in Section 6.4.2 , energy consumption of this sector is expected to grow very rapidly in BAU scenario. Hence this study suggests setting an ambitious target of 33% reduction of transport sector energy consumption against BAU scenario as of 2041. This means that this sector's energy consumption will be controlled so that is will not exceed the level in BAU scenario as of mid-2030s when the rapid growth of economy and motorization is reaching certain maturity.

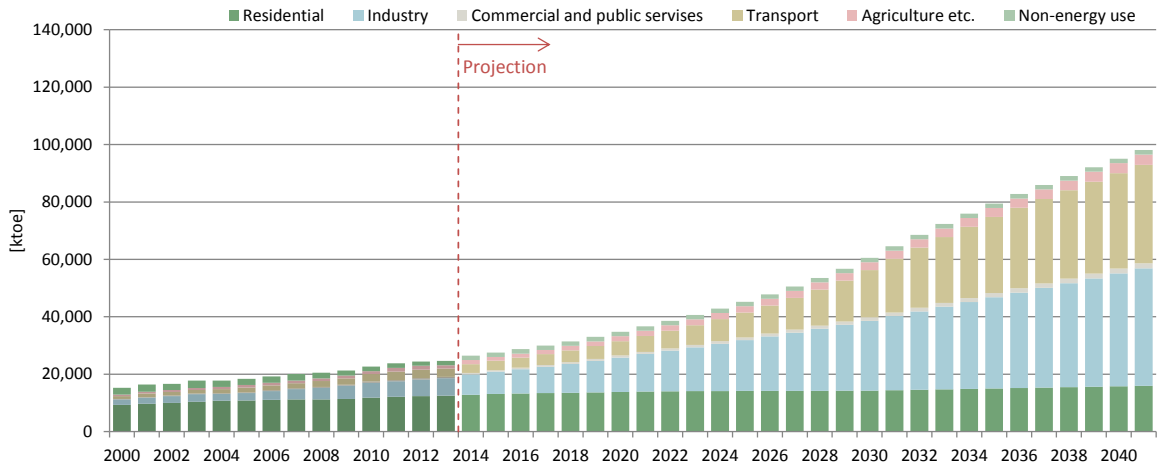
[22] Assuming that the Scenario 3 is chosen among six scenarios of power development that are discussed in Chapter 11.

Table 6-10 Sector-wise Energy Efficiency Target

Sectors	Reduction from BAU Scenario			Energy Intensity: Down from 2014		
	2021	2030	2041	2021	2030	2041
Residential	-6%	-21%	-30%			
Industrial	-5%	-15%	-25%			
Commercial & Public Service	-5%	-17.5%	-25%			
Transport	-6.6%	-16.5%	-33%			
Agriculture	-3%	-10.5%	-15%			
Total	**-5.3%**	**-16.4%**	**-28.2%**	**-15.7%**	**-22.6%**	**-25.1%**

Source: JICA Survey Team

Projection of total energy consumption considering the achievement of aforementioned energy efficiency targets is shown in Figure 6-45 and Table 6-11. The average growth rate of total final energy consumption will be 5.0% p.a. from 2014 to 2041, which is lower than GDP growth rate in the same period.



Source: JICA Survey Team

Figure 6-45 Projection of Total Final Energy Consumption – Energy Efficiency Scenario

Table 6-11 Projection of Total Final Energy Consumption – Energy Efficiency Scenario

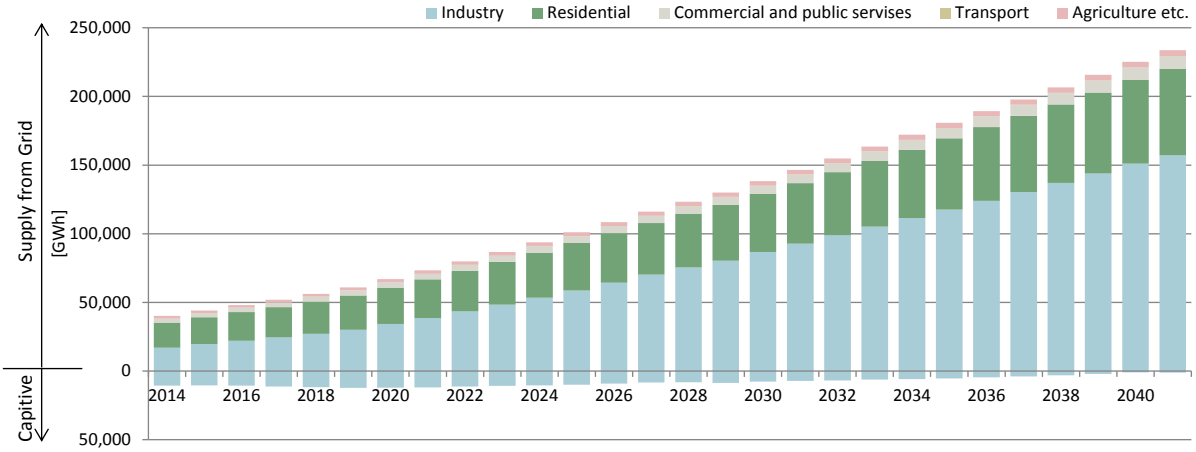
Sectors	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Residential	12,815	(48%)	**15,958**	**(16%)**	**0.8% p.a.**
Industrial	7,116	(27%)	**40,893**	**(42%)**	**6.7% p.a.**
Commercial & Public Service	475	(2%)	**1,776**	**(2%)**	**5.0% p.a.**
Transport	3,080	(12%)	**34,295**	**(35%)**	**9.3% p.a.**
Agriculture	1,409	(5%)	**3.568**	**(4%)**	**3.5% p.a.**
Others	47	(0%)	**47**	**(0%)**	**0.0% p.a.**
Non-energy use	1,534	(6%)	**1,534**	**(2%)**	**-**
Total	**26,475**	**(100%)**	**98,071**	**(100%)**	**5.0% p.a.**

Source: JICA Survey Team

Source: JICA Survey Team

Figure 6-46 shows the projection of electricity consumption in the "Energy Efficiency Scenario". The area above the "0" horizontal axis in this figure is the consumption of electricity supplied from the

grid wheras the area below this line is the electricity consumption from capitive power generation. For convenience, all the captive power generation is classified in the industrial sector. Because the growth rate of the industrial sector energy demand is higher than other sectors, its share in the total electicity will become still higher. Captive power generation will be gradually decrease after 2020s when the capacity of grid power supply is strengthened.



Source: JICA Survey Team

Figure 6-46 Projection of Electricity Consumption – Energy Efficiency Scenario

6.6.2 Projection of total primary energy supply

Based on the projection of total final energy consumption in the energy efficiency scenario, which was discussed in the previous sections, the total primary energy supply (TPES) in Bangladesh up to 2041 is projected. Methodologies for projecting TPES are as follows.

- Breakdown of the modes of energy supply to end consumption, such as electricity, gas, oil products, is determined for each sector.
  - Industrial sector:
    Considering that the share of each mode of energy supply has been almost constant for the past years, the same share as the current level will be maintained for several years to come, that is "Electricity: about one-third, Natural gas: about half, Coal: about 10%, Oil: remainder".
    A gradual shift from natural gas to electricity will occur in the long run, considering that the natural gas usage for captive power generation will be gradually replaced by the power supply from the grid.
  - Transport sector:
    Since 2000s, conversion to CNG has been promoted in Bangladesh, but recently opinion to review this trend has been raised, reflecting the possible shortage of domestic gas production. On the contrary, there's also an argument that increasing dependence on oil products (including LPG) should be avoided and that continued promotion of CNG using imported LNG is preferred.
    Because there appears to be no decisive direction with this regard at the moment, this study assumes that the same share as the current level, that is "Natural gas: about one-third, Oil: two-thirds". Decision on the fuel usage for road transport can be a big variation factor for the future primary energy supply.
    In addition, usage of electricity in the transport sector following the development of modernized railway system (including MRT in Dhaka area) is also considered, though its impact on the total energy consumption is not very large.
  - Residential sector:
    A shift from conventional energy sources (e.g. firewood etc.) will be gradually replaced by

modern energy sources such as electricity and gas, as discussed in Section 6.2.3 .
This study's assumption reflected the opinion of some local stakeholders that the natural gas supply to new residential customers and that it will be substituted by LPG. As a result, the share of LPG in residential sector will be significantly increased.

- Commercial & public services sector:
  Because the historical trend of the share is "Electricity: about half, Natural gas: about half" and this ratio has been almost constant, this study assumed that the same share as the current level will be maintained.
- Agriculture, others:
  This study assumed that the same share as the current level will be maintained.

- Conversion and transfer from primary energy supply to final energy consumption
  - Regarding the energy conversion from primary to electricity supply, several scenarios of fuel mix for power generation was considered, as discussed more specifically in Chapter 11. There are six scenarios of fuel mix varying the composition of natural gas and coal for power generation, among which the Scenario 1 depends maximally on coal usage whereas the Scenario 5 relies maximally on natural gas. Scenarios from 1 to 5 assume that the power import from other countries will expand as expected and Scenario 6 is also prepared to assume that this plan is not realized as expected.
  - Loss of fuel and electricity in transferring to end consumption is considered referring to the historical trend.
  - Thermal efficiency in fuel combustion for electricity generation is considered referring to the projection as discussed in in Chapter 11.
- In this chapter, necessary volume of primary energy supply to meet the final energy consumption was calculated. How to procure this primary energy supply, such as domestic production, import, and export of energy, will be discussed in the following chapters.

Reflecting the five scenarios of power development that are evaluated in Chapter 11, the projection of primary energy supply and the table of energy supply and demand balances are shown in the following figures and tables.

- Scenario 1: Source: JICA Survey Team
  Figure 6-47, Table 6-13 and Table 6-14;
- Scenario 2: Source: JICA Survey Team
  Figure 6-48, Table 6-15 and Table 6-16;
- Scenario 3: Source: JICA Survey Team
  Figure 6-49,Table 6-17 and Table 6-18;
- Scenario 4: Source: JICA Survey Team
  Figure 6-50, Table 6-19 and Table 6-20;
- Scenario 5: Source: JICA Survey Team
  Figure 6-51, Table 6-21 and Table 6-22;

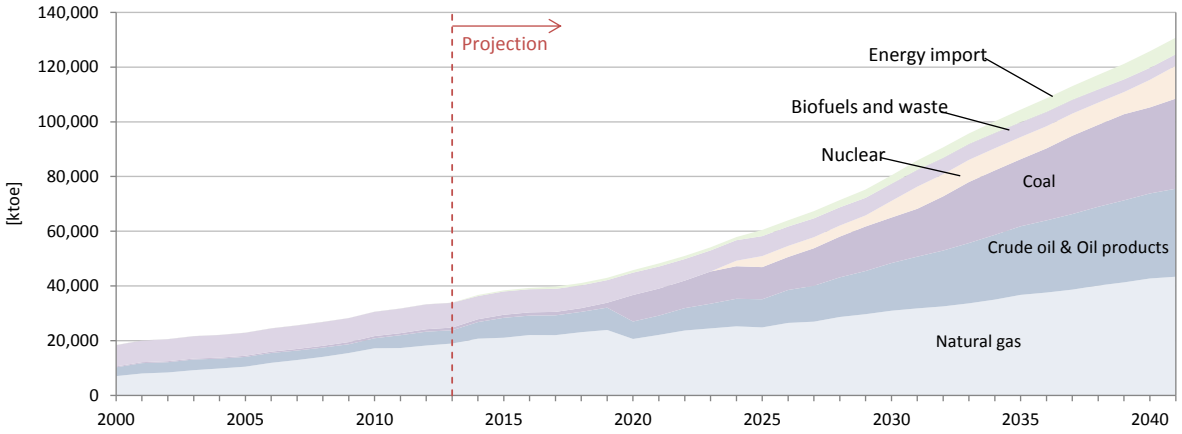
Up to mid-2020s the energy supply and demand balances are the same in all of the five scenarios of power development. For reference, the energy supply and demand balances as of 2021 is shown in Table 6-12.

Table 6-12 Energy Supply and Demand Balances in 2021 –All Scenarios

Year: 2021 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	9,723	1,361	5,625	21,925	0	36	8,030	1,507	48,207
Electricity plants	-8,281	0	-49	-8,378	0	-36	0	8,811	-7,933
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-26		-72	-346			-144	-1,450	-2,038
Total final consumption	1,416	0	6,825	13,201	0	0	7,885	7,361	36,688
Industry	1,416		330	6,958				4,341	13,045
Transport			3,756	1,769				3	5,528
Residential			1,028	2,654			7,885	2,420	13,987
Commercial and public services			0	350				394	743
Agriculture/forestry			1,619	28				157	1,804
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-47 Projection of Total Primary Energy Supply –Scenario 1

Table 6-13 Projection of Total Primary Energy Supply –Scenario 1

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**44,149**	**(33%)**	**2.8% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(24%)**	**6.2% p.a.**
Coal	1,361	(4%)	**33,747**	**(26%)**	**13.8% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**129**	**(0%)**	**4.9% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**132,233**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-14 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 1

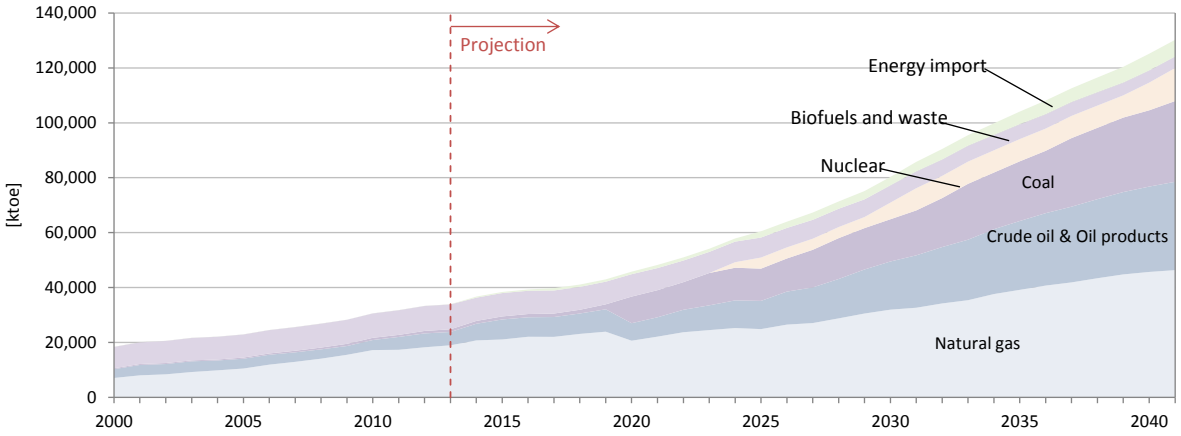
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,637	1,361	17,448	33,119	7,953	172	6,009	3,390	86,090
Electricity plants	-13,782	0	-365	-8,234	-7,953	-172	0	15,967	-14,539
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	33,747	1,361	30,792	44,149	11,942	129	4,086	6,027	132,233
Electricity plants	-29,226	0	-1	-5,803	-11,942	-129	0	24,333	-22,768
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-48 Projection of Total Primary Energy Supply –Scenario 2

Table 6-15 Projection of Total Primary Energy Supply –Scenario 2

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**46,627**	**(35%)**	**3.0% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(24%)**	**6.2% p.a.**
Coal	1,361	(4%)	**30,641**	**(23%)**	**13.4% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**143**	**(0%)**	**5.3% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**131,619**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-16 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 2

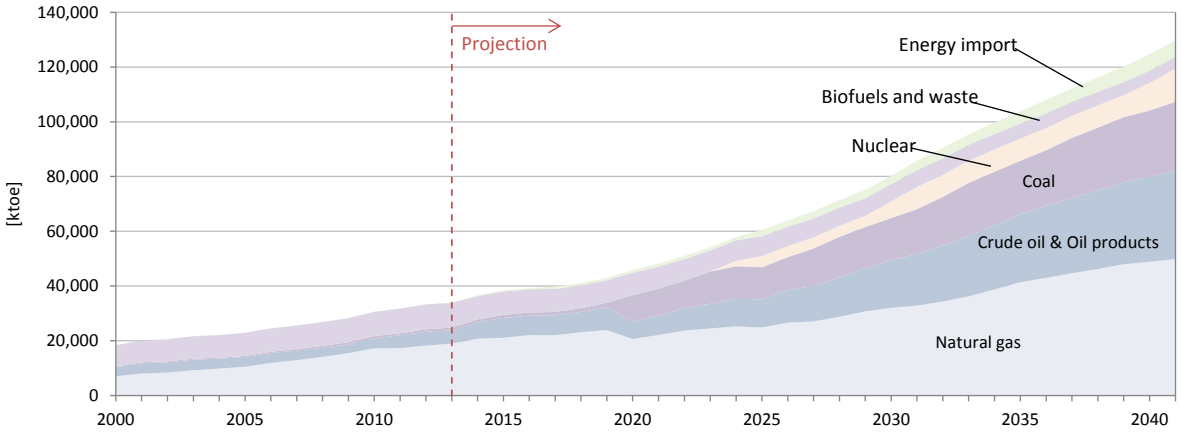
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,637	1,361	17,448	33,119	7,953	172	6,009	3,390	86,090
Electricity plants	-13,782	0	-365	-8,234	-7,953	-172	0	15,967	-14,539
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	30,641	1,361	30,792	46,627	11,942	143	4,086	6,027	131,619
Electricity plants	-26,120	0	-1	-8,281	-11,942	-143	0	24,333	-22,153
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-49 Projection of Total Primary Energy Supply –Scenario 3

Table 6-17 Projection of Total Primary Energy Supply –Scenario 3

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**50,149**	**(38%)**	**3.3% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(25%)**	**6.2% p.a.**
Coal	1,361	(4%)	**26,273**	**(20%)**	**12.7% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**197**	**(0%)**	**6.5% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**130,827**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-18 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 3

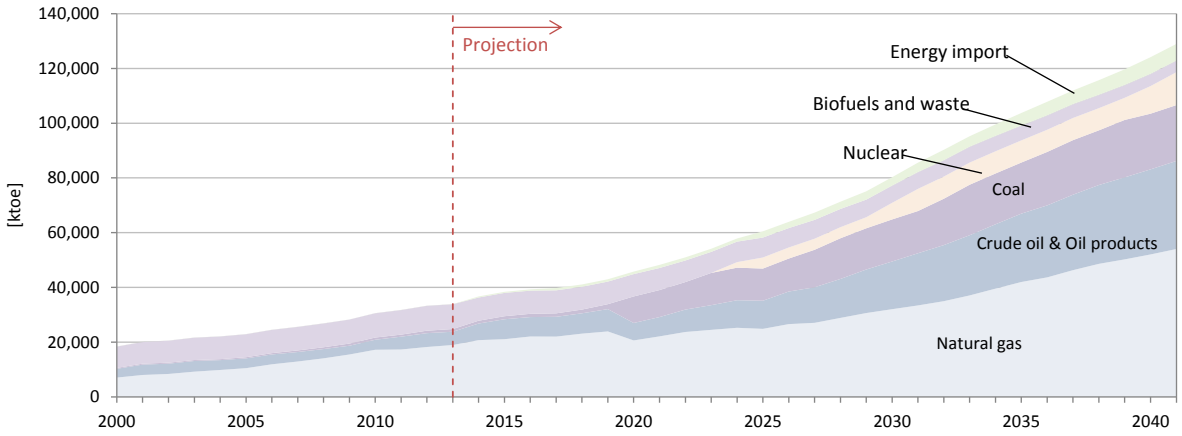
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,637	1,361	17,448	33,119	7,953	172	6,009	3,390	86,090
Electricity plants	-13,782	0	-365	-8,234	-7,953	-172	0	15,967	-14,539
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	26,273	1,361	30,792	50,149	11,942	197	4,086	6,027	130,827
Electricity plants	-21,752	0	-1	-11,803	-11,942	-197	0	24,333	-21,362
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-50 Projection of Total Primary Energy Supply –Scenario 4

Table 6-19 Projection of Total Primary Energy Supply –Scenario 4

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**54,493**	**(42%)**	**3.6% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(25%)**	**6.2% p.a.**
Coal	1,361	(4%)	**20,922**	**(16%)**	**11.8% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**204**	**(0%)**	**6.7% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**129,826**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-20 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 4

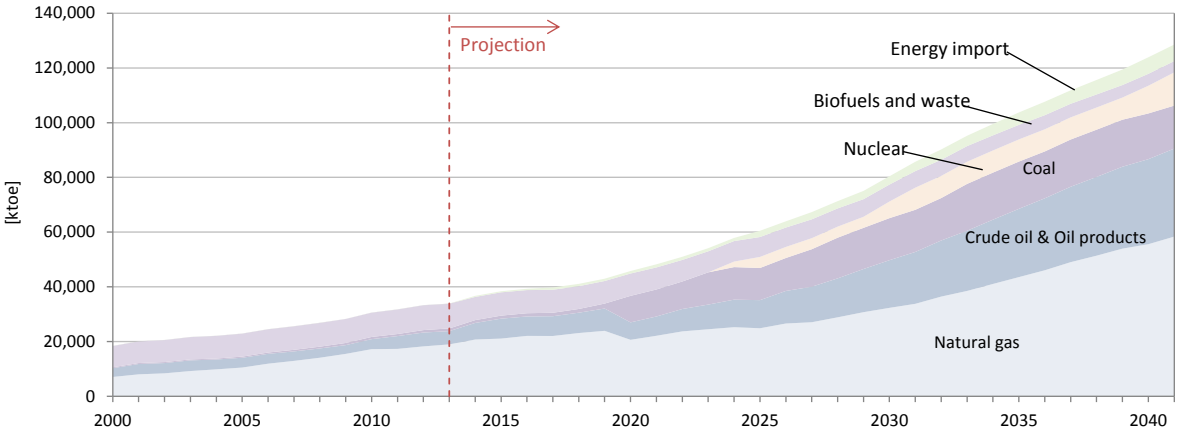
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,573	1,361	17,348	33,277	7,953	163	6,009	3,390	86,075
Electricity plants	-13,718	0	-265	-8,392	-7,953	-163	0	15,967	-14,524
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	20,922	1,361	30,792	54,493	11,942	204	4,086	6,027	129,826
Electricity plants	-16,401	0	-1	-16,146	-11,942	-204	0	24,333	-20,361
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-51 Projection of Total Primary Energy Supply –Scenario 5

Table 6-21 Projection of Total Primary Energy Supply –Scenario 5

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**58,726**	**(46%)**	**3.9% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(25%)**	**6.2% p.a.**
Coal	1,361	(4%)	**15,677**	**(12%)**	**10.6% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**207**	**(9%)**	**6.7% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**128,817**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-22 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 5

Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	15,228	1,361	17,683	34,121	7,953	171	6,009	3,390	85,917
Electricity plants	-12,373	0	-600	-9,236	-7,953	-171	0	15,967	-14,366
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	15,677	1,361	30,792	58,726	11,942	207	4,086	6,027	128,817
Electricity plants	-11,156	0	-1	-20,379	-11,942	-207	0	24,333	-19,352
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

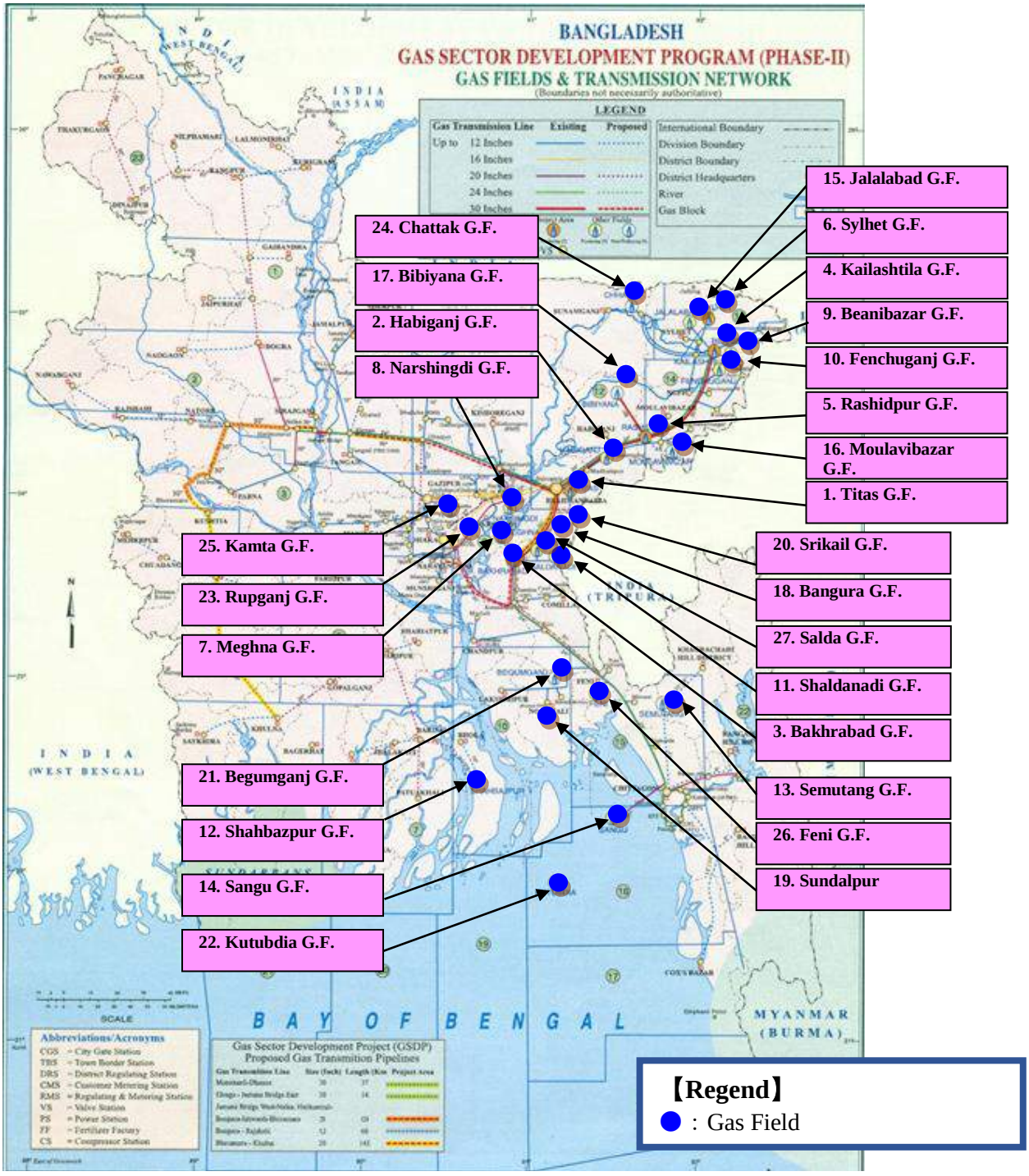
Source: JICA Survey Team

Chapter 7 Domestic Natural Gas Supply

7.1 Natural Gas Reserve

7.1.1 Gas field location

To date 26 gas fields has been discovered in Bangladesh as shown in Figure 7-1



Source: Domestic Gas Field Location Map for "Proved Reserves" provided by Petrobangla

Figure 7-1 Gas Field Location Map

Geology of Bangladesh started from Upper Paleozonic time when eastern Gondwanaland was broken up. Part of the fragment, Indian Plate, drifted and collided with Asian Plate, and subsided in the period of Oligocene-Holocene Orogenic, and up to now.

The country is divided into three major lithostratigraphic units as follows:

- Folding Bed in the Eastern part of Bangladesh
- Fore Deep in the Central part of Bangradesh
- Stable Shelf and Hinge Zone in the West and North West part of Bangladesh

Majority of gas fields discovered in Bangladesh to date are located in the Folding Bed and adjacent eastern part of Foredeep areas.

These areas are extended from east part of Dhaka to the west and Sylhet Division to the north and Comilla, Chittagon and Cox's Bazar to the south.

The gas of this area has been generated at the depth of 6,000-8,000 m below the surface and migrated up through multi-kilometer sand shale sequence for long vertical distance before being accumulated in the Mio-Pliocene sand reservoirs at the depth of 1,000-4000 m. Some amounts of gases are accumulated at the depth of 1,000 m, known as Pocket Gas.

Special care is required to develop gas in this area due to a fragile nature of strata and reservoir sandstones. They are young and not fully solidified. Four major blowouts have occurred in the Sylhet area, and lost significant amount of gas resources. Gas is still leaking out to the atmosphere from these blown out wells.

Stable Shelf and Hinge Zone in the West and North West part of the country is covered by a sedimentation deposit of Upper Paleozonic to Lower Cretazeous era. According to the report by USGS/Petrobangla 2001, potential of gas and oil deposit in the area is not as high as Folding Bed area, and commercial scale gas field has not been discovered in this area so far.

Natural gas produced in Bangladesh contains 95-99% methane and all others are hydrocarbon components. It contains almost no other impurities such as hydrogen sulfide, carbon dioxide and/or nitrogen.

Produced gas entrains significant amount of condensate. Production of condensate in Bangladesh is 7,800 bpd, with the gas production of 2,500 mmscfd, or 3 bbl/mmcf, in December 2014. Rate of condensate production per unit gas production is higher in the Sylhet area, and Beanibazar produces 16 bbl/mmcf.

7.1.2 Gas reserve evaluation

The gas reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019" prepared by Petrobangla is provided as a basis for production forecasts in this study.

Data of gas reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019" is considered updates of those used in the Petrobangla Annual Report 2013. The updated points are as follows:

- Addition of the data on the Rupganj gas field discovered in 2014
- Remaining 2P reserves are as of January 2015

Gas reserves used for production forecasts in PSMP2010 were based on the report by Hydrocarbon Unit (HCU) (2011) (called as "HCU report" hereafter).

On the other hand, the gas reserves in this Study are based on the "Draft Five Year Gas Supply Strategy 2015-2019"

The reserves (except for the Rupganj field) shown in the draft policy are updates of those shown in Petrobangla Annual Report 2013 and are also the same as those shown in Petrobangla Annual Report 2014.

Comparison of the gas reserves between the HCU report and Petrobangla's "Draft Five Year Gas Supply Strategy 2015-2019" was shown in the Figure 7-1. The summary is as follows:

- The gas reserves shown in the HCU report were originally prepared by Gustavson Associates, US-based consulting company. On the other hand, the gas reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019" were prepared by updating those in the Petrobangla Annual Report 2013, which were derived from different sources such as RPS Energy, a UK-based consulting company, and Petrobangla.

- The HCU report was prepared in 2011, whereas the RPS Energy's report was prepared in 2009, which was cited for the estimates of the gas reserves on most of the fields shown in the Petrobangla Annual Reports 2011 to 2014. Note that some of the gas reserves shown in the "Draft Five Year Gas Supply Strategy" (or Petrobangla Annual Report 2014) are updated.

- Recoverable gas reserves estimated by HCU are slightly larger than that of Petrobangla's "Draft Five Year Gas Supply Strategy 2015-2019" due presumably to a difference of reserve modeling/production philosophy.

Table 7-1 Comparison of Natural Gas Reserves Estimated by HCU (2011) and Petrobangla (2015)

Unit: BCF

Sl. No.	Gas Field	Year of Discovery	Reserves Estimated by				GIIP		Recoverable Reserves Proved (1P)		Recoverable Reserves Proved + Probable (2P)		Remaining 2P Reserves	
			HCU (2011)		Petrobangla (2015)		HCU	Petrobangla	HCU	Petrobangla	HCU	Petrobangla	HCU	Petrobangla
			Company	Year	Company	Year	Dec. 2009	Dec. 2014	Dec. 2009	Dec. 2014	Dec. 2009	Dec. 2014	Dec. 2009	Jan. 2015
A. Producing														
1	Titas	1962	Gustavson Assoc.	2010	RPS Energy	2009	9,039	8,148.9	6,838	5,384.0	7,582	6,367.0	4,514	2,515.7
2	Habiganj	1963	Gustavson Assoc.	2010	RPS Energy	2009	3,981	3,684.0	2,413	2,238.0	2,787	2,633.0	1,116	523.8
3	Bakrabad	1969	Gustavson Assoc.	2010	RPS Energy	2009	1,825	1,701.0	1,201	1,052.9	1,387	1,231.5	689	456.4
4	Kailashtila	1962	Gustavson Assoc.	2010	RPS Energy	2009	3,463	3,610.0	2,553	2,390.0	2,880	2,760.0	2,400	2,163.6
5	Rashidpur	1960	Gustavson Assoc.	2010	RPS Energy	2009	3,887	3,650.0	2,416	1,060.0	3,134	2,433.0	2,677	1,889.8
6	Sylhet/Haripur	1955	Gustavson Assoc.	2010	RPS Energy	2009	580	370.0	323	256.5	408	318.9	219	113.6
7	Meghna	1990	Gustavson Assoc.	2010	RPS Energy	2009	122	122.1	76	52.5	101	69.9	65	16.8
8	Narshingdi	1990	Gustavson Assoc.	2010	RPS Energy	2009	405	369.0	317	218.0	345	276.8	239	116.4
9	Beani Bazar	1981	Gustavson Assoc.	2010	RPS Energy	2009	225	230.7	108	150.0	137	203.0	77	115.3
10	Fenchuganj	1988	Gustavson Assoc.	2010	RPS Energy	2009	483	553.0	195	229.0	329	381.0	258	256.2
11	Saldanadi	1996	Gustavson Assoc.	2010	RPS Energy	2009	393	379.9	156	79.0	275	279.0	215	197.4
12	Shahbazpur	1995	Gustavson Assoc.	2010	Petrobangla	2011	415	677.0	214	322.0	261	390.0	260	379.5
13	Semutang	1969	Gustavson Assoc.	2010	RPS Energy	2009	654	653.8	318	151.0	318	317.7	318	308.0
14	Sundulpur Shahzadpur	2011	Gustavson Assoc.	2010	BAPEX	2012	—	62.2	—	25.0	—	35.1	—	27.1
15	Srikail	2012	Gustavson Assoc.	2010	BAPEX	2012	—	240.0	—	96.0	—	161.0	—	135.6
16	Jalalabad	1989	Gustavson Assoc.	2010	D & M	1999	1,346	1,491.0	1,013	823.0	1,128	1,184.0	583	281.2
17	Moulavi Bazar	1997	Gustavson Assoc.	2010	Unocal	2003	630	1,053.0	402	405.0	494	428.0	342	160.5
18	Bibiyana	1998	Gustavson Assoc.	2010	D & M	2008	5,321	8,350.0	4,075	4,415.0	4,532	5,754.0	4,056	3,873.2
19	Bangura	2004	Gustavson Assoc.	2010	Tulllow	2011	730	1,198.0	558	379.0	621	522.0	522	241.0
B. Non-Producing														
20	Begumganj	1977	Gustavson Assoc.	2010	BAPEX	2014	47	100.0	10	14.0	33	70.0	33	70.0
21	Kutubdia	1977	Gustavson Assoc.	2010	HCU	2003	65	65.0	46	45.5	46	45.5	46	45.5
22	Rupganj	2014	—	—	BAPEX?	2014	—	48.0	—	—	—	33.6	—	33.6
C. Production Suspended														
22	Chhatak	1959	Gustavson Assoc.	2010	HCU	2000	677	1,039.0	265	265.0	474	474.0	448	447.5
23	Kamta	1981	Gustavson Assoc.	2010	Niko/BAPEX	2000	72	71.8	21	50.3	50	50.3	29	29.2
24	Feni	1981	Gustavson Assoc.	2010	Niko/BAPEX	2000	185	185.2	63	125.0	130	125.0	67	62.6
25	Sangu	1996	Gustavson Assoc.	2010	Cairn/Shell	2010	976	899.6	678	544.4	771	577.8	304	89.9
Total (A + B + C) in BCF							**35,522**	**38,952.2**	**24,255**	**20,770.1**	**28,222**	**27,121.1**	**19,476**	**14,549.4**
Total (A + B + C) in TCF							**35.5**	**39.0**	**24.3**	**20.8**	**28.2**	**27.1**	**19.5**	**14.5**

Source: Prepared based on HCU (2011) and Petrobangla (2015) ("Draft Five Year Gas Supply Strategy 2015-2019")

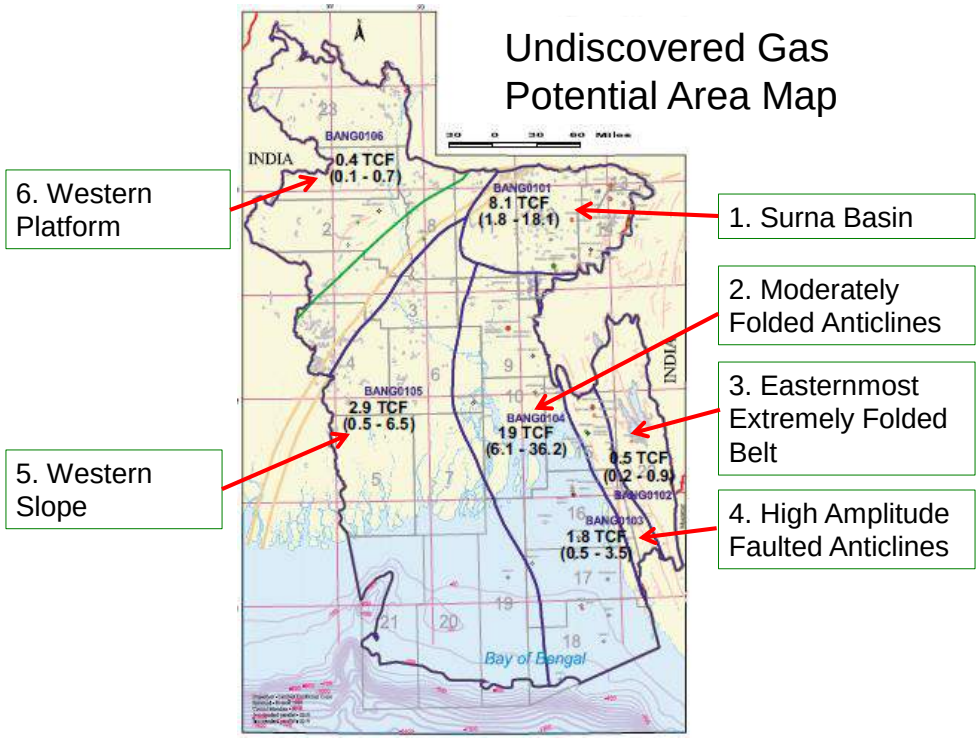
7.1.3 Gas Reserves and Resources

(1) Yet to find resources

According to the report by USGS/Petrobangla joint Study in 2001, Gas resources Yet to Find is considered as follows:

- 8.4 TCF（95% probability）
- 65.7 TCF（5% probability）
- 32.1 TCF（mean）

A geological characteristic of Bangladesh described in the previous section is further broken down by the report of USGS/Petrobangla 2001. Figure 7-2 shows potential of Yet to Find Resources in Bangladesh estimated by a joint effort of Petrobangla and USGS in 2001.



Source: Petrobangla/USGS Bulletin 2208-A, 2001

Figure 7-2 Yet to Find Resources

According to USGS Report, higher probability is indicated in the Eastern Folding Bed area and assumed 90% of Yet to Find resources in the area. On the other hand, Western and North Western area shows lower probability than eastern Folding Bed. The report indicates that main target area for gas exploration should be in the Folding Bed and East part of Foredeep area.

Table 7-2 Yet to Find Resources

Geological Characteristics	USGS Classification	Mean Probability (TCF)	95% Probability (TCF)	5% Probability (TCF)
East Folding Bed	Surma Basin	8.1	1.8	18.1
	Easternmost Extremely Folded Belt	0.5	0.2	0.9
	High Amplitude Faulted Anticlines	1.8	0.5	3.5
	Moderately Folded Anticlines	18.5	6.1	36.2
Central Foredeep	Western Slope	2.9	0.5	6.5
West and North West	Western Platform	0.4	0.1	0.7
[illegible]		32.1	8.4	65.7

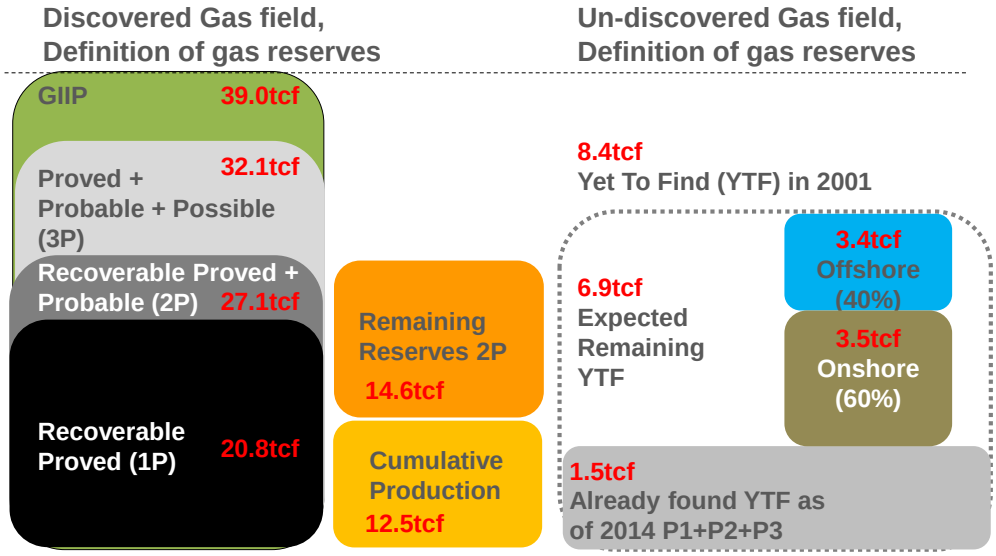
Source: Petrobangla/USGS Bulletin 2208-A, 2001

Note that Onshore portion of mean Yet to Find reserve is estimated 23.3 TCF out of 32.1 TCF of mean probability resources, and Offshore portion is remaining 8.8 TCF. Higher probability is indicated in onshore areas.

After the USGS/Petrobangla Joint Study in 2001, four gas fields, i.e., Bangura, Srikail, Sundalpur and Rupganj were discovered in the Folding Belt and east of Foredeep areas, and total of these confirmed reserves is 1.5TCF.

According to a draft Five year Gas Supply Strategy (2015-2019) by Petrobangla, GIIP of existing gas field is estimated 39 TCF, Recoverable Proved (1P) is 20.8 TCF, Recoverable Proved + Probable (2P) is 27.1 TCF and Recoverable Proved + Probable + Possible (3P) is 31.3TCF. Produced gas to date is 12.1 TCF and remaining 2P Reserve is estimated 14.5 TCF. Undiscovered Conventional gas resources are also estimated by Petrobangla and USGS in 2001. According to the report, undiscovered gas with 95% confidence is estimated 8.4TCF. Since the time 1.5TCF was newly discovered and the balance would be 6.9TCF.

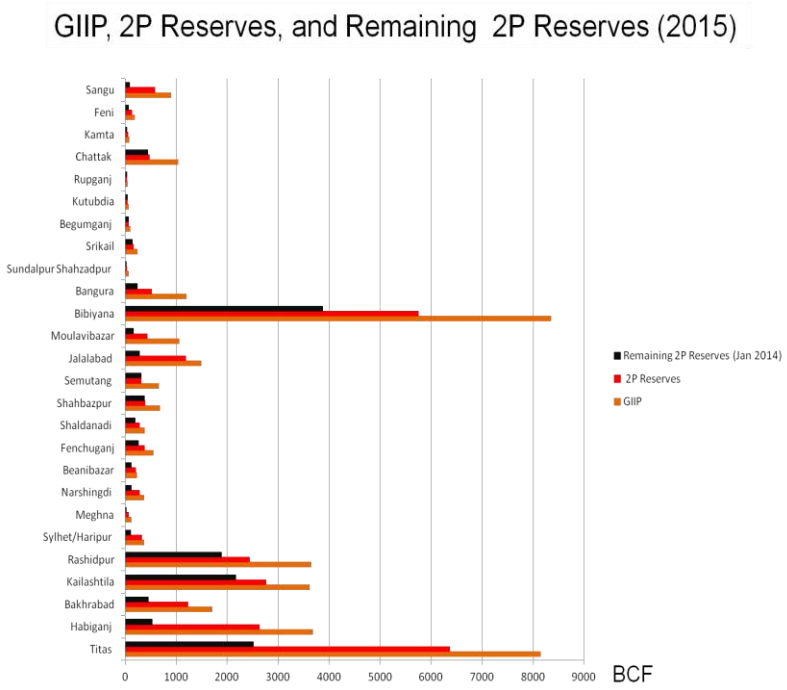
Gas Reserve Balance in Bangladesh is illustrated as follows. Undiscovered gas is assumed based on a statistical approach covering all of the Bangladesh. On the other hand, GIIP, 1P, 2P, and 3P are based on existing gas fields. Based on the reasonable assumption that higher potential of undiscovered gas can be reserved in the existing gas field area, the illustration is useful to understand the gas reserve situation in Bangladesh.



Source: Field-wise natural gas reserve estimates (Petrobangla, Nov. 2014), and Draft Five Year Gas Supply Strategy 2015-2019)

Figure 7-3 Gas Resource Balance

Following is a comparison of GIIP, Recoverable 2P gas Reserves, and Remaining 2P Gas Reserves. This illustrates that major gas fields of Titas、Habiganj、Bakrabad、Jalalabad are aging and the largest gas field of Bibiyana is coming to the peak of production.



Source: Petrobangla2013

Figure 7-4 GIIP, 2P Gas Reserves 2P and Remaining 2P Gas Reserves

(2) Gas reserves of suspended wells/ gas fields

According to Draft Five Year Gas Supply Strategy 2015-2019, gas production from some of the gas bearing sands have been suspended mainly due to an excessive water production from wells in those sands. Amount of such reserve is 761.13 BCF and might be or might not be deducted from the reserves shown in the Table 7-1. The report indicates that systemic study would be required to ascertain the status of these suspended sands.

(3) Non-conventional gas

For non-conventional gas potential such as coal bed methane (CBM), underground coal gasification (UCG) (these are described in Chapter 9) and shale gas, there are many uncertainties in terms of resources, locations and legal framework such as surface right and underground right. At this stage it is not recommended to include shale gas potential in the supply plan.

7.1.4 Discovery of new gas field and probability

Probability of discovery of new gas fields are higher in Folding Bed area and recommended to forcus more on this area. On the other hand, unexploited area will also need to be explored although statistics indicates negative. The JICA report entitled the “Preparatory Survey on the Natural Gas Efficiency Project in the People's Republic of Bangladesh (March 2014)” (hereinafter “JICA (2014) Report”), the following exploration programs are proposed.

- Underexplored areas: 2D seismic survey over the Bogra-Lalmai low amplitude broad regional structure and exploratory deep drilling
- Underexplored areas: 2D seismic survey and exploration drilling in the Madarganj and

Sariakandi areas
- Difficult areas: 2D seismic survey over the marshy-swampy areas of the Sunamganj-Kishorganj and surrounding areas and deep drilling
- High resolution 2D seismic survey to identify CBM potential in Gondwana basin

Further accumulation of date is required to evaluate the probability of these areas.

7.2 Petrobangla Companies and Cost Structure

7.2.1 Petrobangla companies

Activities of Petrobangla have expanded to manage from gas exploration, production, transmission, distribution, to product marketing. Currently there are following specialized companies operating under Petrobangla.

(1) BAPEX (Bangladesh Petroleum Exploration and Production Company)

Exploration right for new onshore gas fields or concessions is granted to BAPEX exclusively. BAPEX owns six gas fields (Saldanadi, Fenchuganj, Shahbazpur, Semutang, Sundalpur and Srikail) and producing 105 mmscfd of gas in 2014 FY. This accounts for 4% of gas supply in Bangladesh. In addition to six existing gas fields, two other gas fields, Rupganj and Begumganj, are about to produce gas, on completion of pipeline infrastructure.

BAPEX owns and operates drilling rigs and develops its own gas fields, and also provides drilling services to other gas producing companies under Petrobangla. BAPEX has 2D/3D seismic survey units and provides also services to other gas producing companies under Petrobangla in addition to its own concession exploration activities.

(2) Gas producing company

Role of gas production is assigned to BAPEX、BGFCL (Bangladesh Gas Field Company Ltd), SGFL (Sylhet Gas Field Limited), and also to Chevron and Tullow, called IOC (International Oil Company) under Petrobangla.

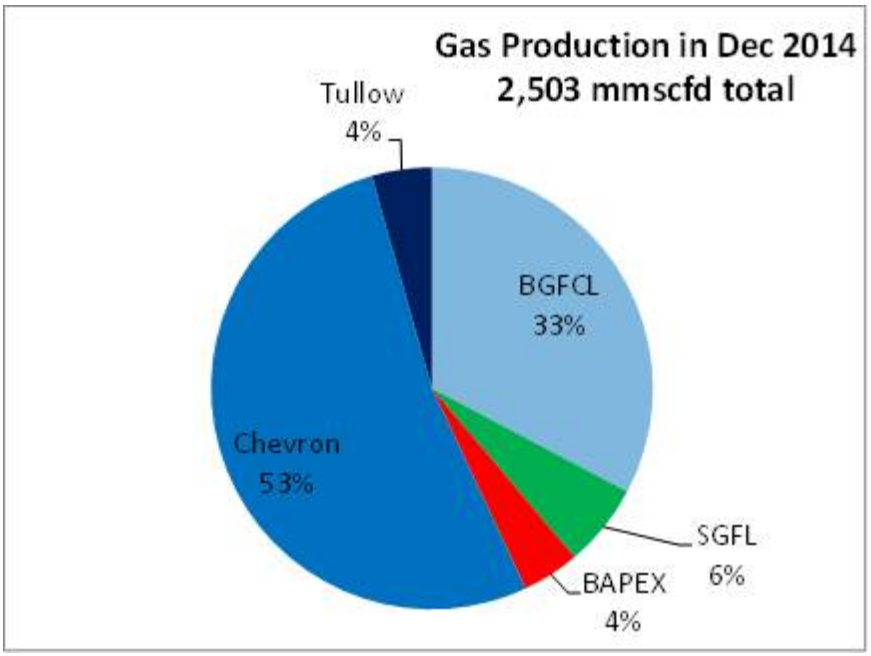
BGFCL owns and operates five gas fields, including Titas, Bakrabad, Habigan, Narshingdi and Meghna.

SGFL owns and operates four gas fields including Sylhet, Kailashtila, Rashidpur and Beani Bazarin.

Chevron and Tullow produces gas based on Product Sharing Contract (PSC) in 1996.

Chevron operates three gas fields including Bibiyana, Jalalabad and Moulavi Bazar and started production in 2006. Cheveon is known as the first company that introduced 3D seismic survey in Bangradesh. Tullow operates Bangura gas field.

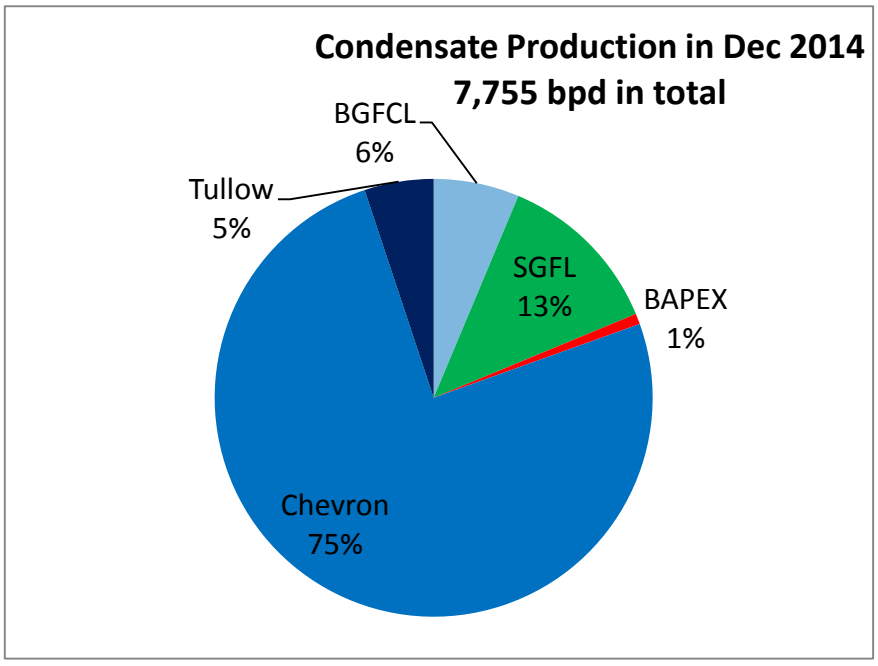
Following figure shows that contribution by Chevron and Tullow is significant in gas production in Bangladesh and accounts for 60 % of overall production.



Source: Petrobangla Annual report 2014

Figure 7-5 Gas Production in Dec 2014- by Company

Significant amount of condensate is associated with gas production. Production rate of the condensate was 7,755 bpd in Dec 2014. Revenue from the sale of condensate is contributing the economics of gas producing companies, in addition to gas revenue. SGFL relies on 75% of revenue from the sale of oil products produced from condensate.



Source: Petrobangla Annual report 2014

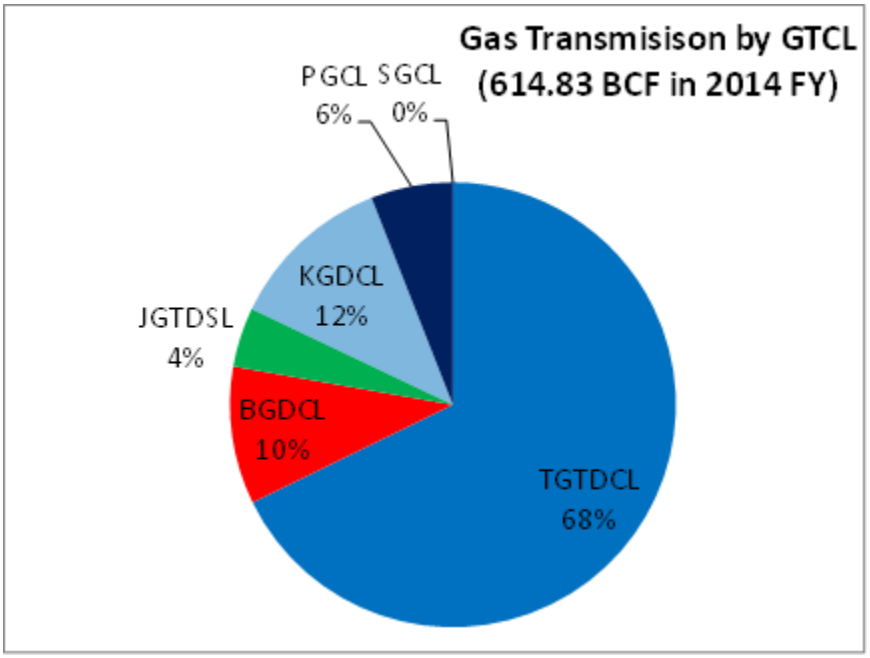
Figure 7-6 Condensate and NGL Production in Dec 2014- by Company

Produced condensate is transported via. Pipeline to Titas Gas Field and Bakhrabad Gas Field for refining and produced oil products are sold national and private oil marketing companies.
SGFL is constructing new fractionators and reformer (gasoline production) by its own finance.

(3) Gas Transmission Company

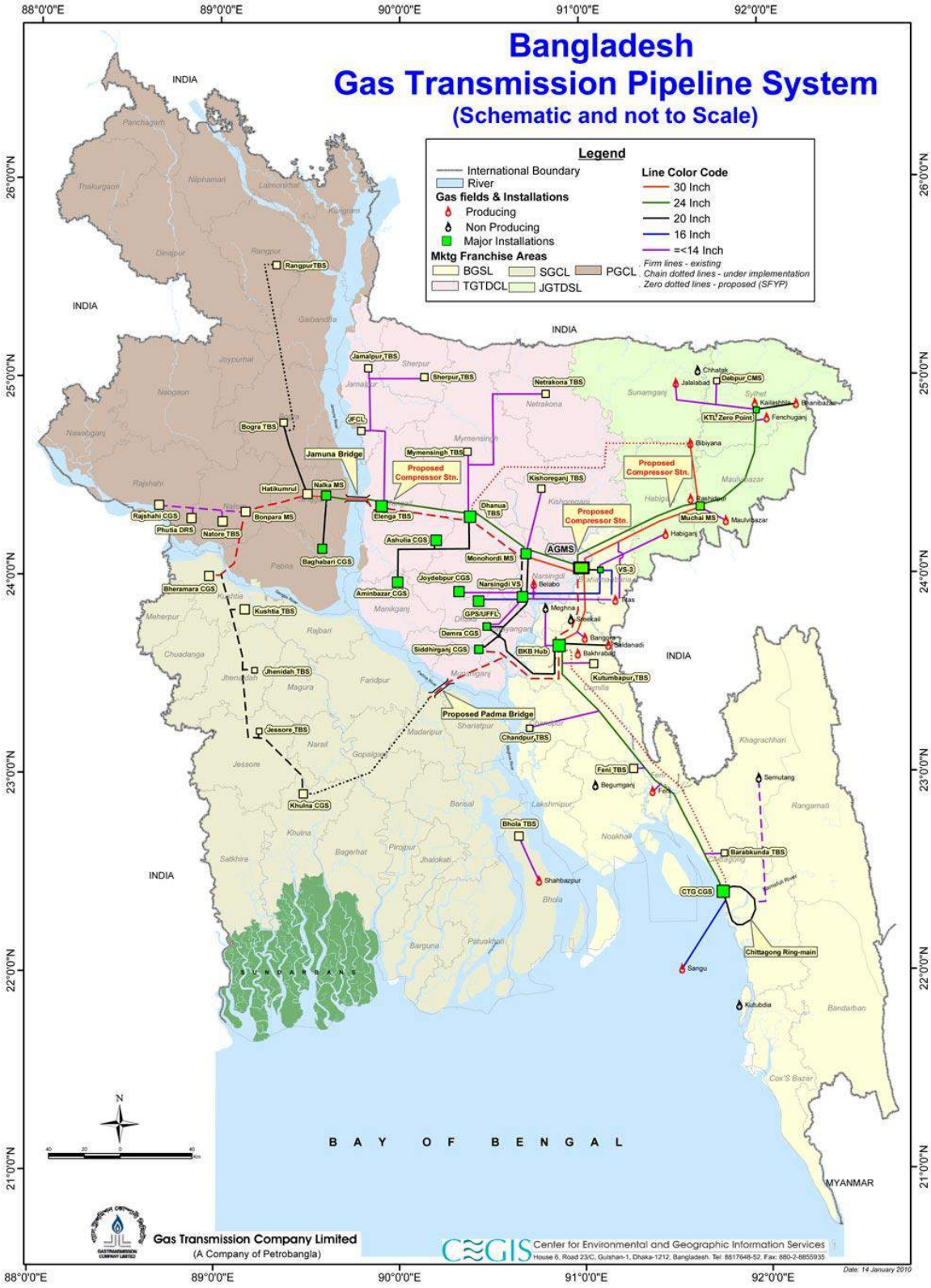
GTCL (Gas Transmission Company Limited) was incorporated in 1993 with the objectives of centralized operation and maintenance of national grid, and expanding the system as required, ensuring balanced supply and usage of natural gas in all regions of the country.

GTCL transported 614.83 BCF of gas in 2014 FY and this account for 70 % of gas produced in Bangladesh (the rest 30% are directly transported by local gas distribution and marketing companies). Gas transmission infrastructure has improved significantly since the time of GTCL incorporation. In near future volume of gas from LNG will increase significantly and reinforcement of the current infrastructure may be required to cater to an increasing gas volume from LNG.



Source: Petrobangla Annual Report 2014

Figure 7-7 Gas Transmission by GTCL- by Customer 2014 FY



Source: GTCL

Figure 7-8 GTCL Gas Transmission System

(4) Gas distribution and marketing company

There are six regional gas distribution companies under Petrobangla. These companies are given gas quota allocated sector-by-sector and/or project-by-project basis under the limited supply situation. Total supply of gas to end users was 826.65 BCF in 2014 FY[23], and considered much lower than actual demand.

1) Titas Gas Transmission Distribution Company Limited (TGTDCL)

TGTDCL is supplying gas to Dhaka Division, and the largest gas distribution and Sale Company. Gas supply is 520.28 BCF in 2014 FY

2) Karnaphuli Gas Distribution Company Limited (KGDCL)

KGDCL is supplying gas to Chittagong, Rangamati, and Cox's Bazar divisions. Gas supply to endusers in 2014 FY was 82.32 BCF.

3) Bakhrabad Gas Distribution Company Limited (BGDCL)

BGDCL is supplying gas to Comilla, Brahamanbaria, Feni, Noakhali and Lakxmipur provinces. Gas supply to end users in 2014 FY is 110.31 BCF.

4) Jalalabad Transmission and Distribution Systems Limited (JTDSL)

JTDSL is supplying gas to Sylhet Division. Gas supply to end users in 2014 FY was 75.68 BCF.

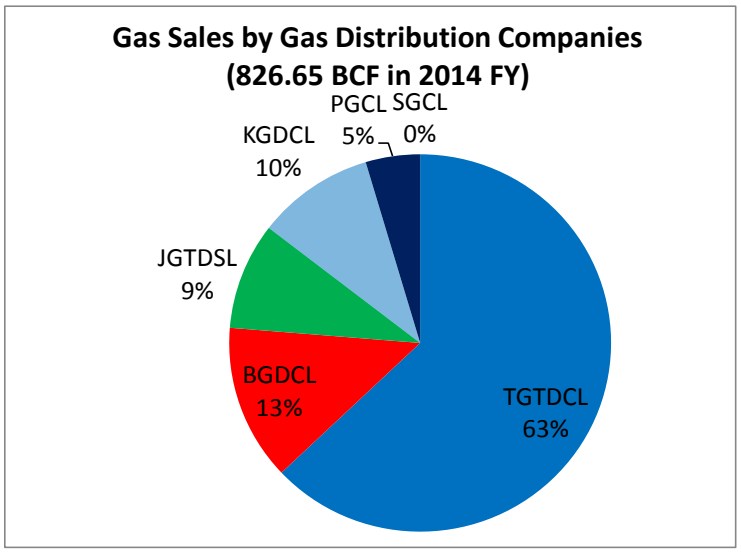
5) Pashchimanchal Gas Company Limited (PGCL)

PGCL is supplying gas to Rajshahi Division. Gas supply to end users in 2014 FY is 38.06 BCF. PGCL is expected to supply gas to Rangpur Division also.

6) Sundarban Gas Company Limited (SGCL)

SGCL is formed in Nov 2009. Its franchise areas is Khulna and Barisal Division

[23] The gap between the quantity transported by GTCL (614.83 BCF) and the total sales volume (826.65 BCF) is what local gas distribution and marketing companies directly transport and supply to customers.



Source: Petrobangla Annual Report 2014

Figure 7-9 Gas Sale by Gas Distribution Companies in 2014FY

(5) CNG and LPG

Pupantarita Prakritik Gas Company Limited (RPGCL) was formulated in 1987 to promote the use of CNG and LPG. RPGCL and private entrepreneurs have set up 587 CNG filling stations and 180 conversion workshop as of June 2014. These filling stations are supplying CNG to almost 220 thousand vehicles daily. This account for 3.58 BCF per month or 5% of total gas supply. RPGCL owns and operate LPG Extraction Plant in Golapgonj, Sylhet. Further details of LPG can be referred in Chapter 10.

(6) Gas infrastructure design standard

Early gas infrastructure was constructed before independence and it is still in service. It appears that condition of old infrastructure has not been systematically investigated and design standard has not been updated. To modernize the gas infrastructure, these need to be reviewed and investigated further.

7.2.2 Gas price and cost structure

Gas pricing system is prepared and decided by the Bangladesh Energy Regulatory Commission (BERC). There are eight market sectors and each has its own pricing structure. These price figures are revised from time to time under the circumstances to suit.

Table 7-3 Gas Price by Sector

	Sector	BDT/M3	USD/MMBTU
1	Power	2.820	1.02
2	Captive Power	8.360	3.03
3	Fertilizer	2.580	0.94
4	Industry	6.740	2.44
5	Tea Garden	6.450	2.34
6	Commercial	11.360	4.12
7	CNG	27.000	9.79
8	Domestic	7.000	2.54

Source: BERC September 2014

Cost component and profit mergine of each sector consists of following:

(1) Profit to the Government: 55% (2)Profit to Petrobangla: 45%

1) Petroleum Development Fund: Petrobangla is custodian of the fund and used for petroleum development
2) BAPEX Margin: Allocated to BAPEX as a revenue
3) Price Deficit Wellhead Margin: Created in Dec 1998 to meet up the deficit arisen from sale of gas at a rate lower than the purchase rate by Petrobangla from IOCs
4) Wellhead Gas Margin: Gas producer receive as a revenue
5) Transmission Charge: Wheeling fee for gas transmission. Revenue for GTCL
6) Distribution Charge: Distribution fee for gas distributors
7) Gas Development Fund Margin: In Aug 2009, BERC ordered to create GDF which currently in use for oil and gas exploration and production activities. Petrobangla is custodian of the fund.
8) Gas Asset Price: BERC ordered gas marketing and distribution companies in Sep 2015 to create fund kept in a separate account. This fund will be used for future energy project such include LNG etc.

Table 7-4 Gas Price Component

Unit: BDT/M3

	Sector	Government Tax	Petroleum Development Fund	BAPEX Margin	Price Deficit Wellhead Margin	Wellhead Gas Margin	Transmission Charge	Distribution Charge	Gas Development Margin	Gas Asset Price	End User Price
1	Power	1.4363	0.3170	0.0480	0.0400	0.2250	0.1565	0.2650	0.2087	0.1235	2.8200
2	Captive Power	4.3519	0.4560	0.0480	0.0400	0.2250	0.1565	0.1550	0.4474	2.4802	8.3600
3	Fertilizer	1.2362	0.2680	0.0000	0.0400	0.2250	0.1565	0.2650	0.3358	0.0535	2.5800
4	Industry	3.3621	0.7660	0.0480	0.0400	0.2250	0.1565	0.2450	0.6279	1.2695	6.7400
5	Tea Garden	3.2026	0.7660	0.0480	0.0400	0.2250	0.1565	0.2450	0.6279	1.1390	6.4500
6	Commercial	5.5710	1.3355	0.0480	0.0400	0.2250	0.1565	0.2450	1.2350	2.5040	11.3600
7	CNG	14.8500	6.1000	0.1100	0.2000	0.3000	0.1565	0.1550	3.1640	1.9645	27.0000
8	Domestic	3.5344	0.7090	0.0480	0.0400	0.2250	0.1565	0.2450	0.5739	1.4682	7.0000

Source: BERC Sep 2014

Translation to USD/MMBTU is as follows:

Table 7-5 Gas Price Component

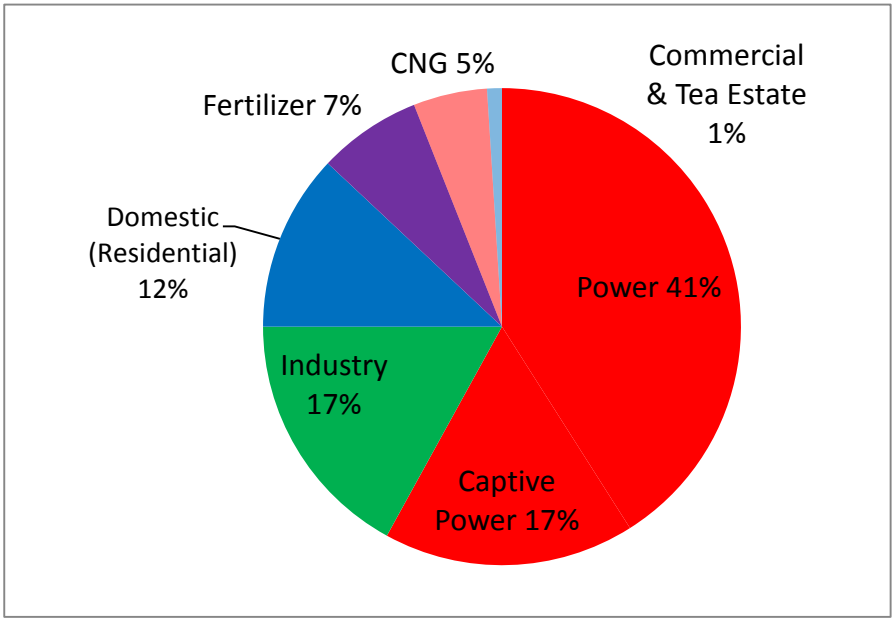
Unit: USD/MMBTU

	Sector	Government Tax	Petroleum Development Fund	BAPEX Margin	Price Deficit Wellhead Margin	Wellhead Gas Margin	Transmission Charge	Distribution Charge	Gas Development Margin	Gas Asset Price	End User Price
1	Power	0.52	0.11	0.02	0.01	0.08	0.06	0.10	0.08	0.04	1.02
2	Captive Power	1.58	0.17	0.02	0.01	0.08	0.06	0.06	0.16	0.90	3.03
3	Fertilizer	0.45	0.10	0.00	0.01	0.08	0.06	0.10	0.12	0.02	0.94
4	Industry	1.22	0.28	0.02	0.01	0.08	0.06	0.09	0.23	0.46	2.44
5	Tea Garden	1.16	0.28	0.02	0.01	0.08	0.06	0.09	0.23	0.41	2.34
6	Commercial	2.02	0.48	0.02	0.01	0.08	0.06	0.09	0.45	0.91	4.12
7	CNG	5.38	2.21	0.04	0.07	0.11	0.06	0.06	1.15	0.71	9.79
8	Domestic	1.28	0.26	0.02	0.01	0.08	0.06	0.09	0.21	0.53	2.54

Source: BERC Sep 2014

7.2.3 Financial status of companies under Petrobangla

In FY 2013-2014 by sector gas consumption shows that more than 60% of total gas consumption went for the power generation (including captive power).



Source: Petrobangla Annual Report 2014

Figure 7-10 Gas Consumption by Sector in FY2014

Due to a shortage of gas supply and also under the gas quota system, actual gas demand for each sector will be potentially larger than current consumption, and demand spectrum may also be different.

Gas producing companies under Petrobangla receives Wellhead Margin of USD 0.08/MMBTU, while IOC receives USD 2.48/MMBTU. SGFL has worked to maximize the recovery of condensate and produce oil products produced for sale. 75% of revenue comes from the sale of oil product. In order to enhance the revenue further, SGFL is constructing 4,000 bpd fractionators and 3,000 bpd reformer to manufacture gasoline by its own finance.

GTCL receives Gas Transmission Charge. The rate has reduced to half i.e., USD 0.06/MMBTU after Sep 2014, assuming that growth of flow rate would compensate the reduced unit rate. GTCL is constructing 36 inch Bibiyana-Dhanua pipeline with the length of 137 Km by its own finance. GTCL expects that this project will bring some more revenue and contribute to the financial status of the company. GTCL is caring out other investment projects supported by dinners such includes ADB, World Bank, and JICA, and also government funding.

Major portion of revenue for Gas distribution companies comes from Distribution Charge, which varies from sector to sector but no significant difference among the sectors. Since there are no significant differences between large scale customers and Residential customers, major marketing effort favors large customers.

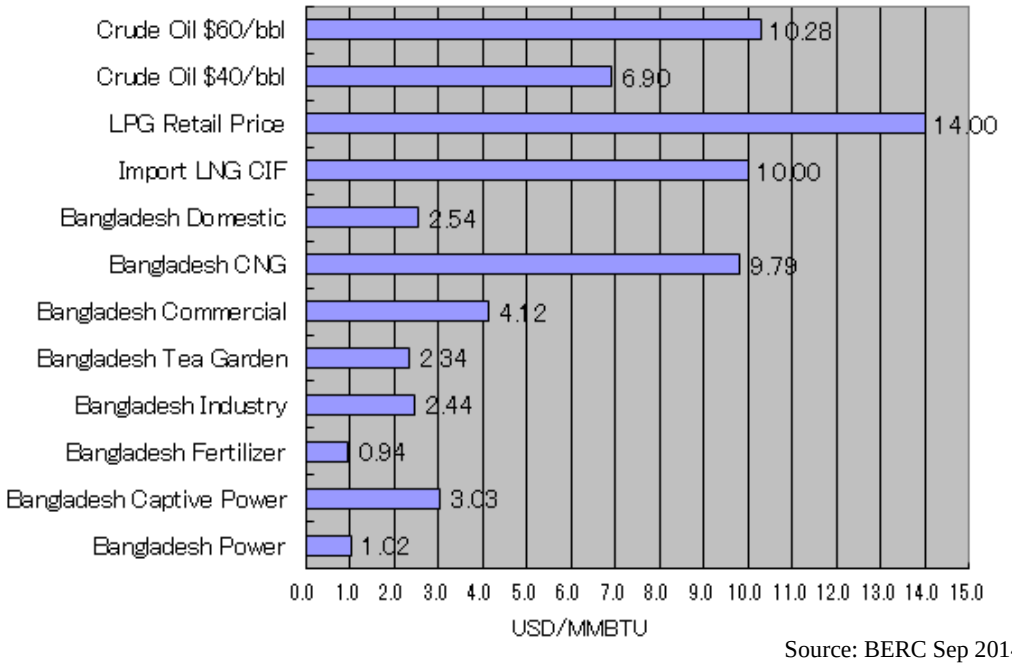
Gas distribution companies are trying to increase the revenue by making investment on Transmission Pipeline Project and receive Transmission Charge if economics favors. They are also utilizing Security Charge from their customers to raise revenue from fund operation.

Government of Bangladesh is promoting LPG for domestic (residential) use, discouraging the use of natural gas. Petrobangla is also promoting the use of gasoline in lieu of CNG to save natural gas.

To balance out the price difference between natural gas and alternative fuels, Distribution Charge for domestic (residential) sector and CNG to be raised.

Average gas market price in Bangladesh in 2014FY in terms of USD/MMBTU is USD 2.34 /MMBTU, and on the other hand, purchase price from IOC is USD 2.48/MMBTU.

Comparison of Energy Price in Bangladesh is shown in the Figure 7-11. Gas price for power and fertilizer are significantly low in comparison and need to be adjusted considering envisaged future introduction of LNG. Raising the gas price might necessitate the enhancement of gas use efficiency for these sectors. Discussion on future gas tariff should be referred in Chapter 20 and Chapter 21.



Source: BERC Sep 2014and others

Figure 7-11 Gas Price Comparison

7.3 Gas Production Forecast

7.3.1 Assessment of existing gas fields and fast track program

(1) Assessment of existing gas fields

Tracing of production record of the existing gas fields helps to make forecast of future gas production. A comparison of actual production (average daily production) from each gas field over the years from 2010 to 2014 and the production forecast by PSMP2010 is shown in Table 7-6.

Table 7-6 Comparison between Actual Average Daily Production and PSMP2010 Forecasts

Unit: mmscfd

Sl. No.	Gas Field	Average Daily Production							
		Actual					PSMP2010 Forecasts		
		2010	2011	2012	2013	2014	2010	2014: Case1	2014: Case 2
1	Titas	404	445	450	490	515	408	578	560
2	Habiganj	235	260	227	225	225	240	260	260
3	Bakhrabad	35	33	32	41	41	36	51	51
4	Kailashtila	91	86	89	84	74	87	97	97
5	Rashidpur	49	49	47	47	61	49	84	85
6	Sylhet/Haripur	3	10	9	9	8	7	30	30
7	Meghna	0	10	10	11	10	0	5	5
8	Narshingdi	33	30	30	28	28	35	25	25
9	Beanibazar	15	9	11	10	10	15	15	15
10	Fenchuganj	25	23	36	37	39	24	65	60
11	Saldanadi	8	18	16	15	12	8	8	8
12	Shahbazpur	6	0	7	7	8	8	10	10
13	Semutang	0	14	8	6	5	0	15	15
14	Sundalpur	0	0	10	10	4	0	60	60
15	Srikail	0	0	0	42	39	0	60	60
16	Sangu	37	14	23	0	0	40	0	0
17	Jalalabad	163	165	232	249	246	130	250	200
18	Moulavi Bazar	58	42	94	77	63	60	160	80
19	Bibiyana	658	753	792	822	1,007	716	900	850
20	Bangura	105	102	86	111	110	120	120	120
21	Begumganj	0	0	0	0	0	0	0	0
22	Kutubdia	0	0	0	0	0	0	0	0
23	Chattak	0	0	0	0	0	0	0	0
24	Kamta	0	0	0	0	0	0	0	0
25	Feni	2	0	0	0	0	2	2	2
Total		**1,926**	**2,062**	**2,210**	**2,323**	**2,435**	**1,995**	**2,765**	**2,563**

Note: A production rate of 60 mmscfd for Sundalpur and Srikal by the PSMP2010 forecasts means that the sum of production from Sundalpur and Srikail should be equal to 60 mmscfd in this case.

Source: Prepared based on Petrobangla Annual Reports 2010 to 2014 and PSMP2010 report (JICA, 2011)

Based on the information/data about remaining 2P reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019", and also description about the drilling and work-over activities shown in the Petrobangla Annual Reports, assessment of current gas field status and the future outlook are investigated (refer to the Attachment 7-1)

As a result of study, followings are understood.

- Only Bibiyana gas field has shown a steady increase in production since 2010 in Bangladesh.
- The Jalalabad gas field also significantly increased production in 2012, but after that production from the field has not increased significantly.
- Production from the Sangu gas field was suspended from October 1, 2013.
- Measures to be taken (e.g. meticulous casing and cementing work) to prevent incidents such as xcessive water production from sands
- Develop new gas field for further gas production while maintaining current production level as much as possible.
- Installation of wellhead gas compressors to maintain gas production.

(2) First truck program

To meet the increasing gas demand within the soonest possible time, decision was made as per Government directives and under the Speedy Supply of Power and Energy-Special Provision- Act 2010, to drill a total of 10 wells by Gazprom EP, Russia. The Contract was signed in April 2012 and Drilling work was carried out 2013-2014, as follows:

Titas Gas Field (BGFCL): Well No.19, 20, 21, 22
Rasidpur Gas Field (SGFCL): Well-No.8
Semutang gas Field (BAPEX): Well No. 6
Begumganji Gas Field (BAPEX): Well No. 3
Shrikail Gas Field (BAPEX): Well No. 3
Shahbazpur Gas Field (BAPEX): Well No. 3, 4

Expected gas production by the contract was 300 MMCFD, however, actual confirmed gas production ended up with 150 MMCFD. Five wells are producing gas. Three wells are waiting for completion of processing facilities and connecting pipeline infrastructure. Titas No. 21 well produced gas at 10 MMCFD for the first 6 months, and suspended due to an excessive water production. Work-over is underway by BAPEX at the cost of Petrobangla. Semutang No. 6 well was relinquished due to an excessive water production.

Additional contract was signed in end 2015 with Gazprom to drill following five wells:

Bhakrabad Gas Field (BGFCL): Well No. 10
Rashidpur Gas Field (SGFCL): Well No. 9, 10, 12
Shrikail Gas Field (BPEX): Well No. 4

(3) Introduction of "Best Industrial Practice" through competitive bidding

BGFCL has introduced "Best Industrial Practice" through competitive bidding for Titas Gas Field Well No. 23、24、25、26, financed by ADB under "Gas Seepage Control and Appraisal and Development of Titas Gas Field" As a result, SINOPEC China was awarded the contract at the price of 25% lower than that of Gazprom paid for the First Truck Program, and the result was satisfactory. This project indicates that there is an alternative way for the future exploration project in addition to the First Truck Program.

7.3.2 Production forecast for existing gas fields 2015-2019

Production forecast for the existing gas fields for the next five years will provide a base for preparing long-term production forecast. In this Study, production forecasts for the period of 2015 to 2019 are prepared by reviewing the Draft Five Year Gas Supply Strategy 2015-2019 (Petrobangla Five Year Plan 2015).

As a result of the review, it is considered that the production rate shown in the Draft Five Years Gas Supply Strategy is considered a little too optimistic. And therefore, correction factor is introduced. (Refer to Attachment 7-1)

(1) Review of schedule and performance of wells in the Petrobangla Five-Year Plan

Well completion schedule and production rate shown in the in the "Gas Evacuation Plan 2010-2015" prepared in 2010 was reviewed by comparing against Petrobangla Five year Plan 2015. The summary of the review outcome is as follows:

- Times of well completion: At least one year behind the schedule
- Production rates for new wells: About 70% of initial estimates (Gazprom performance is reflected)

(2) Correction factors for schedule delay and production rate is introduced as follows:

Impact of schedule delay on the production rate is expressed as a discount factor for production rate. One-year delay in a five-year period is discounted by 20% from the initial estimate.

- Times of well completion: 80% of the initial estimates
- Production rates for new wells: 70% of the initial estimates

The values of production rates are corrected by multiplying 0.8 and 0.7 for all wells scheduled to be completed after 2016.

(3) Production forecasts for 2015-2019

Taking above review result into account, Production forecast in Petrobangla Five year Plan was modified. The modified production forecasts are shown in Table 7-7.

Note that:

- Production profiles are basically the same as those shown in the Petrobangla Five-Year plan 2015.
- According to the Petrobangla Five-Year Plan 2015 include the production of 5 mmscfed from Shahbazpur gas field after 2018 is not taken into consideration in this study because there is no clear development plan is publicized yet.
- Peak gas production will be in July-December 2016 and the rate is estimated 2,811 mmscfd. While production forecasts by the Petrobangla Five-Year Plan 2015 also shows a peak production in the same period with the estimated rate of 2,916 mmscfd. Differential of Production rate between the cases are about 100 mmscfd, or discounted by 5% .

Table 7-7 Daily Gas Production Forecast for 2015-2019

Unit: mmscfd

Company	Field	2015		2016		2017		2018		2019		Remarks
		Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	
1. BGFCL	Titas	525	520	520	510+56	556	546	489	489	441	441	Production start-up: Jul-Dec 2016—Well nos. 23, 24, 25 and 26
	Bakrabad	40	38	36	34	30	26	23	23	30	30	
	Habiganj	224	224	224	224	220	218	215	215	200	200	
	Narsingdi	28	28	28	28	26	25	24	24	23	23	
	Meghna	10	10	10	10	10	10	9	9	9	9	
	Sub-total	**827**	**820**	**818**	**862**	**842**	**825**	**760**	**760**	**703**	**703**	
2. SGFL	Sylhet	8	8	7	7+6	12	11	11	10	10	9	Production start-up:Jul-Dec 2016—Well no. 9
	Kailashtila	72	70+8	78+14	92+8	100	96	96	92	92	88	Production start-up: Jul-Dec 2015—Well no. 1&5, Jan-Jun 2016—Well no. 9, Jul-Dec 2016—Well no. 7
	Rashidpur	60	59	58	57	56	61	72	70	67	67	Production start-up: Jul-Dec 2017--Well no. 9, Jan-Jun 2018--Well nos. 10 & 11
	Beani Bazar	9	9	9	9	8	8	8	8	8	8	
	Sub-total	**149**	**154**	**166**	**179**	**176**	**176**	**187**	**180**	**177**	**172**	
3. BAPEX	Saldanadi	10	6+10	16	13	12	11	10	10	10	10	Prpduction start-up: Jul-Dec 2015—Well no. 4
	Fenchuganj	35	34	32	30	30	29	28	28	28	28	
	Shahbazpur	10	10+9	29	29	29	29	29	29	29	29	Production start-up: Jul-Dec 2015—Well no. 4
	Semutang	4	3	2	2	2+4	6+4	10	10	10	10	Production start-up: Jan-Jun 2017—Well no. 7, Jul-Dec 2017—Well no. 8
	Sundalpur	3	3	2	0+4	4	4	4	4	4	4	Production start-up: Jul-Dec 2016—Well no.2
	Srikail	38	36	35+11	46	41	41	41	41	36	36	Production start-up: Jan-Jun 2016—Well no. 4
	Rupganj	0	8	8	8	8	8	7	7	7	7	
	Begumganj	4	4+8	12	12	10	10+8	16	16	12	9	Jan-Jun 2015: Actual production, Production start-up: Jul-Dec 2015—Well no. 3, Jul-Dec 2017—Well no. 4
	Sub-total	**104**	**141**	**147**	**144**	**140**	**150**	**145**	**145**	**136**	**133**	
Sub-total (1+2+3)		**1,080**	**1,115**	**1,131**	**1,185**	**1,158**	**1,151**	**1,092**	**1,085**	**1,016**	**1,008**	
4. Chevron	Jalalabad	250	250	250	250	220	220	220	220	220	220	
	Maulavibazar	50	50	50	50	45	45	45	45	45	45	Jan-Jun 2015: Actual production
	Bibiyana	1,100	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	Jan-Jun 2015: Actual production
5. Tullow	Bangora	110	110	109	109	81	81	69	69	58	58	Jan-Jun 2015: Actual production
Sub-total (4+5)		**1,510**	**1,610**	**1,609**	**1,609**	**1,546**	**1,546**	**1,534**	**1,534**	**1,523**	**1,523**	
6.	Feni				6	6+6	12	12	11	9	8	Resumption of production: Jul-Dec 2016—Well no. 6, Jan-Jun 2017—Well no. 7
7.	Chhatak				11	11+11	22	22	19	19	16	Resumption of production: Jul-Dec 2016—Well no. 3, Jan-Jun 2017—Well no. 4
Ground Total (1+2+3+4+5+6+7)		**2,590**	**2,725**	**2,740**	**2,811**	**2,738**	**2,731**	**2,660**	**2,649**	**2,567**	**2,555**	

Note: 1) Production rates in yellow cells were modified from those shown in the Petrobangala's five-year plan based on the actual production data or corrected production rates shown in Table 1.4-2.
2) The expression such as "510+56" means a daily production rate without additional production plus an additional daily production rate.

Source: Petrobangla's "Draft Five Year Gas Supply Strategy" (2015) and JICA SurveyTteam

(4) Gas production forecast 2020 and after

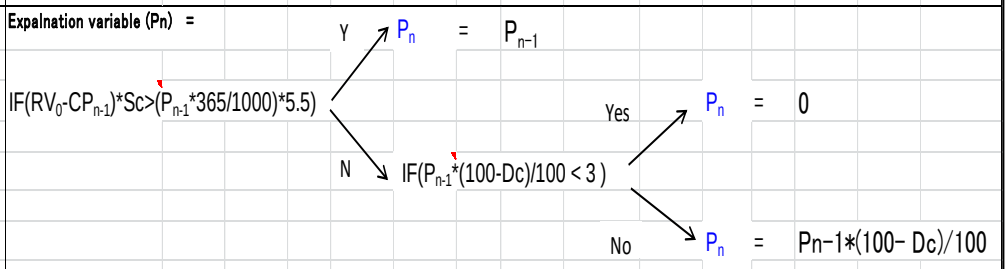
Gas production forecast from 2020 through to 2041 is calculated:

- based on the data (such includes GIIP, 1P, 2P, and Remaining 2P of all of the existing gas fields-Producing, Non-Producing, Production Suspended) shown in "Draft Five Year Gas Supply Strategy 2015-2019" and other publication materials by Petrobangla,
- using formula for estimating gas production profile as shown below.

Note that the calculation methodology is agreed upon with Petrobangla.

JICA Team further uses discount factor of 95% to estimate gas production profile till 2041, since the estimate by petrobangla has tended to be larger than actual as stated in the previous section.

Formula used for Gas Production Profile:

Estimation expression	Expalnation variable (Pn) =	
	$IF((RV_0-CP_{n-1})*Sc > (Pn-1*365/1000*5.5, Pn-1, IF(Pn-1*(100-Dc)/100<3, 0, Pn-1*(100-Dc)/100,0))*Gc$	
Structure of the expression for production in the year	**Expalnation variable (Pn) =** 	
Variable explanation	RV_0	Remaining P1+P2+P3 Reserve
	0 year	The base year in the study is 2013
	CP_{n-1}	Cumulative Production up to "n-1" year
	Sc	Probability of the production from remaining reserves, The Value 0 < Sc <1.0
	RV_0-CPn-1	Remaining P1+P2+P3 Reserves in "n-1" year
	P_n	Natural gas production in the year of "n"
	Pn-1*365/1000)	Convert from Production unit with mmcfd to Bcfa
	5.5	Depletion rate in the deciline period, the vale is summation of "1.0+0.9+0.8+0.7+0.6+0.5+0.4+0.3+0.2+0.1"
	Dc	Depletion rate, when the remaining reserves are not enough for annual production, the production is declined with Dc
	$P_{n-1}*(100-Dc)/100<3$	When declining production become less than 3 mmcfd, the production is fixed by 0.
	Gc	Production expansion plan factor, Gc is set by 1.1 (10% per year up per yaer) when the remaining reseves have allowance of production expansion

Source: JICA Survey Team

Figure 7-12 Formula for Estimating Gas Production Profile

a) Explanation of IF(RV0-CPn-1)*Sc > (Pn-1*365/1000)*5.5)

The above expression means whether the previous year production operations can be continued for the next 10 years or not.

By the expression of (RV0-CPn-1), the remained probable reserves are calculated. RV0 indicates GIIP and CPn-1 indicates accumulative production of the fields.

"Sc" means the existing probability of the remained probable reserves, "1.0"is set for all " Sc" of the fields.

The expression of "Pn-1*365/1000)*5.5" means the accumulative production for the next 10 years.

"5.5 （＝1.0+0.9+0.8+0.7+0.6+0.5+0.4+0.3+.2+0.1） " is a coefficient for calculating accumulative production for the next 10 years under condition of depletion rate 10%.

b) When "IF(RV0-CPn-$_1$)*Sc > (Pn-1*365/1000)*5.5) " is true

When field production for the next 10 years can be continued by the previous year production operation, the current production (Pn) is defined by the following expression.

Current production (Pn)= Previous year production(Pn$_{-1}$)

c) When "IF(RV0-CPn-1)*Sc > (Pn-1*365/1000)*5.5) " is not true

It means that the previous year production operation cannot be continued for the next 10years. The future field production is calculated in line with production decline factor. The decline factor is externally estimated by the remained probable reserve and the previous year production. The decline factor for each field is defined from 10% to 30%. By the decline factor, the annual productions of the fields gradually are declined year by year.

d) IF(Pn-1*(100-Dc)/100 < 3)

The above expression means to stop the productions of the fields when the previous production (Pn$_{-1}$) becomes less than the threshold of the production. In the study, the threshold is defined by "3 mmcfd ".

Following table shows the result of calculation, showing gas production profile of each Producing Gas fields, Gas Production Profile based on Petrobangla data, and JICA Team assumption using 95% of discount factor till 2041.

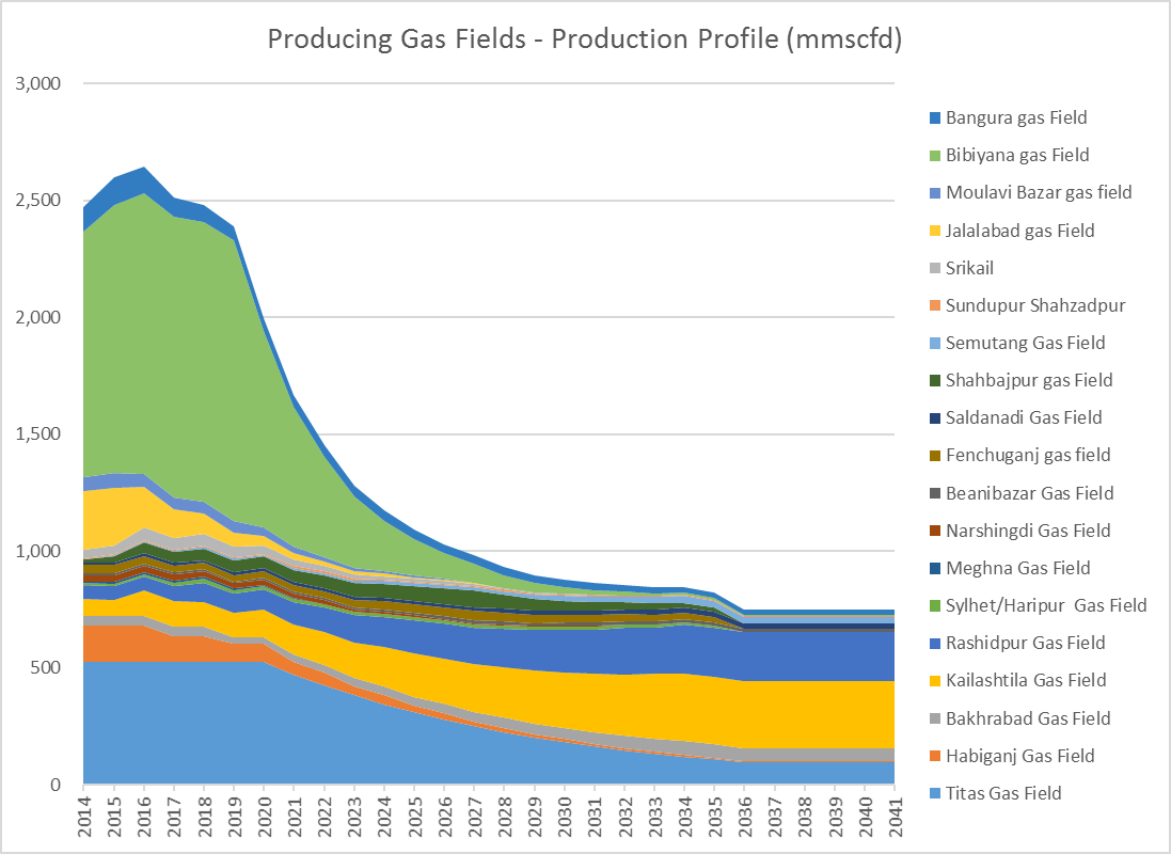
Note that the table include non-producing gas field and production suspended gas field. These gas fields are capable of produing gas, and contributing gas production in future. JICA estimate is considered to include production of these gas fields.

Table 7-8 Estimate of Gas Production Profile 2016～2041

Sl No.		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
1	Titas Gas Field	525	525	525	525	525	473	425	383	344	310	279	251	226	203	183	165	148	133	120	108	97	97	97	97	97	97
2	Habiganj Gas Field	157	110	110	77	77	54	54	38	38	26	26	18	18	13	13	9	9	9	6	6	4	4	4	4	4	4
3	Bakhrabad Gas Field	40	40	40	30	30	32	33	35	36	38	40	42	44	47	49	51	54	57	59	59	53	53	53	53	53	53
4	Kailashtila Gas Field	110	110	108	105	116	127	140	154	169	186	195	205	215	226	237	249	262	275	289	289	289	289	289	289	289	289
5	Rashidpur Gas Field	57	65	83	80	88	97	106	117	129	142	149	156	164	172	181	190	199	199	209	209	209	209	209	209	209	209
6	Sylhet/Haripur Gas Field	12	15	14	13	13	13	13	13	13	13	13	13	13	13	13	13	13	12	11	9	0	0	0	0	0	0
7	Meghna Gas Field	10	10	9	9	6	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Narshingdi Gas Field	28	25	24	23	23	18	15	12	12	9	8	6	5	5	4	3	0	0	0	0	0	0	0	0	0	0
9	Beanibazar Gas Field	9	8	8	8	8	8	9	9	10	10	11	11	12	12	13	14	14	15	16	14	13	13	13	13	13	13
10	Fenchuganjgas field	30	29	28	28	28	29	31	32	34	36	38	39	37	35	33	31	30	28	25	23	0	0	0	0	0	0
11	Saldanadi Gas Field	15	13	12	12	12	13	13	14	15	15	16	17	18	19	20	21	22	23	23	23	23	23	23	23	23	23
12	Shahbajpur gas Field	45	45	50	50	50	53	55	58	61	64	67	70	59	50	42	35	29	25	21	17	0	0	0	0	0	0
13	Semutang Gas Field	5	8	8	8	8	9	10	11	12	13	14	16	17	19	21	23	25	28	30	30	30	30	30	30	30	30
14	Sundupur Shahzadpur	4	4	4	5	5	5	6	6	6	6	6	6	6	5	5	5	5	5	5	5	4	4	4	4	4	4
15	Srikail	55	50	50	45	36	29	23	18	15	12	9	8	6	5	4	3	0	0	0	0	0	0	0	0	0	0
16	Jalalabad gas Field	175	123	86	60	42	29	21	14	10	7	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Moulavi Bazar gas field	55	50	50	50	35	25	18	13	9	7	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Bibiyana gas Field	1,200	1,200	1,200	1,200	840	600	428	306	218	156	111	79	57	41	29	21	15	11	8	5	4	4	4	4	4	4
19	Bangura gas Field	114	85	72	60	54	51	48	46	43	41	38	36	34	32	31	29	27	26	24	23	21	21	21	22	23	24
A Producing Total		2,645	2,514	2,481	2,388	1,995	1,669	1,451	1,278	1,173	1,091	1,030	981	932	897	877	862	853	845	846	821	748	748	748	749	750	751
20	Begumganj Gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Kutubdia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Rupganji																										
B Non-Producing		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Chattak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Kamta Gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Feni gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	Sangu gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Production suspended		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total of Domestic production		2,645	2,514	2,481	2,388	1,995	1,669	1,451	1,278	1,173	1,091	1,030	981	932	897	877	862	853	845	846	821	748	748	748	749	750	751
	Additional production	8	202	181	175	551	519	454	403	374	351	335	323	309	299	294	291	289	289	291	283	248	248	248	248	249	249
PSMP2015 Estimate (95% of Petrobangla Forecast)		2,653	2,716	2,662	2,563	2,547	2,188	1,905	1,681	1,547	1,441	1,366	1,305	1,240	1,196	1,171	1,153	1,142	1,133	1,137	1,104	996	996	996	997	999	999
Natural Gas Production Forecast by Petrobangla		2,793	2,859	2,802	2,698	2,681	2,303	2,005	1,769	1,628	1,517	1,437	1,373	1,306	1,259	1,233	1,213	1,203	1,193	1,197	1,162	1,048	1,048	1,048	1,050	1,051	1,052

Source: Perobangla "Draft Five Year Gas Supply Strategy" (2015) and JICA Survey Team

Gas Production Profile of Producing Gas Fieldis are shown in the following Figure. Note that the Figure does not include Non-Producing Gas Field and Production Suspended Gas Fields.



Source: JICA Survey Team

Figure 7-13 Gas Production Profile of Each Producing Gas Field

7.3.3 Natural gas supply scenario 2015-2041

(1) Narutal gas supply scenario

Natural gas Supply Scenario 2015-2014 is based on the following assumptions:

1) Primary supply scenario is based on the existing gas production profile by Petrobangla.
2) 95 % of discount factor is introduced based on the assessment by PSMP2015.
3) Assuming new Onshore Gas Fields are developed as follows:
   - 2022 and After: Supply of 170 mmscfd by BAPEX as shown in the Petrobangla Five Year Plan
   - 2024 and after: 30 mmscfd from new gas field
   - 2025 and after: 100 mmscfd from new gas field
   - 2026 and after: 100 mmscfd from new gas field
   - 2027 and after: 100 mmscfd from new gas field
4) Assuming new Offshore Gas Field are developed as follows:
   - 2034 and after: 500mmmscfd from new gas field
5) FSRU Project
   - 2018and after: 500 mmscfd is supplied by FSRU Phase 1
   - 2022 and sfter: Additional 500mmscfd is supplied by FSRU Phase 2
6) Onshore LNG Terminal
   - 2027 and after: 500 mmscfd at the initial phase with 3 x 180,000 kl tanks
   - By 2041, Capacity is increased to 3,000 mmscfd
7) Gas Introduction from abroad
   - 2019 and after: 200 mmscfd from India

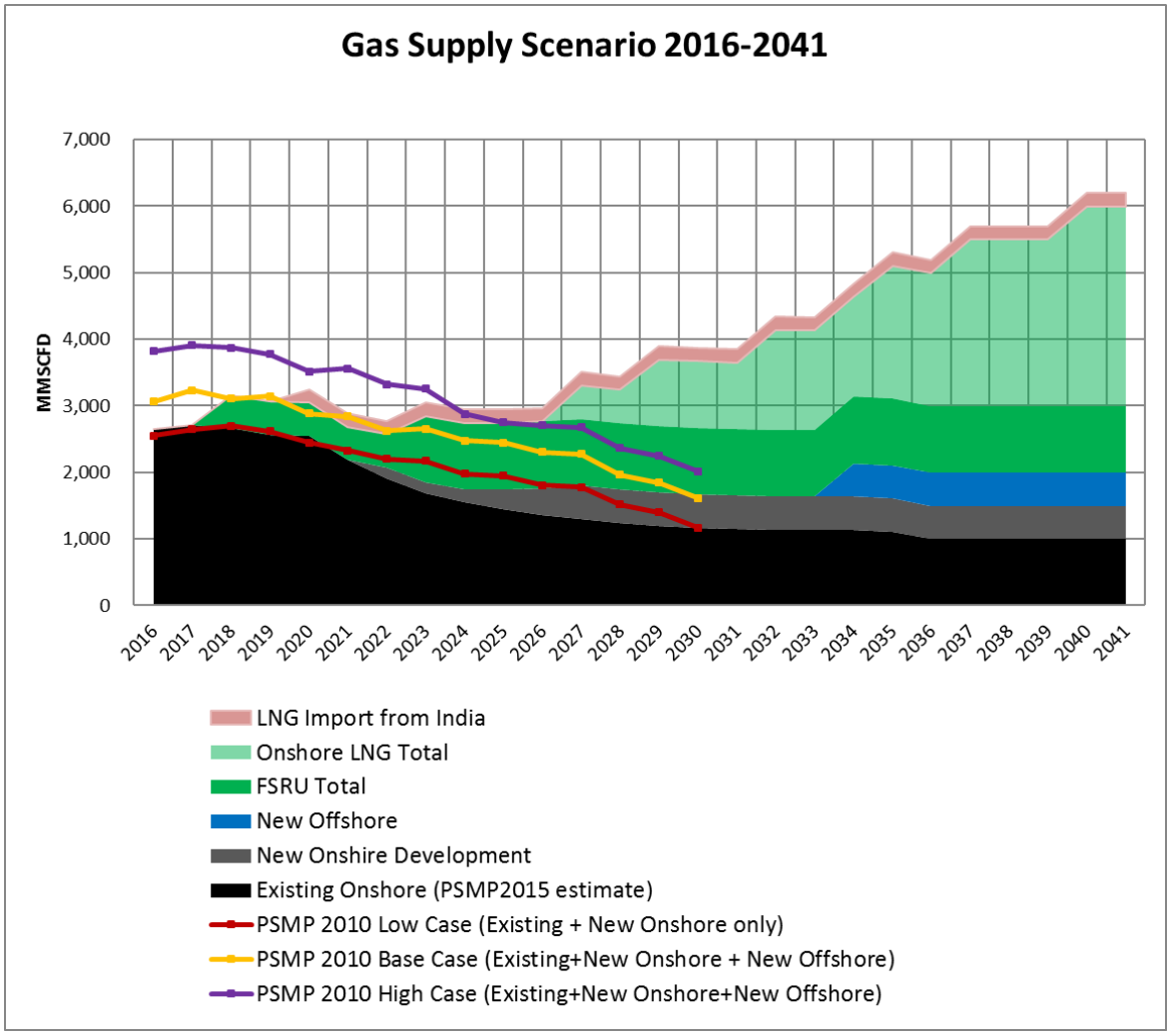
Gas supply from future possible gas field from Onshore and offshore and gas from overseas are summarized in the following table.

Table 7-9 Gas Supply Scenario -New Domestic Gas Field and Gas Import 2016～2041

	Unit	ity	COD	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Existing (PSMP2015 estimate)	mmcfd			2,653	2,716	2,662	2,563	2,547	2,188	1,905	1,681	1,547	1,441	1,366	1,305	1,240	1,196	1,171	1,153	1,142	1,133	1,137	1,104	996	996	996	997	999	999
New (5 wells)	mmcfd	500		0	0	0	0	0	0	170	170	200	300	400	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
1st Well	mmcfd	170	2,022	0	0	0	0	0	0	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
2nd Well	mmcfd	30	2,024	0	0	0	0	0	0	0	0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
3rd Well	mmcfd	100	2,025	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
4th Well	mmcfd	100	2,026	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
5th Well	mmcfd	100	2,027	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Offshore	mmcfd	500	2,034	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500
Total Domestic	mmcfd			2,653	2,716	2,662	2,563	2,547	2,188	2,075	1,851	1,747	1,741	1,766	1,805	1,740	1,696	1,671	1,653	1,642	1,633	2,137	2,104	1,996	1,996	1,996	1,997	1,999	1,999
FSRU Total	mmcfd	1,000		0	0	500	500	500	500	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Energy Divisoin	mmcfd	500	2018	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Energy Division	mmcfd	500	2022	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Onshore LNG Total	mmcfd	4,000		0	0	0	0	0	0	0	0	0	0	0	500	500	1,000	1,000	1,000	1,500	1,500	1,500	2,000	2,000	2,500	2,500	2,500	3,000	3,000
Energy Divisoin	mmcfd	3,000		0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	1,000	1,000	1,000	1,500	1,500	2,000	2,000	2,000	2,500	2,500
Phase 1	mmcfd	500	2029	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500
Phase 2	mmcfd	500	2032	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500
Phase 3	mmcfd	500	2035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500
Phase 4	mmcfd	500	2037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500
Phase 5	mmcfd	500	2040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500
Power Division	mmcfd	1,000		0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Phase 1	mmcfd	500	2027	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
LNG Import from India	mmcfd	200	2019	0	0	0	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Total Import	mmcfd	5,200		0	0	500	700	700	700	1,200	1,200	1,200	1,200	1,200	1,700	1,700	2,200	2,200	2,200	2,700	2,700	2,700	3,200	3,200	3,700	3,700	3,700	4,200	4,200
Supply Total	mmcfd			2,653	2,716	3,162	3,263	3,247	2,888	3,275	3,051	2,947	2,941	2,966	3,505	3,440	3,896	3,871	3,853	4,342	4,333	4,837	5,304	5,196	5,696	5,696	5,697	6,199	6,199

Source: JICA Survey Team

Overall Gas supply scenario including existing gasfields, future domestic gas field, and gas import is shown in the following Figure. It appears that it is inevitable to introduce significant amount of LNG in near future.



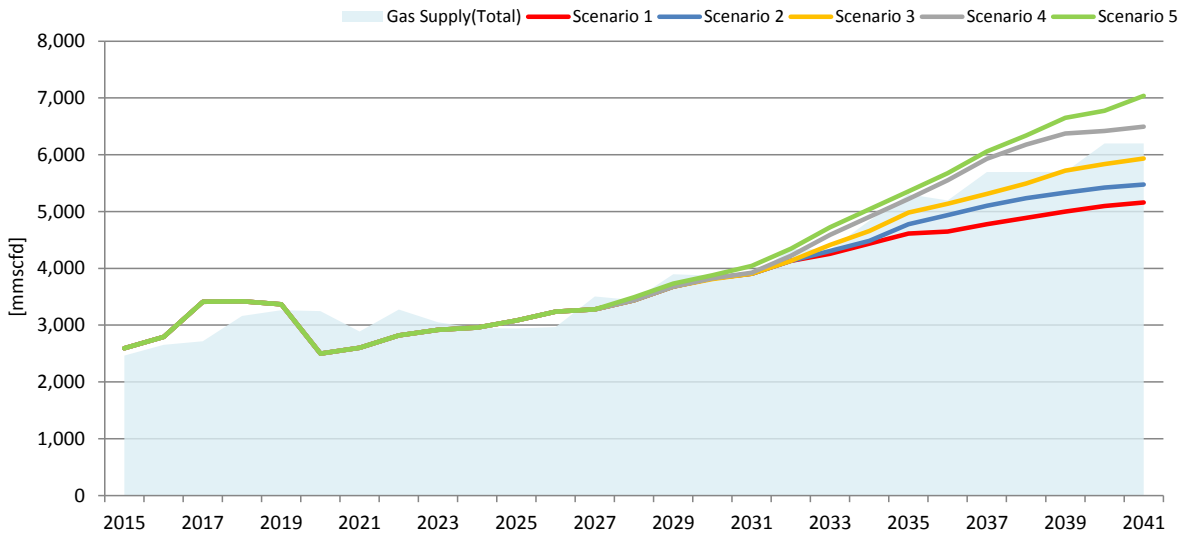
Source: JICA Survey Team, based on Petrobangla data and projection

Figure 7-14 Gas Supply Scenarios 2016-2041

(2) Comparison with the natural gas demand projection

In order to evaluate whether the gas supply scenario in the previous section asures the necessary supply of natural gas (mmscfd) to satisfy the growing demand, the future gas demand is formulated based on the projection of energy consumption (ktoe) that was discussed in Chapter 6 is compared with the gas supply scenario, as shown in Figure 7-15. Because the future gas demand varies depending on the five scenarios of power development that are evaluated in Chapter 11, the necessary supply is calculated for each of these scenarios.

This figure shows that, though both demand and supply has a charactereristic to increase or decrease from year to year, the increased gas supply based on the gas supply scenario generally satisfies the necessary demand from 2020 in power demand cenarios from 1 to 3. However, in scenarios 4 and 5, where the share of gas-fired thermal power generation is higher than in the previous three scenarios, the gas supply constantly falls below the demand from mid-2030s, additional power supply plans need to be considered besides the aforementioned gas supply scenario.



Source: JICA Survey Team

Figure 7-15 Comnparison between Gas Supply Scenarios and Gas Demand Projection

7.3.4 Cost estimate for future investment on gas field development

The investment costs required for the exploration, drilling, and constructions of the gas production facility till 2027 were estimated. The construction costs for the new gas production facility were estimated based on Bangladesh's gas field development plan. Cost Estimate was made by using cost estimate software developed by SIMENS. (See Attachment 7-2 for detail)

Some area is not covered by the Software and these are assumed based on the following figures:

1) Significant labor works and time/cost will be required to identify oil and gas deposit in the green field in general, and cost for these area will also differ from country to country and also to the local conditions. In case of Bangladesh, it is assumed that potential of gas borne area is identified already, and actual cost information used for particular field is used as a benchmark cost, i.e., 2D Seismic Survey: USD 3 million (80 L Km), 3D Seismic Survey: USD 28 million (400 km2)

2) Drilling cost assumes four development wells and used as a production well at later stage. Based on the recent experience by BGFCL, total of 4 wells cost USD 60 million.

3) Assuming that production rate from future onshore wells is 500 mmscfd, cost for production facilities will be assumed USD 90 million as per SIMENS Cost Estimate Software.

4) LNG Receiving Onshore terminal assumes 3x 180,000 M3 LNG tanks at the initial phase, with jetty and re-gasification facilities. Total estimated cost is USD 760 million.

Table 7-10 Total Investment Costs for Gas Development

	Item	Cost [mill. USD]
A	**Domestic Gas Development Costs for the Remaining Reserves 2P**	
A1	Field Exploration Costs	*30*
A2	Field Development Costs	
A2.1	Drilling Costs	*60*
A2.2	Facility Construction Costs	
(1)	Facility construction costs for domestic gas which has already been discovered	302.8
(2)	Gas transmission pipelines from gas production facilities for domestic gas which has already been discovered	9.0
(3)	Facility construction costs for domestic gas which has not been discovered	*90*
(4)	Gas distribution pipelines for future power plants	5.0
	Subtotal (A)	*496.8*
B	**Import Gas Development Costs**	
B1	Facility Construction Costs	
(1)	LNG Receiving Terminal	*760*
(2)	LNG transmission pipeline	115.1
	Subtotal (B)	*875.1*
C	**Contingency (= (A+B) x 50%)**	
	Subtotal (C)	*686*
	Total (A+B+C)	***2057.9***

Source: JICA Survey Team

Numbers of assumptions were made to make cost estimate and the result is not necessarily close enough to predict future cost.

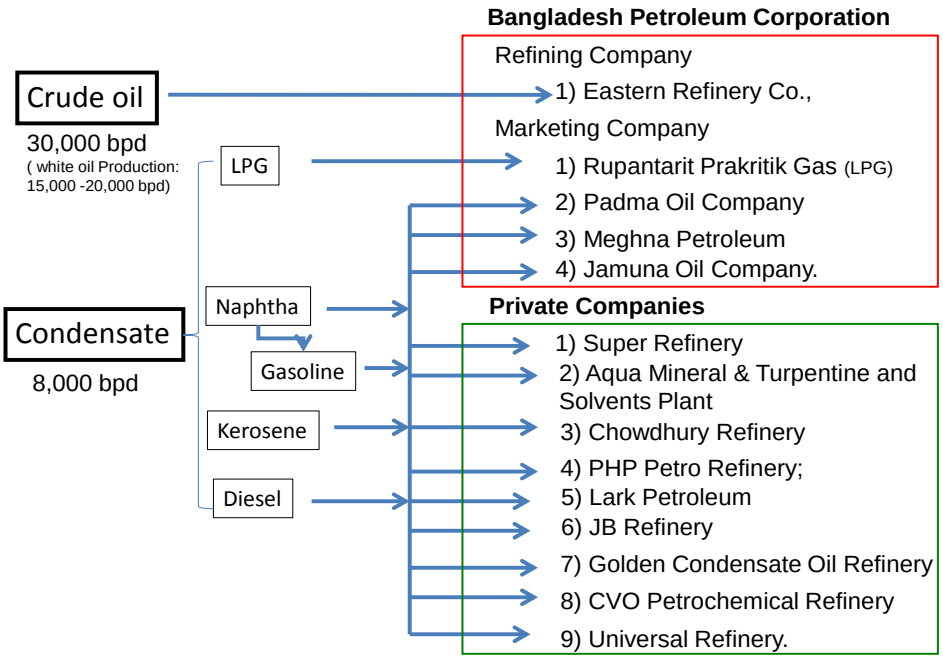
(1) Reinforcement cost for Existing Pipeline Infrastructure is not included in the cost estimate.
(2) Impact of LNG introduction to existing gas infrastructure and to gas field processing facilities/wellhead compressors is not included.
(3) All the cost data and assumed infrastructure models used for cost estimate to be reviewed.

7.3.5 Condensate production

Significant amount of condensate has been produced from gas field in Bangladesh. Revenue from the sale of oil product from condensate has been an important side revenue for gas producing companies. Investment for condensate fractionation facilities has been made to recover and monetize the condensate.

Recovered condensate is fractionated to LPG, Gasoline, Kerosene and Diesel products and soled to National Oil and/or LPG Marketing Companies and private oil refining and marketing companies

Production rate for condensate in Dec. 2014 was 7,800 BPD. On the other hand, Eastern Refining Co., National Refining Company with 30,000 BPD throughput capacity, produces 15,000-20,000 BPD of white oil products. This translates that 30-35% of white oil products are supplied from the distillates of condensate.



Source: JICA Survey Team

Figure 7-16 Overview of Condensate Marketing

Condensate recovery relies on the pressure differential. Recovery of the condensate has not necessarily been maximized yet. Once wellhead pressure declines, recovery of the condensate will also decline and flooding the transmission pipeline/ downstream distribution systems with condensate. Enhancement of the condensate recovery should be also be considered at the time of wellhead compressor installation, considering the impact of the LNG introduction.

7.4 Gas Field Development and PSC

7.4.1 Future gas field development

As discussed, hydrocarbon bearing potential in Bangladesh is divided into three onshore areas geologically. Offshore areas are categorized into Shallow Water and Deep Water as indicated in the model PSC.

- Folding Bed area in the east
- Foredeep area in the central
- Stable Shelf and Hinge Zone area in the west and north west
- Offshore (Shallow and Deep Waters)

Current operating gas fields are mostly in the Folding Bed area. Production from these existing gas fields are declining. Higher probability of new gas field discovery is expected in this Folding Bed area. On the other hand, Probability of the discovery in Central and West/North West part of the country is considered not high. No commercial scale gas field has been discovered in these areas.

Regarding offshore exploration in Myanmar, Daewoo of Korea discovered Shwa gas field on the east side of Bengal Bay in 2004. Confirmed reserve is 9.1 TCF with significant production of associated condensate. Commercial operation commenced in 2014 and all the gas and condensate are sold to CNPC China, via pipeline. Production rate is 700 MMCFD. Some new gas field discoveries were also reported at adjacent area of this Shwa Gas Field. Due to a geological similarity, there would be a potential of new gas field discoveries on the east part of Bengal Bay.

Oil and gas exploration has been exercised on the west side of Bengal Bay for a decade. No significant discovery has been made yet except Krishna-Godavari basin

Gas development in future areas will be more difficult and risky. It requires higher technological skills and financial backup to manage the oil and gas exploration. In the 1990's and after, significant advancement has been made in the oil and gas development area. A performance in exploration, and gas and oil recovery has been improved significantly.

In order to minimize exploration risks and maximize the recovery of resources, it is worth to consider partnership with internationally known IOCs, through attractive PSC, both for onshore and offshore exploration.

The recently adopted 7th Five Year Plan claims that Petrobangla undertake onshore exploration and development "on its own" to explore "relatively lower cost" and seek for a "strategic partnership" with experienced IOCs for offshore. However, it should be noted that the poor performance of the recent explorations and production implies that Petrobangla requires not only more financial resources, but also state-of-art well exploration and development skills and experiences for onshore resources as well. It is recommendable that Petrobangla take strategic partnership with the internationally renowned IOCs and utilize their technologies, not only off-shore, but for onshore resources too. Measures for the more involvement of IOCs will be discussed in the next section.

7.4.2 2012 model PSC

Gas pricing in 2012 Model PSC offered by Bangladesh shows that Government of Bangladesh (GoB) has the first right to purchase Contractor's Gas. The Contractor will be assumed a domestic market outlet within 6 months of commercial discovery of gas failing which the Contractor would be free to find outlet within the country. Gas Pricing is as follows;

(1) Onshore Gas Field: 75% of Market Price with biddable discount. The price will have a floor of USD 100 /metric ton and ceiling of USD 200 /metric ton of HSFO. (Note that these figures translate that gas floor price would be USD 2.25 /MMBTU and ceiling price will be USD 4.5/MMBTU.)
(2) Offshore (Shallow Water): 100% of Market Price
(3) Offshore (Deep Water): 110% of Market Price
(4) Onshore Western area: 90% of Market Price

With the development of oil and gas market in US and UK, world oil and gas prices have been linked with these market prices, and affected world oil and gas development activities. Fiscal terms of PSC by the GoB may need to be linked with the international market pricing system to make the PSC attractive.

After the lift of economic sanction on Myanmar, oil and gas exploration through PSC has been accelerated. Recent PSC prepared by the Government of Myanmar require that 25% of product to be supplied to domestic market (domestic Requirement) at 90% of Fair Market Value but the rest volume can be sold by Contractor by its own free will. This indicates that natural gas from Myanmar can be exported to Bangladesh. The price may be at Fair Market Value.

After the resolution of the maritime boundary dispute with Myanmar by virtue of the judgment awarded in March 2012 by the International Tribunal for the Law of the Sea (ITLOS), the Deep Water blocks on the eastern part were re-arranged.

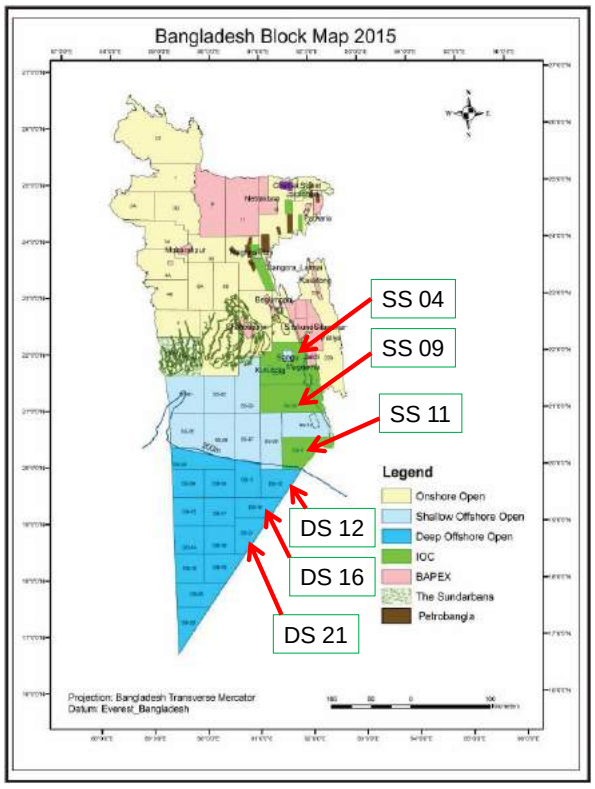
Current PSC for offshore blocks are as follows:

(1) Shallow Water Blocks

- JV of ONGC Videsh, Oil India, and BAPEX signed PSC with GoB for Block SS-04 and SS-09
- JV of Santos, Kris Energy, and BAPEX signed PSC with GoB for Block SS-11

(2) Deep Water Blocks

JV ConocoPhillips and Statoil negotiated with GoB for DS-12, DS-16 and DS-21, however, did not reach agreement.



Source: Petrobangla Annula Report 2014

Figure 7-17 Offshore Concession Blocks

7.4.3 Attractive PSC and partnership

Current target for gas exploration and development activates can be as follows:

1) Maintain production rate from existing gas field as much as possible
2) Develop new gas field in the Folding Bed area

To maximize the production and recovery of gas and condensate, the latest technologies need to be introduced. It is worth to consider preparing attractive terms of PSC and formulate partnership with experienced IOCs.

7.4.4 Role of BAPEX

There may be a resource limitation to achieve i) Enhancement of technological capabilities, ii) Own and operate 2D/3D survey units and drilling rigs, and iii) Produce oil and gas at the same time. Speed

of advancement in technology is so fast to catch up. It is the management skill needed to be developed, not to use its own resources for operating drilling rigs.

Role of national oils has been changed responding to changing times and social needs. ONGC of India, Petronas of Malaysia, and CNPC of China are typical example how they have been evolved. These national oils are responsible for developing their own resources and also acquire recourses in overseas. As a result, they have increased the "Domestic Energy Resources" and contribute to the energy supply security of the country.

BAPEX has played a very important role in the area of domestic oil development and provision of associated services. BAPEX has made significant effort to build up capability of 2D and 3D seismic survey and operating drilling rigs, however, the performance of these may not necessarily be satisfactory. On the other hand, there may be opportunities to work jointly with other national oil companies in neighboring countries, or develop oil and gas fields jointly with the international oil companies in overseas. It may be a time to review role of BAPEX thoroughly.

7.5 Improvement of Gas Supply Infrastructure and Gas Use Efficiency

7.5.1 Improvement of gas supply infrastructure

There are following issues for gas transmission and distribution system in Bangladesh to be solved and improved.

(1) Condensate recovery

It appears that gas heating value may differ from location to location due to a condensate fraction in the pipeline system. Gas Transmission Company and Distribution Companies need to evacuate the built up condensate regularly. It is recommended to dry the gas as much as possible at the wellhead gas treatment facilities. Benefit of the improvement will be:

1) Increase the revenue by the sale of oil products produced from condensate
2) Save investment cost for installation of knock out drums and/or heaters
3) Life time of the pipeline infrastructure can be extended

(2) Gas meter installation and gas leak monitoring

Gas will be a very valuable energy resource and it should be used efficiently and safely, and inflow and outflow of gas must be monitored. All of the gas inlet and outlet points must have gas meters. Gas leak monitoring works will contribute to the process safety, protecting the people from fire/explosion, and also preventing energy loss from the system.

The Residential (Domestic) sector customers have long been indulged with a fixed tariff system, which encourage the overuse of natural gas. To address this issue, JICA is assisting in the installation of gas meters (pre-paid) to Dhaka Area (200,000 locations for residential customers) and Chittagong Area (60,000 locations for residential customers).

Under the gas allocation system, gas supply quota to each captive facility is manually controlled against a reading of volumetric flow meter located at the facility gate. Overdrawn facility will be subject to a penalty due to a violation of rule. Flow meter inspection and capitulation is conducted by each regional gas distribution company. Measurement accuracy may need to be improved.

(3) Digitized and Computerized Gas Infrastructure Management System

Digitized and Computerized Gas Infrastructure Management System should be installed sooner since

"older the infrastructure is higher the risk of accident can be".

Gas transmission and distribution system is considered as a lifeline Infrastructure. All the process information including gas flow rate and pressure, and abnormal signals need to be collected and stored and processed, and all the history of maintenance, expansion/replacement record need to be stored. All of these data should be made available for all the parties concerned.

Significant advancement has been made in the area of such lifeline Infrastructure Management System for the last two decades. Appearance of new technology, a concept of Object-Oriented Database applied for Infrastructure Management, will be one of the choices to be introduced.

(4) Improvement of Gas Transmission System

Significant volume of gas will be supplied from LNG in near future and the system need to be reinforced to accommodate the increasing volume of gas. Integrated gas flow and pressure monitoring system (or SCADA system) will need to be introduced. In addition to advanced SCADA system, introduction of gas flow simulator to predict gas flow and pressure in the system will also be required.

(5) Impact of LNG introduction

After LNG introduction, gas flow rate and pressure balance will change. This could affect the performance of gas field production facilities and condensate recovery system. Also affect plan for wellhead compressor installation projects. Impact of LNG introduction will need to be studied further.

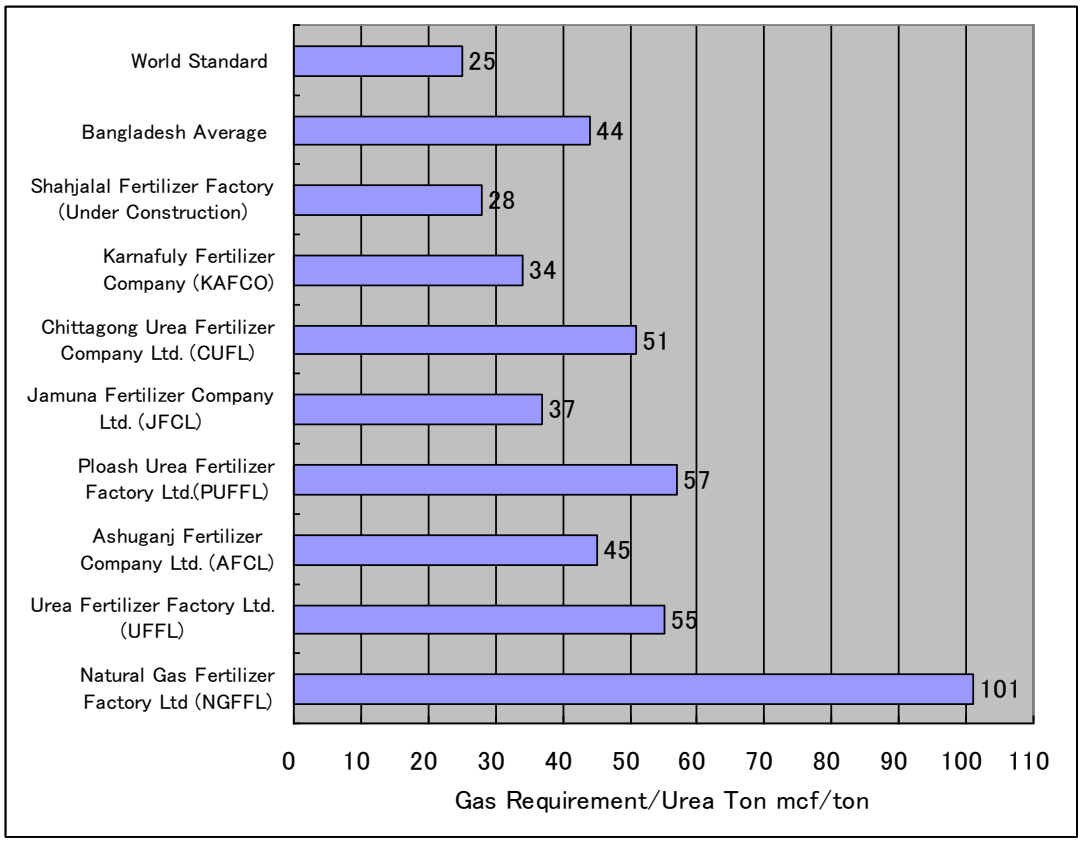
7.5.2 Improvement of gas use efficiency

Gas Use Efficiency is one of the critical issuers need to be addressed. "Cheap gas" will not be available in future and gas users need to enhance the efficiency to save indigenous gas resource in the country. It appears that both Urea Manufacturing and Power Sectors have a significant room for energy efficiency enhancement.

(1) Efficiency Enhancement in Urea Manufacturing

Urea is manufactured from natural gas. As seen in the below figure, the world benchmark efficiency in Urea Manufacturing is 25mcf/ton. On the other hand, average efficiency in Bangladesh is 44 mcf/ton as of 2014 FY, and much lower than that of international benchmark. Specifically the existing public fertilizer factories largely lag behind the world benchmark efficiency.

Provided that annual Urea production in Bangladesh is 2,375,000 ton, 130 mmcfd of natural gas is wasted due to an inefficient use of gas. This figure will be translated into the equivalent of 1000 MW of power plant.



Source: Five Year Gas Supply Strategy 2015-2019

Figure 7-18 Comparison of Urea Efficiency

(2) Efficiency enhancement in power sector

Gas Consumption for Power Sector (under BPDB) is 337.4 BCF in 2014 FY while Power Generation Capacity was 8,340 MW and Generated Power was 42,200 GWh. From these figures, it is assumed that current power generation efficiency is around 38%. Provided that efficiency can be raised to 45%, which is considered as a international benchmark as a gas based power plant, Energy gas consumption will be reduced to 285 BCF, and differential of 52 BCF is wasted. This is equivalent of 1,300 MW power plants.

The further details of gas-fired thermal plant efficiency issue are addressed in Chapter 17 and Chapter 18. JICA-supported “Power System Master Plan 2010” (February 2011) also well describes the public power plant efficiency issue.

7.6 Possible Assistance from Japan

Gas supply in Japan is highly dependent on LNG import. Japan has developed the technological and organizational system to use the gas efficiently and safely from the time of beginning stage of LNG development.

True economic value of the hardware, i.e., gas pipeline and distribution system, depends on the existence of the appropriate operation system, sustainable maintenance system and technology, and supporting organization.

With the development of the economic globalization, discussion about the construction of cross-country gas and power infrastructure has started. This will involve globally extended areas, and therefore, it is very important to introduce and utilize IT system to operate the infrastructure

effectively and efficiently and manage various operational risks.

To meet with the needs of the above, technology transfer based on the BOT (build, Operate, Transfer) approach will be listed as one of the best idea to be considered.

Through the BOT approach, technology and management system can be transferred as a sustainable business scheme, attaining human resource development and technology transfer the same time. This Business unit will work as a platform for operation and maintenance of gas infrastructure and support various expansion projects, and more importantly providing job opportunities to young talented people in Bangladesh.

7.7 Environmental and Social aspects of Natural Gas development

7.7.1 Environmental Impact Assessment

Basic rules of Environmental Impact Assessment are given by Environment Conservation Act 1995. The clause 12 of the Act "No industrial unit or project shall be established or undertaken without obtaining, in the manner prescribed by rules, an Environmental Clearance Certificate from the Director General". Environment Conservation Rules 1997 (subsequent amendments in 2002 and 2003) stipulate the procedures and required documents by categories (see Table 7-11).

Table 7-11 EIA Categories and Required Clearance and Documents

Category	Required clearance	Required documents
Red	Location clearance, Environmental Clearance	Feasibility Study report (FS report), IEE or EIA, Resettlement Action Plan (RAP), No Objection Certificate of the local authority (NOC), Emergency and pollution minimization Plan
Orange B	Location clearance, Environmental Clearance	FS report, IEE, NOC, Emergency and pollution minimization Plan, RAP
Orange A	Location clearance, Environmental Clearance	General Info, Raw materials and the manufactured product, NOC, Process flow, Layout, Effluent discharge arrangement, RAP
Green	Environmental Clearance	General Info, Raw materials and the manufactured product, NOC

Source: Environment Conservation Rules 1997

MOE has prepared various guidelines of EIA such as Guidelines for Industries in 1997, EIA Guideline for Project in the Natural Gas Sector, Guideline for Gender Responsive Environmental Management. All the coal and gas development projects have to apply Environmental Clearance to DOE of Dhaka, Chittagong, Khulna, or Rajshahi Division. It is not clear that which categories should be applied to various kinds of Gas and coal projects (see Table 7-12)

Table 7-12 EIA Guidelines for Gas and Coal Sector

Activities	Category	Guidelines to be referred
Gas and Oil exploration	?	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil extraction	Red	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil refinery	Red	EIA Guideline for Project in the Natural Gas Sector
Gas pipeline	Red	EIA Guideline for Project in the Natural Gas Sector
Gas distribution line	?	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil storage	Red	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil Power Plant	Red	EIA Guideline for Project in the Natural Gas Sector

Source: JICA Survey Team

7.7.2 Experienced environmental and social impact of gas development

(1) Impact during exploration

Bangladesh Petroleum Exploration Company (BAPEX) is the only company which is conducting exploration work in Bangladesh. BAPEX has conducted more than ten exploration works so far. It is not clear how many EIAs have been prepared for the exploration works.

(2) Impact during construction and operation

There are more than 20 gas fields are operating in Bangladesh. Environmental, Health, and Safety Guidelines for Onshore Oil and Gas Development (IFC, 2007) identifies major environmental impact as air emissions, wastewater discharges, solid and liquid waste management, Noise generation, Terrestrial impacts and project footprint and Spills. But in terms of the gas development in Bangladesh water and air pollution issues are relatively lower than the other countries like Middle Eastern countries, Indonesia, and Australia. It is because the component of the Gas in Bangladesh is very pure. Gas of Middle Eastern countries contains hydrogen sulfide. But no hydrogen sulfide is contained in the gas in Bangladesh. Then there is no need to install hydrogen sulfide recovery unit and no production water is discharged in Bangladesh. The content of CO2 is very lower in Bangladesh than the other countries (see Table 7-13). Then there is no need to install CO2 recovery unit and recharge in the aquifer layer. pH of the production water in Middle Eastern countries is very low but it is near-neutral in Bangladesh. Then neutralization facility is not required too. Heavy metal such as mercury is not found in produced water in Bangladesh.

Table 7-13 Rates of Gas Component by Gas Fields

	Australia A	Australia B	Sakhalin	Bangladesh Titas
Methane（CH4）	76.8	66.6	92	96.76
Ethane（C2）	3.5	3.8	4.62	1.8
Propane（C3）	1.3	1.3	1.73	0.36
Butane（C4）	0.5	0.4	0.62	0.14
Pentane (+C5)	0.6	0.7	0.32	0.26
N2	4.3	15.4	0.46	0.37
CO2	13	11.8	0.25	0.31

Source: JICA Survey Team

When it comes to biological and social issues not so serious problems are reported during operation. Hearing survey at Bangladesh Gas Fields Company Ltd.(BGFCL), Sylhet Gas Fields Limited (SGFL), Gas Transmission Company Limited (GTCL) did not find any serious problem during operation. The reasons of the little impact on biological and social issues are that the drilling holes can be angled and houses and ecological important areas can be avoided at the location selection stage.

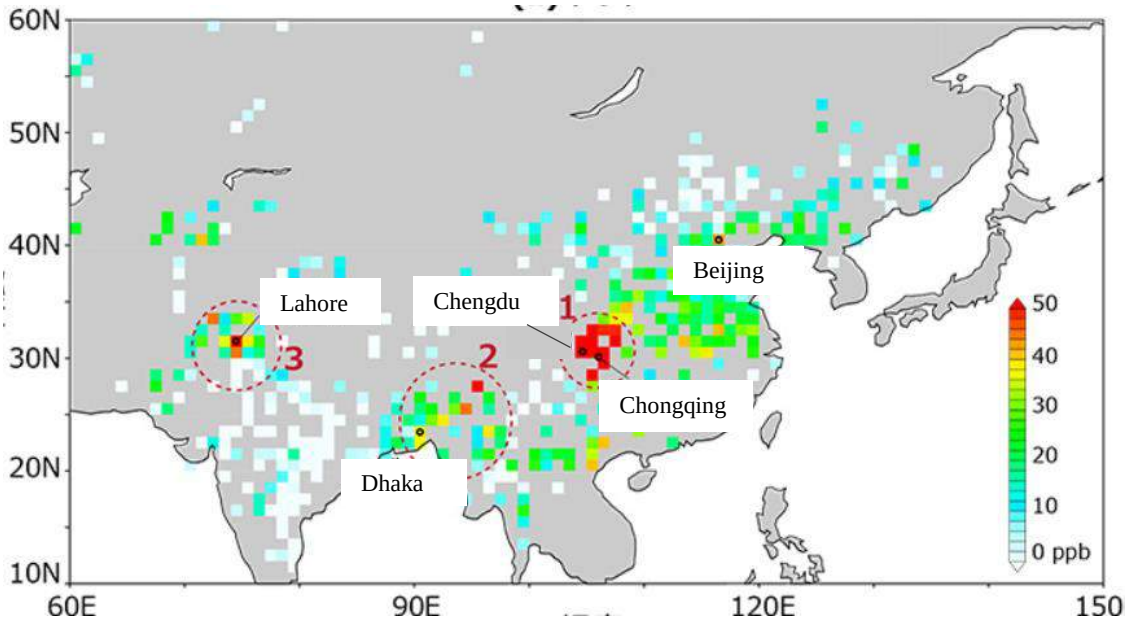
(3) Blowout accident

According to Khan (2014) there are some serious blowout accidents happened during exploration activities which are Sylhet 1, Sylhet 4, Moulvibazar-1 and Chattak-2. The impacts are furious and wide expanses of areas are affected (see Table 7-14). Unfortunately the killing well activities are failed and compensation is not enough. Then the effects are continuing still now. And to make matters worse the methane gas which keeps running out still now is one of the global warming gas. The satellite observation result also shows the high concentration of methane gas over the Sylhet area too (see Figure 7-19). The blowout during exploration is the highest risk of the gas development in Bangladesh.

Table 7-14 Main Blowouts in Bangladesh

Well	Year	Blowout type	Reasons	Effect
Sylhet-1	1955		Drilling mistake	A crater was formed and filled with water, creating a large pond which is still there today and vent gas from the subsurface into the year
Sylhet-4	1962		Drilling mistake	Well was abandoned then and gas is still venting out from the fissures in the well site and nearby hill side which often cause fire.
Moulvibazar-1	1997		Casing mistake	About 96 acres of Lawachara forest were completely burnt. Fifty percent of the forest resources on 111.15 acres of land and 30 percent resources on 106.21 acres of land were also damaged. An estimated Tk 9000 crore loss to the nation and gas reserve of about 245 billion cubic feet was burnt in the explosion while the environment, ecology and wildlife of the area were also severely affected.
Chattak-2	2005	Surface type	Casing mistake	Homestead area, forest trees, and hilly fruit bearing trees were affected by the fire. Underground sand and clay soil were throughout with gas from the main field to 2-3 km areas of the Tengratila.

Source: Md. Ashraful Islam Khan, Fuad Bin Nasir (2014) Review Over Major Gas Blowouts In Bangladesh, Their Effects And The Measures To Prevent Them In Future (INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 3, ISSUE 9)

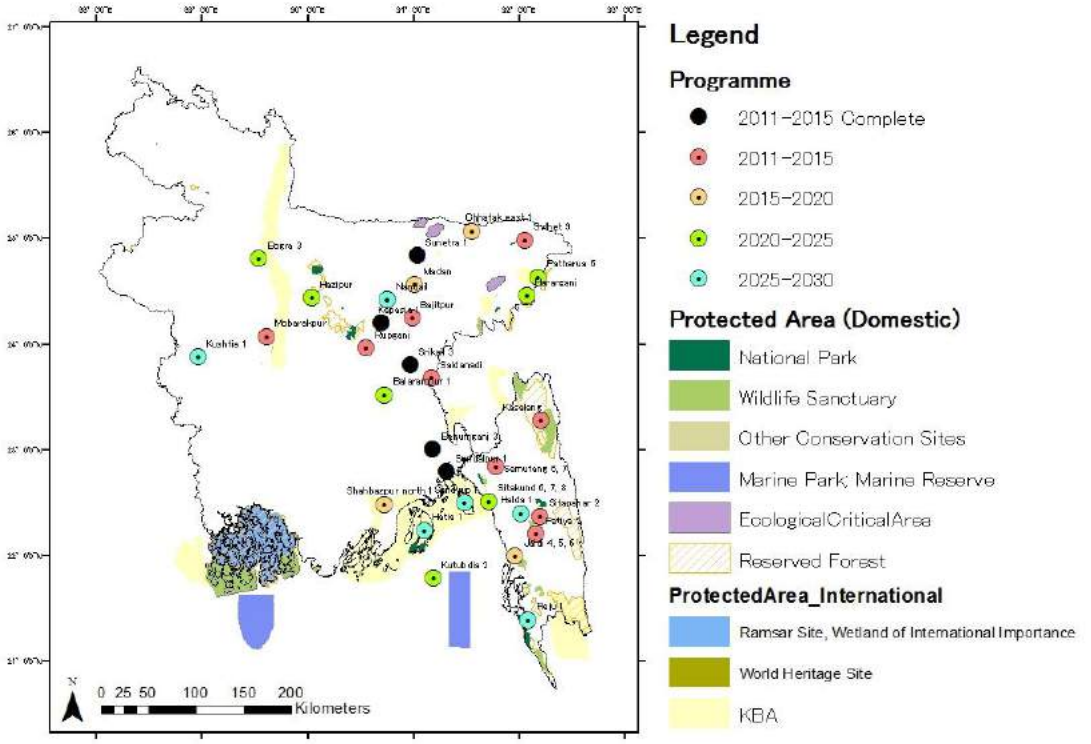


Source: JAXA (2015) Greenhouse gases Observing Satellite "IBUKI" (GOSAT)

Figure 7-19 Methane Gas Concentration by Human Activities in Asia

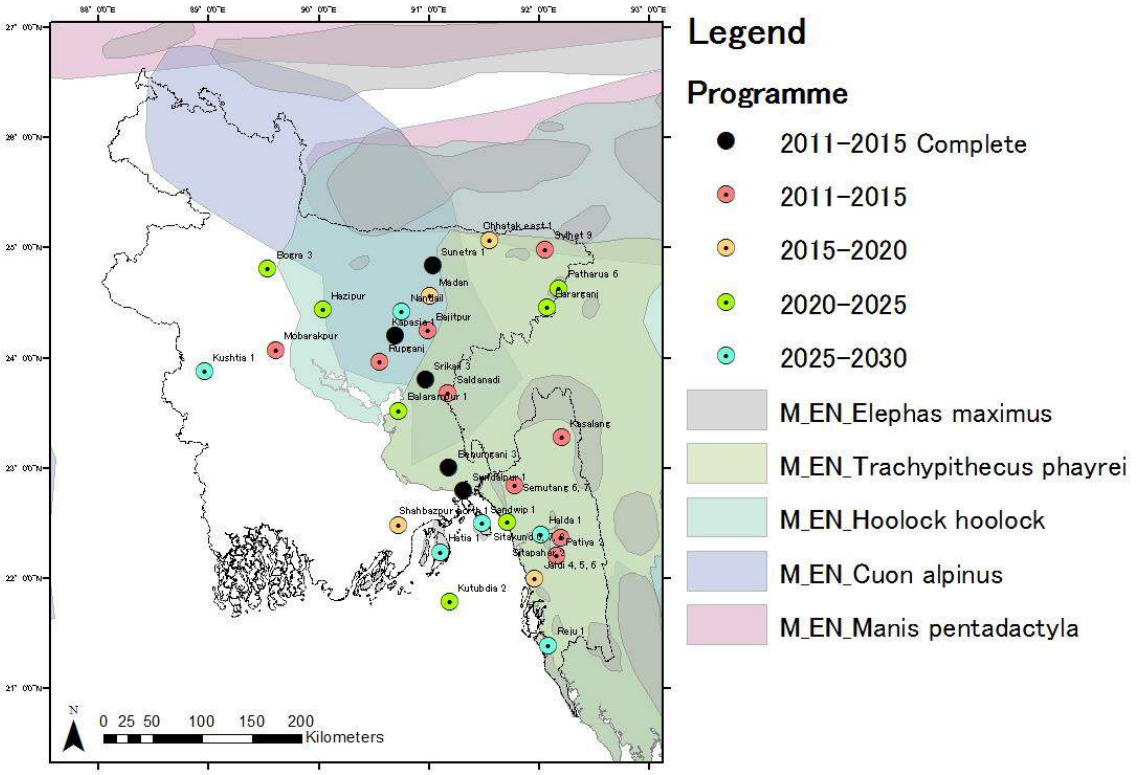
7.7.3 Environmental and social risk of gas development

According to Preparatory Survey on The Natural Gas Efficiency Project in The People's Republic of Bangladesh (2014, JICA), planned gas fields are 24 on shore and 1 off shore. Six locations are in the domestic or international protected areas. 21 fields are in the known distribution areas of five mammals listed in IUCN red list as Endangered (EN) category. No EIA report is confirmed for the planned projects. Kasalang, Hararganj, Hazipur, Hatia 1, Reju 1, Sandwip 1 are located in the National parks or other protected areas. Then the layout should be planned to avoid the impacts on the protected areas (See Table 7-15). Saldanadi, Sylhet 9, Chhatak east 1, and Patharua 6 are located in the habitats of more than three protected species. Then detail biological survey before identifying the location and off-set mitigation planning is recommended. Although 16 fields locate in the agricultural areas, the resettlements will be avoided by carefully site selection (Table 7-16). The most anxious risk is a blowout. In order to lower the risk of blowout, the exploration companies with high technic should be selected.



Source: Preparatory Survey on The Natural Gas Efficiency Project in The People's Republic of Bangladesh (2014, JICA)

Figure 7-20 Protected Areas and Possible Gas Fields



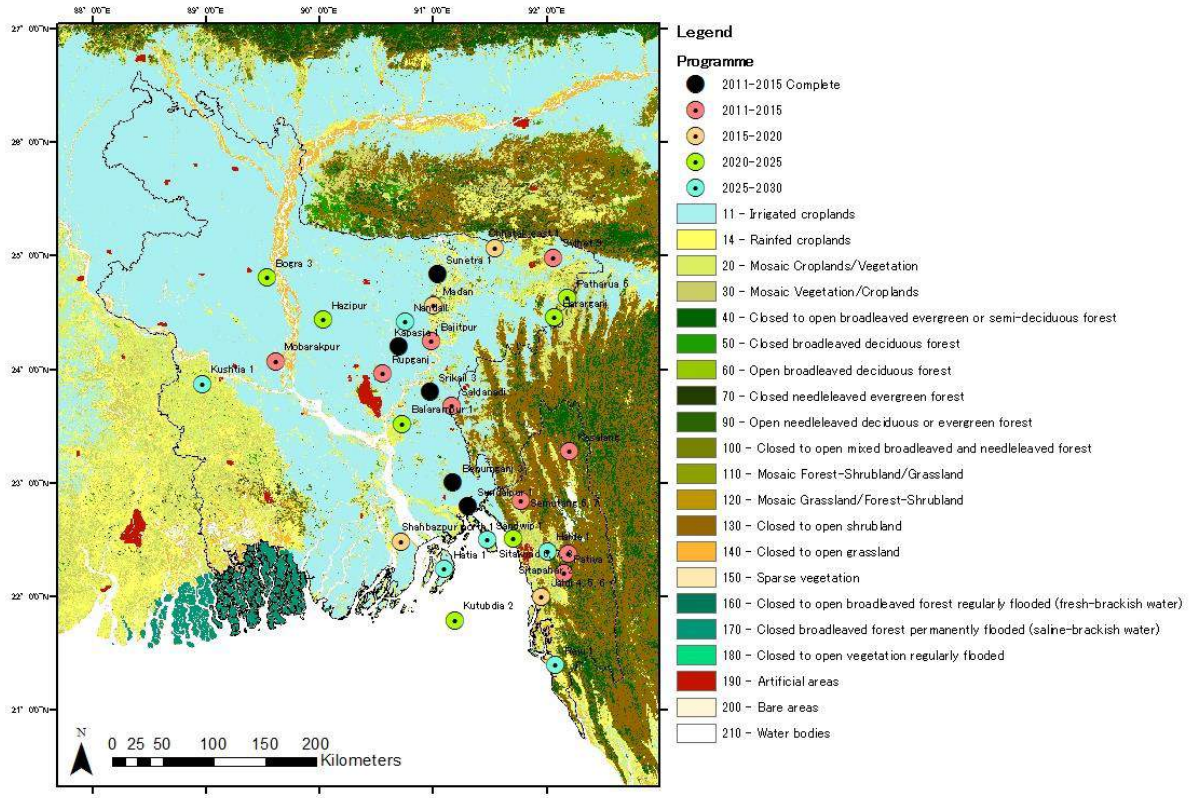
Source: JICA Survey Team

Figure 7-21 Habitat of Protected Mammals and Possible Gas Fields

Table 7-15 Possible Gas Fields and Protected Areas and Protected Mammals

Programme	Name	Protected Area	IUCN Red list species (Mammal, Endangered)				
			Elephas maximus	Trachypithecus phayrei	Hoolock hoolock	Cuon alpinus	Manis pentadactyla
2011-2015	Bajitpur				*	*	
	Kasalang	Reserved Forest		*	*		
	Mobarakpur						
	Patiya 2			*	*		
	Rupganj				*	*	
	Saldanadi			*	*	*	
	Semutang 6, 7			*	*		
	Sitapahar 2			*	*		
	Sylhet 9			*	*		*
2015-2020	Chhatak east 1			*	*		*
	Jaldi 4, 5, 6			*	*		
	Madan				*	*	
	Shahbazpur north 1						
2020-2025	Balarampur 1			*	*		
	Bogra 3						
	Hararganj	Reserved Forest		*	*		
	Hazipur	Reserved Forest			*		
	Kutubdia 2						
	Patharua 6		*	*	*		
	Sitakund 6, 7, 8			*	*		
2025-2030	Halda 1			*	*		
	Hatia 1	KBA, Reserved Forest	*				
	Kushtia 1						
	Nandail				*	*	
	Reju 1	National Park		*	*		
	Sandwip 1	KBA	*				

Source: JICA Survey Team



Source: JICA Survey Team

Figure 7-22 Land Use and Possible Gas Fields

Table 7-16 Possible Gas Fields and Land Use

Programme	Name	Farm land	Forest	Water
2011-2015	Bajitpur	Irrigated croplands		
	Kasalang		Closed to open shrub land	
	Mobarakpur	Irrigated croplands		
	Patiya 2		Closed to open shrub land	
	Rupganj	Irrigated croplands		
	Saldanadi	Mosaic Croplands/Vegetation		
	Semutang 6, 7	Mosaic Vegetation/Croplands		
	Sitapahar 2		Closed to open shrub land	
	Sylhet 9	Mosaic Croplands/Vegetation		
2015-2020	Chhatak east 1	Mosaic Croplands/Vegetation		
	Jaldi 4, 5, 6		Closed to open shrub land	
	Madan	Mosaic Croplands/Vegetation		
	Shahbazpur north 1	Irrigated croplands		
2020-2025	Balarampur 1	Irrigated croplands		
	Bogra 3	Irrigated croplands		
	Hararganj		Closed to open broadleaved evergreen or semi-deciduous forest	
	Hazipur	Irrigated croplands		
	Kutubdia 2			Water bodies
	Patharua 6		Closed to open shrub land	
	Sitakund 6, 7, 8		Closed to open shrub land	
2025-2030	Halda 1		Closed to open shrub land	
	Hatia 1	Irrigated croplands		
	Kushtia 1	Mosaic Vegetation/Croplands		
	Nandail	Irrigated croplands		
	Reju 1		Closed to open shrub land	
	Sandwip 1	Mosaic Vegetation/Croplands		

Source: JICA Survey Team

Chapter 7 Attachment

7-1 Natural Gas Supply Analysis

7-1 Natural Gas Supply Analysis

1. Current Status of Existing Gas fields

Understanding of the current status of the existing gas fields is very important for production forecasts for each gas field. Therefore, a comparison of actual production (average daily production) from each gas field over the years of 2010 to 2014 and the forecasts by PSMP 2010 is shown in Table 17.

Based on the information/data such as the remaining 2P reserves shown in the "Draft Five Year Gas Supply Strategy" and the results of drilling and workover shown in Petrobangla Annual Reports, The current status of the existing gas fields in Bangladesh and the future outlook are summarized in Table 18.

Table 17and Table 18 indicate the following points.

- Only Bibiyana gas field has shown a steady increase in production since 2010 in Bangladesh.
- The Jalalabad gas field also significantly increased production in 2012, but after that production from the field has not increased significantly.
- Production from the Sangu gas field was suspended from October 1, 2013.
- Measures for troubles associated with excessive water production need to be taken
- Successes of new development wells are important to increase production in the future.
- Additions of recoverable reserves by introduction of wellhead gas compressors in mature gas fields resulting in the extension of the field life are expected.

Table 17 Comparison between Actual Average Daily Production and PSMP2010 Forecasts

Unit: mmscfd

Sl. No.	Gas Field	Average Daily Production							
		Actual					PSMP2010 Forecasts		
		2010	2011	2012	2013	2014	2010	2014: Case1	2014: Case 2
1	Titas	404	445	450	490	515	408	578	560
2	Habiganj	235	260	227	225	225	240	260	260
3	Bakhrabad	35	33	32	41	41	36	51	51
4	Kailashtila	91	86	89	84	74	87	97	97
5	Rashidpur	49	49	47	47	61	49	84	85
6	Sylhet/Haripur	3	10	9	9	8	7	30	30
7	Meghna	0	10	10	11	10	0	5	5
8	Narshingdi	33	30	30	28	28	35	25	25
9	Beanibazar	15	9	11	10	10	15	15	15
10	Fenchuganj	25	23	36	37	39	24	65	60
11	Saldanadi	8	18	16	15	12	8	8	8
12	Shahbazpur	6	0	7	7	8	8	10	10
13	Semutang	0	14	8	6	5	0	15	15
14	Sundalpur	0	0	10	10	4	0	60	60
15	Srikail	0	0	0	42	39	0	60	60
16	Sangu	37	14	23	0	0	40	0	0
17	Jalalabad	163	165	232	249	246	130	250	200
18	Moulavi Bazar	58	42	94	77	63	60	160	80
19	Bibiyana	658	753	792	822	1,007	716	900	850
20	Bangura	105	102	86	111	110	120	120	120
21	Begumganj	0	0	0	0	0	0	0	0
22	Kutubdia	0	0	0	0	0	0	0	0
23	Chattak	0	0	0	0	0	0	0	0
24	Kamta	0	0	0	0	0	0	0	0
25	Feni	2	0	0	0	0	2	2	2
Total		**1,926**	**2,062**	**2,210**	**2,323**	**2,435**	**1,995**	**2,765**	**2,563**

Note: A production rate of 60 mmscfd for Sundalpur and Srikal by the PSMP2010 forecasts means that the sum of production from Sundalpur and Srikail should be equal to 60 mmscfd in this case.

Source: Prepared based on Petrobangla Annual Reports 2010 to 2014 and PSMP2010 report (JICA, 2011)

Table 18 Evaluation of Current Status of Existing Gas Fields

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
1	Titas	21	578	560	518	515.2	6,367.0	2,515.67	• The actual daily production rate was lower than that predicted by PSMP2010 study because the drilling of new development wells was delayed from initilal schedule. • Production rates for recently drilled development wells Titas-19, 20, 21 and 22 were significantly lower than expected (see Table 1.4-1). • Production from the Titas-21 well has been suspended from late June 2014. • It is expected that an increase in the production capacity depending on the plan and results of future development drilling. • It is possible to add the reserves and extend the field life by installation of the wellhead gas compressors being scheduled around 2016. The installation of the wellhead gas compressors will be limited to a part of the production sites, it is necessary to intstall them in other production sites in future.
2	Habiganj	7	260	260	225	225.1	2,633.0	523.81	• The actual production in 2014 was slightly lower than that predicted by PSMP2010. • A significant increase in production will not be expected because the remaining 2P reserves are only 20% of recoveralbe (2P) reserves, although the size of the remaining recoverable (2P) reserves are evaluated as medium.
3	Bakhrabad	7	51	51	43	41.0	1,231.5	456.37	• The overall field's production has not increased because workover of the existing suspended wells were unsuccessful, although the well Bakharabad-9 resulted in success. • An increase in production is expected by drilling of new development wells in the future.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
4	Kailashtila	4	97	97	80	73.5	2,760.0	2,163.60	• The field's production has not increased. This is due to in part the delay in drilling of new development well Kailashtila-7. • The future production performance will be dependent on whether new development drilling and well workover operations will be sucessful or not. • Prior to preparing the programs for the future development drilling the review of 3D seismic data over the field is required.
5	Rashidpur	5	84	85	64	60.7	2,433.0	1,889.79	• An increase in production is small at present because drilling of new development wells, including the Rashipur-8 well from which production was started in August 2014, has been delayed from the initial schedule. • According to the Petrobangla's five-year plan, drilling of three development wells is planned. • Gas production will not increase to the level such as over 500 MMscfd in the future, which was predicted by PSMP2010.
6	Sylhet/Haripur	2	30	30	11	8.4	318.9	113.64	• Based on recent development activities an increase in production can be expected, depending on the results of future development wells, although a significant increase in production will not be expected from the development plan shown in the Petrobangla's five-year plan. • The installation of wellhead gas compressor scheduled around 2017 makes it possible to add substantial reserves to the current reserves and extend the field life.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
7	Meghna	1	5	5	11	10.0	69.9	16.84	• The field life will be short because the remaining 2P reserves are small. According to the production forecasts by PSMP2015, the field production will continue up to 2022, whereas it will continue only up to 2015 by PSMP2010's forecasts.
8	Narshingdi	2	25	25	30	28.1	276.8	116.40	• Gas production has been continuing as forecasted by PSMP2010 since 2010. • The installation of wellhead gas compressor scheduled around 2017 makes it possible to have substantial quantity of additional reserves and extend the field life.
9	Beanibazar	1	15	15	14	9.6	203.0	115.28	• Average daily production of 9.5 MMscfd in 2014 is significantly lower than that predicted by PSMP2010.
10	Fenchuganj	3	65	60	40	38.7	381.0	256.21	• There is no increase in production because the Fenchuganj-5 well drilled in 2014 resutlted in unsuccessful. • An increase in production will not be expected for some time because any programs of development drilling are not shown in the Perobangla's five-year plan.
11	Saldanadi	1	8	8	20	12.0	279.0	197.44	• The reserves are small. Therefore the field's production will not increase significantly in the future, although this may be dependent on the results of new development wells. However, the size of the remaining 2P reserves indicates that the field can produce gas at a rate of about 20 MMscfd, about twice as much as the average daily production as of December 2014, in the near future. • According to the Petrobangla's five-year plan, development well Saldanadi-4 are to be drilled and then completed in May 2015.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
12	Shahbazpur	2	10	10	30	7.9	390.0	379.50	• Daily production in 2014 is almost the same as that predicted by PSMP2010. • Development wells Shahbazpur-3 and 4 were completed in September 2014 and November 2014, respectively, and a flow rate of about 19 MMscfd of gas from well no. 3 and about 32 MMscfd of gas from well no. 4 were confirmed by the flow tests, respectively. But gas production from both wells have not started yet. • According to the Petrobangla's five-year plan, any new development wells are not planned. However, from the viewpoin of the size of recoverable reserves, drlling of new development wells for increasing production is expected in the near future
13	Semutang	2	15	15	12	4.6	317.7	308.03	• Gas production in 2014 was significantly lower than that predicted by PSMP2010. This is because the field development may have not progressed as planned. • Regarding the actual production as of December 2014, an average daily production rate of 4.7 MMscfd from 2 wells is very low. • The future production will depend on the results of the planned two development wells shown in the Petrobangla's five-year plan.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
14	Sundalpur Shahzadpur	1	60	60	10	3.6	35.1	27.10	• According to the production forecasts by PSMP2010, this field is considered to be one of newly discovered gas fields, and an average daily production is estimated to be 60 MMscfd including production from other new fields in 2014. • From the viewpoint of the size of the remaining reserves, a significant increase in production is not expected. • According to the Petrobangla's five-year plan, drilling of one development wells is planned.
15	Srikail	2	60	60	44	38.7	161.0	135.57	• Gas production from the field started in March 2013. • According to the production forecasts by PSMP2010, this field is considered to be one of newly discovered gas fields, and an average daily production is estimated to be 60 MMscfd including production from other new fields in 2014. • According to the Petrobangla's five-year plan, drilling of one development wells is planned and production from the well is expected to start 2016..
16	Sangu	0	0	0	0	0.0	577.8	89.85	• Gas production from the field has been suspended from 1 October 2013. The production facilities have been handed over to Petrobangla as per contract. However, whether Petrobangla resume production from this field is unknown. • According to the forecasts by PSMP2010, production was not expected after 2014. • According to the forecasts by PSMP2015, production is also not expected over the years from 2015 through 2041.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
17	Jalalabad	4	250	200	246	246.2	1,184.0	281.15	• The results of case 1 in the production forecasts by PSMP2010 shows that the production rate of 250 MMscfd in 2014 is almost the same as that of actual production. • Even in case 2 by PSMP2010, in which the field life is longer life compared to case 2, production will continue only to 2022. On the other hand, PSMP2015 forecasts that the field production will be sustained up to 2027. • The field life can be extended by, for example, introduction of wellhead gas compressors.
18	Moulavi Bazar	6	160	80	60	62.6	428.0	160.51	• Cases 1 and 2 in the production forecasts by PSMP2010 were 160 MMscfd and 80 MMscfd, respectively, whereas gas was produced at a rate of 60 MMscfd in 2014. • An increase in production could not be expected in the future from recent decrease in production. The field's production was less than 40 MMscfd in late February 2015.
19	Bibiyana	18	900	850	960	1,006.7	5,754.0	3,873.19	• Actual production rate in 2014 was significantly higher than those of both cases 1 and 2 by PSMP2010. • Production increased in November 2014 and February 2015, respectively. • A peak daily production rate of 1,200 MMscfd, following the production rate shown in the Petrobangla's five-year plan, is expected to be maintained over the period of 2015 to 2019 in the long-term production forecasts. Based on the information of the processing capacity of 1,200 MMscfd in the current production facilities, an average daily production rate of 1,200 MMscfd will continue at least until 2019.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
20	Bangura	4	120	120	100	110.0	522.0	241.00	• According to the production forecasts by PSMP2010, the average production rate of 120 MMscfd in 2014 in both of cases 1 and 2. However, gas was produced actually at a rate of 109 MMscfd which was slightly lower than the expected. • Accoding to the production forecasts by PSMP2010, the field' production was expected to continue up to 2023. However, the production is expected to further continue because gas has been produced constantly at a rate of about 110 MMscfd since early 2014.
21	Begumganj	0	0	0	0	0.0	70.0	70.00	• According to the production forecasts by PSMP2010, the field's production will start in 2017. On the other hand, according to the Petrobangla's five-year plan, the production will start soon (from the Begumganj-3 well). • According to the Petrobangla's five-year plan, drilling of one development well is planned and production from the well is expected to start in 2017.
22	Kutubdia	0	0	0	0	0.0	45.5	45.50	• According to the forecasts by PSMP2010, the field's production is expected to be from Block 16, and the start-up of production is scheduled to be 2017. However, from the information available at present it is difficult to start production. • No production from the field is expected in the long-term production forecasts in this survey.
23	Chhatak	0	0	0	0	0.0	474.0	447.54	• According to the forecasts by PSMP2010, any gas production is not expected. • According to the Petrobangla's five-year plan, drilling of two development wells is planned at Chhatak West, and production from the field is expected to start in 2016.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
24	Kamta	0	0	0	0	0.0	50.3	29.20	• Production was not estimated by the PSMP2010. Production is also not estimated in the Petrobangla's five-year plan. • Based on the above situation, the field's production is not expected in this survey..
25	Feni	0	2	2	0	0.0	125.0	62.60	• There was no production from the field in 2014, whereas according to the production forecasts by PSMP2010, gas was produced at a rate of 2 MMscfd. • According to the Petrobangla's five-year plan, drilling of two development wells is planned and production from the field is expected to resume in 2016.

Note: 1) Remaining 2P reserves = Recoverable 2P reserves - Cumulative production
2) The rcoverable 2P reserves as of the end of 2014 and remaining 2P reserves are based on the Draft Five Year Gas Supply Strategy prepared by Petrobangla.

Source: Prepared based on PSMP2010 report (JICA, 2011), Petrobangla Anuual Reports 2010 to 2014 and Petrobangla's “Draft Five Year Gas Supply Strategy” (2015)

2. Production forecast for existing gas fields 2015-2019

Production forecasts for the existing gas fields for the next five years are necessary for long-term production forecasts. In this survey production forecasts for the period of 2015 to 2019 are conducted based on the production forecasts shown in the Petrobangla's five-year plan
The production rates are overestimated as a whole in the production forecasts for the period of 2015-2019 shown in the Petrobangla's five-year plan. Therefore, as described below, the production rates estimated by Petrobangla were corrected, if necessary, based on the comparison of between expected and actual for the times of well completion and production rates.

(1) Evaluation of Times of Well Completion and Production Rates Shown in the Petrobangla's Five-Year Plan

Evaluation of times of well completion and production rates shown in the Petrobangla's five-year plan is carried out based on a comparison between expected and actual for times of well completion and production rates for the wells shown in the "Gas Evacuation Plan 2010-2015" prepared in 2010. The comparison is shown in Table 19 It is noted that the wells whose actual data were not available are excluded from the table. As a result, the data evaluation was made only on the development and exploratory wells.

Table 19 indicates that the times of completion for newly drilled wells were more than one year behind schedule except for exploratory well Sundalpur-1. Regarding daily production rates it is evaluated as about 70% of the initial estimates, although the actual values ranges from 52 to 167% of the initial estimates. Averaged value of the ratio of actual/expected for daily production rate shows 0.78 for all wells (12 wells) listed in Table 19 and 0.69 for development wells (10 wells), respectively. Production forecasting is focused on development wells in the existing gas fields. Therefore a value of 0.69 was chosen because the evaluation is to be performed on the development wells, and then 0.69 rounded off to one decimal place is 0.7.

Based on these results the times of well completion and production rates shown in the Petrobangla's five-year plan are evaluated as follows,

- Times of well completion: At least one year behind schedule
- Production rates: About 70% of initial estimates

(2) Revision of Production Forecasts by Petrobangla for Existing Gas Field

Based on the comparison described above, correction factors for times of well completion and production rates shown in the Petrobangla's five-year plan are basically assumed as follows.

The risk of the delay in the time of well completion is expressed as decrease in production rate. Based on the idea that if one-year delay occurs in a five-year period, production decreases by 20% of the initial estimate, the production rates shown in the Petrobangla's five-year plan were corrected. The values of production rates are corrected by multiplying 0.8 for the wells to be completed in and after 2016.

- Times of well completion: 80% of the initial estimate
- Production rates: 70% of the initial estimates

Thus, the corrected production rates for the wells shown in the Petrobangla's five-year plan are listed in Table 20.

(3) Production Forecasts for 2015-2019

The production forecasts for the period of 2015-2019 were conducted by party modifying those shown in the "Draft Five Year Gas Supply Strategy" by Petrobangla, if necessary, based on the comparison of between expected and actual for the times of well completion and production rates as described above. Thus, the modified production forecasts are shown in Table 21.

- Patterns of production profiles are basically the same as those shown in the Petrobangla's five-year plan.
- According to the Petrobangla's five-year plan, an increase in production by 5 mmscfed from the Shahbazpur gas field since 2018 is planned. However, this increase in production was not taken into consideration in this survey because any development plans are not presented in the plan.
- The grand total shows a peak production rate of 2,811 mmscfd at the period of July-December in 2016 (Table 21). On the other hand, the production forecasts shown in the Petrobangla's five-year plan also shows a peak production rate of 2,916 mmscfd at the same period as shown above. As a result, the production rate estimated by the survey team is lower than that by Petrobangla by about 100 mmscfd.

Table 19 Times of Well Completion and Production Rate for Wells Shown in Gas Evacuation Plan 2010-2015: Expected vs Actual

As of February 2015

Well Name	Owner/ Operator	Time of Well Completion			Daily Production Rate			Remarks
		Excpected	Actual	Difference (Delay) (month)	Excpected	Actual	Ratio of Actual/Expected	
Development Wells								
Fenchuganj-4	BAPEX	Oct 2010	Feb 2012	16	20	20	1	
Saldanadi-3	BAPEX	Nov 2010	Jan 2012	13	15	15	1	
Saldanadi-4	BAPEX	Mar 2011	—	47+	15	0	0	During drilling
Titas-17	BGFCL	Jun 2011	Mar 2013	21	25	15	0.60	
Fenchuganj-5	BAPEX	Aug 2011	Apr 2014	32	20	0	0	Dry
Titas-18	BGFCL	Nov 2011	Aug 2013	21	25	16	0.64	
Bakhrabad-9	BGFCL	Apr 2012	Aug 2013	16	20	16	0.80	
Titas-19	BGFCL	Jun 2012	May 2014	23	100	15	0.52	
Titas-20	BGFCL		Oct 2013	?		10		
Titas-21	BGFCL		Dec 2013	?		15		Suspended in July 2014 due to production of exccesive amount of water
Titas-22	BGFCL		Mar 2014	?		12		
Rashidpur-8	SGFL	Jun 2012	Aug 2014	26	20	15	0.75	
Exploratory Wells								
Sundalpur-1	BAPEX	Oct 2010	Sep 2011	11	15	12	0.80	Production started in March 2012
Srikail-2	BAPEX	Feb 2011	Jun 2012	16	15	25	1.67	Production started in March 2013
Kapasia-1	BAPEX	Mar 2011	Apr 2012	13	15	0	0	Dry
Mubarakpur-1	BAPEX	Sep 2011	—	41+	15	0	0	During drilling

Source: Prepared based on Petrobangla's "Gas Evacuation Plan (2010-2015)" (2010), Petrobangla Annual Reports, etc.

Table 20 Data Used for Correction of Production Rate in Production Forecast for Existing Gas Fields by Petrobangla

As of February 2015

Gas Field	Development Drilling/Workover		Estimates of Production Rate			Reasons for Correction of Production Rate	Production Outlook
	Well Name	Type of Operations	Estimates by Petrobangla (MMscfd)	Correction Factor	Production Rate after Correction (MMscfd)		
Titas	No. 23	Dev. Drlg	20	0.7	14	• Production rates estimated based on the actual productio rates in recently drilled development wells • Correction: Production rates only	• It is expected that an increase in the production capacity depending on the plan and results of future development drilling. • It is possible to add the reserves and extend the field life by installation of the wellhead gas compressors being scheduled around 2016. The installation of the wellhead gas compressors will be limited to a part of the production sites, it is necessary to intstall them in other production sites in future.
	No. 24	Dev. Drlg	20	0.7	14		
	No. 25	Dev. Drlg	20	0.7	14		
	No. 26	Dev. Drlg	20	0.7	14		
Bakhrabad	No. 10	Dev. Drlg	10	0.8	8	• Correction: Time of production start-up only	• An increase in production is expected by drilling of new development wells in the future.
Kailashtila	No. 7	Dev. Drlg	15	0.56	8	• Workover operational risk is relatively high • Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• The future production performance will be dependent on whether new development drilling and well workover operations will be sucessful or not.
	No. 1&5	Workover	15	0.56	8		
	No. 9	Dev. Drlg	25	0.56	14		
Rashidpur	No. 9	Dev. Drlg	10	0.56	6	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• An increase in production is small at present because drilling of new development wells, including the Rashipur-8 well from which production was started in August 2014, has been delayed from the initial schedule. • According to the Petrobangla's five-year plan, drilling of three development wells is planned.
	No. 10	Dev. Drlg	20	0.56	11		
	No. 11	Dev. Drlg	20	0.56	11		
Sylhet/Haripur	No. 9	Dev. Drlg	10	0.56	6	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• Based on recent development activities an increase in production can be expected, depending on the results of future development wells, although a significant increase in production will not be expected from the development plan shown in the Petrobangla's five-year plan.

Table 4 Data Used for Correction of Production Rate in Production Forecast for Existing Gas Fields by Petrobangla (continued)

As of February 2015

Gas Field	Development Drilling/Workover		Estimates of Production Rate			Reasons for Correction of Production Rate	Production Outlook
	Well Name	Type of Operations	Estimates by Petrobangla (MMscfd)	Correction Factor	Production Rate after Correction (MMscfd)		
Saldanadi	No. 4	Dev. Drlg	10	1	10	• Evaluated based on the production performance of well No. 1	• The reserves are small. Therefore the field's production will not increase significantly in the future, although this may be dependent on the results of new development wells. However, the size of the remaining 2P reserves indicates that the field can produce gas at a rate of about 20 MMscfd, about twice as much as the average daily production as of December 2014, in the near future. • According to the Petrobangla's five-year plan, development well Saldanadi-4 are to be drilled and then completed in May 2015.
Shahbajpur	No. 4	Dev. Drlg	25	—	19	• Production rate is estimated based on the well test results conducted after completion of drilling	
Semutang	No. 7	Dev. Drlg	8	0.56	4	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• The future production will depend on the results of the planned two development wells shown in the Petrobangla's five-year plan.
	No. 8	Dev. Drlg	8	0.56	4		
Sundupur Shahzadpur	No. 2	Dev. Drlg	8	0.56	4	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• From the viewpoint of the size of the remaining reserves, a significant increase in production is not expected. • According to the Petrobangla's five-year plan, drilling of one development wells is planned.
Srikail	No. 4	Dev. Drlg	20	0.56	11	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the Petrobangla's five-year plan, drilling of one development wells is planned and production from the well is expected to start 2016..

Table 4 Data Used for Correction of Production Rate in Production Forecast for Existing Gas Fields by Petrobangla (continued)

As of February 2015

Gas Field	Development Drilling/Workover		Estimates of Production Rate			Reasons for Correction of Production Rate	Production Outlook
	Well Name	Type of Operations	Estimates by Petrobangla (MMscfd)	Correction Factor	Production Rate after Correction (MMscfd)		
Bibiyana	Specific well names or numbers are not disclosed	Dev. Drlg	150	1	150	• Correnction for production rates was not made because the field's average daily production rate was increased to about 980 MMscfd in November 2014 and then will be increased to about 1,200 MMscfd soon.	• A peak daily production rate of 1,200 MMscfd, following the production rate shown in the Petrobangla's five-year plan, is expected to be maintained over the period of 2015 to 2019 in the long-term production forecasts. Based on the information of the processing capacity of 1,200 MMscfd in the current production facilities, an average daily production rate of 1,200 MMscfd will continue at least until 2019.
Begumganj	No. 3	Dev. Drlg	12	0.7	8	• Drilling of well No. 3 has already been completed. • Correction for well No. 3: 0.7 for production rate only • Correction for well No. 4: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the production forecasts by PSMP2010, the field's production will start in 2017. On the other hand, according to the Petrobangla's five-year plan, the production will start soon (from the Begumganj-3 well). • According to the Petrobangla's five-year plan, drilling of one development well is planned and production from the well is expected to start in 2017.
	No. 4	Dev. Drlg	15	0.56	8		
Chattak	No. 3	Dev. Drlg	20	0.56	11	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the Petrobangla's five-year plan, drilling of two development wells is planned at Chhatak West, and production from the field is expected to start in 2016.
	No. 4	Dev. Drlg	20	0.56	11		
Feni	No. 6	Dev. Drlg	10	0.56	6	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the Petrobangla's five-year plan, drilling of two development wells is planned and production from the field is expected to resume in 2016.
	No. 7	Dev. Drlg	10	0.56	6		

Table 21 Daily Gas Production Forecast for 2015-2019

Unit: mmscfd

Company	Field	2015		2016		2017		2018		2019		Remarks
		Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	
1. BGFCL	Titas	525	520	520	510+56	556	546	489	489	441	441	Production start-up: Jul-Dec 2016—Well nos. 23, 24, 25 and 26
	Bakrabad	40	38	36	34	30	26	23	23	30	30	
	Habiganj	224	224	224	224	220	218	215	215	200	200	
	Narsingdi	28	28	28	28	26	25	24	24	23	23	
	Meghna	10	10	10	10	10	10	9	9	9	9	
	Sub-total	**827**	**820**	**818**	**862**	**842**	**825**	**760**	**760**	**703**	**703**	
2. SGFL	Sylhet	8	8	7	7+6	12	11	11	10	10	9	Production start-up:Jul-Dec 2016—Well no. 9
	Kailashtila	72	70+8	78+14	92+8	100	96	96	92	92	88	Production start-up: Jul-Dec 2015—Well no. 1&5, Jan-Jun 2016—Well no. 9, Jul-Dec 2016—Well no. 7
	Rashidpur	60	59	58	57	56	61	72	70	67	67	Production start-up: Jul-Dec 2017--Well no. 9, Jan-Jun 2018--Well nos. 10 & 11
	Beani Bazar	9	9	9	9	8	8	8	8	8	8	
	Sub-total	**149**	**154**	**166**	**179**	**176**	**176**	**187**	**180**	**177**	**172**	
3. BAPEX	Saldanadi	10	6+10	16	13	12	11	10	10	10	10	Prpduction start-up: Jul-Dec 2015—Well no. 4
	Fenchuganj	35	34	32	30	30	29	28	28	28	28	
	Shahbazpur	10	10+9	29	29	29	29	29	29	29	29	Production start-up: Jul-Dec 2015—Well no. 4
	Semutang	4	3	2	2	2+4	6+4	10	10	10	10	Production start-up: Jan-Jun 2017—Well no. 7, Jul-Dec 2017—Well no. 8
	Sundalpur	3	3	2	0+4	4	4	4	4	4	4	Production start-up: Jul-Dec 2016—Well no.2
	Srikail	38	36	35+11	46	41	41	41	41	36	36	Production start-up: Jan-Jun 2016—Well no. 4
	Rupganj	0	8	8	8	8	8	7	7	7	7	
	Begumganj	4	4+8	12	12	10	10+8	16	16	12	9	Jan-Jun 2015: Actual production, Production start-up: Jul-Dec 2015—Well no. 3, Jul-Dec 2017—Well no. 4
	Sub-total	**104**	**141**	**147**	**144**	**140**	**150**	**145**	**145**	**136**	**133**	
Sub-total (1+2+3)		**1,080**	**1,115**	**1,131**	**1,185**	**1,158**	**1,151**	**1,092**	**1,085**	**1,016**	**1,008**	
4. Chevron	Jalalabad	250	250	250	250	220	220	220	220	220	220	
	Maulavibazar	50	50	50	50	45	45	45	45	45	45	Jan-Jun 2015: Actual production
	Bibiyana	1,100	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	Jan-Jun 2015: Actual production
5. Tullow	Bangora	110	110	109	109	81	81	69	69	58	58	Jan-Jun 2015: Actual production
Sub-total (4+5)		**1,510**	**1,610**	**1,609**	**1,609**	**1,546**	**1,546**	**1,534**	**1,534**	**1,523**	**1,523**	
6.	Feni				6	6+6	12	12	11	9	8	Resumption of production: Jul-Dec 2016—Well no. 6, Jan-Jun 2017—Well no. 7
7.	Chhatak				11	11+11	22	22	19	19	16	Resumption of production: Jul-Dec 2016—Well no. 3, Jan-Jun 2017—Well no. 4
Ground Total (1+2+3+4+5+6+7)		**2,590**	**2,725**	**2,740**	**2,811**	**2,738**	**2,731**	**2,660**	**2,649**	**2,567**	**2,555**	

Note: 1) Production rates in yellow cells were modified from those shown in the Petrobangala's five-year plan based on the actual production data or corrected production rates shown in Table 1.4-2.
2) The expression such as "510+56" means a daily production rate without additional production plus an additional daily production rate.

Source: Petrobangla's "Draft Five Year Gas Supply Strategy" (2015) and JICA Survey Team

Chapter 7 Attachment

7-2 Cost Estimation for Natural Gas Exploration and Development

7-2 Cost Estimation for Natural Gas Exploration and Development

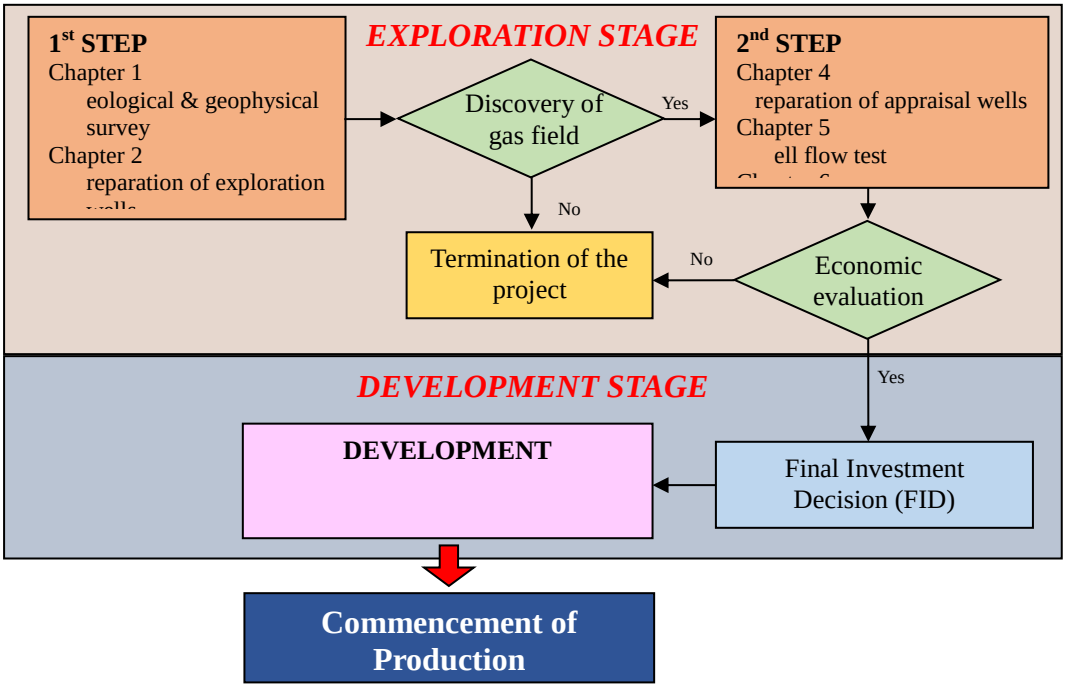
1. Introduction

(1) General

In order to grasp the approximate future gas development costs, the investment costs required for the exploration, drilling, and construction of the gas production facility till 2027 were estimated. The construction costs for the construction of the new gas production facility – intended to increase the nation's gas production - were estimated based on Bangladesh's gas field development plan as scheduled at present.

(2) Cost Estimation Objects

Generally, a flow of natural gas development is divided into "Exploration stage" and "Development stage", and the related activities proceed as shown in Figure 23.



Source: JICA Survey Team

Figure 23 Flow Chart of Gas Field Development

In the exploration stage, the potential of the gas field is mainly ensured and the risk of gas development is reduced by measures including 3D seismic surveys. The gas reservoir is evaluated on a commercial basis and if there are no problems here, the gas field is able to move to the development stage. At this point the final investment decision on the gas field development is made by the company.

In the development stage, the gas production wells are completed with drilling works. Following this, the gas production and related facilities with appropriate plant capacity are constructed to start production.

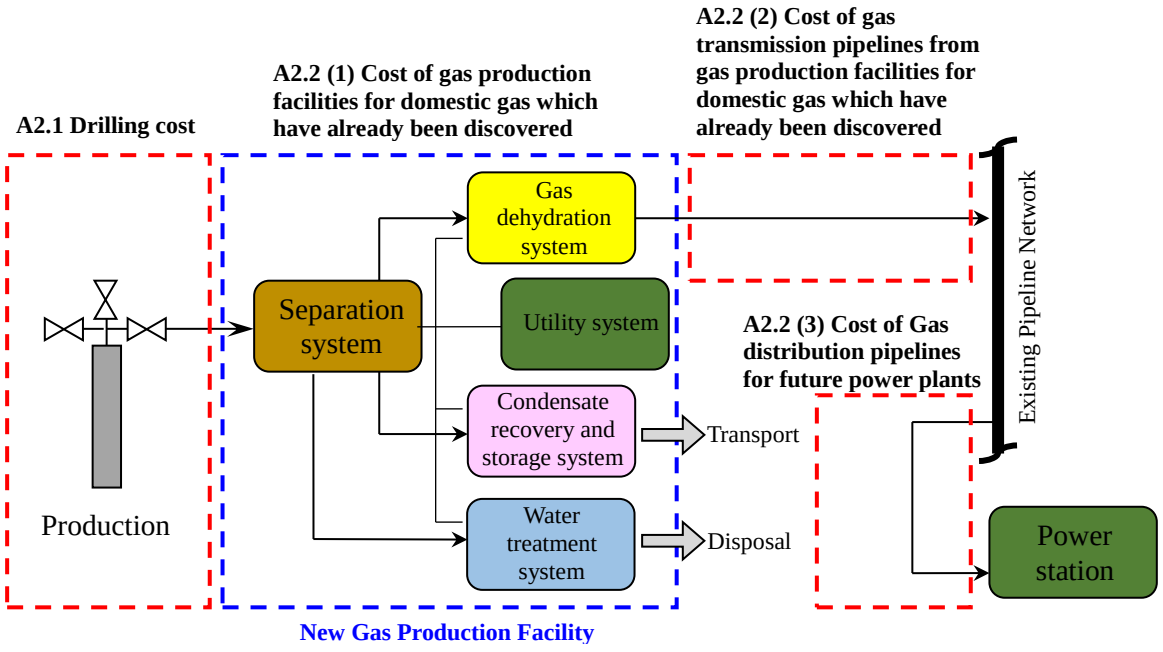
Accordingly, the investment costs are estimated separately and divided into the two stages mentioned above. The facility construction costs are also separately estimated into around four categories

including gas production facilities and pipelines. Furthermore, to properly meet the country's expected future rising gas demand, imports of LNG from overseas as well as domestic gas development is planned by the government. Therefore, the overall investment costs are divided into domestic gas development costs and import gas development costs.

The objectives (and their content) for these cost estimations are listed below, and the scope of these estimations are shown in Figure 24

A. Domestic Gas Development Costs
A.1 Field Exploration Costs
A.1.1.Seismic Survey Cost
A.1.2.Well Drilling Cost

A.2 Field Development Costs
A.2.1 Drilling Costs
A.2.2 Facility Construction Costs
(1) Gas production facilities for alredy-discovered domestic natural gas
(2) Gas transmission pipelines for alredy-discovered domestic natural gas
(3) Gas distribution pipelines for future power plants



Source: JICA Survey Team

Figure 24 Scope of Cost Estimations

B. Import Gas Development Costs
B1. Facility Construction Costs
(1) LNG receiving terminal
(2) LNG transmission pipeline

(3) Cost Estimation Procedure

Prior to conducting the cost estimation, a facility development concept of the future gas field and/or the existing gas field to be enhanced is examined based on the data and information provided by Petrobangla. Following this, a typical gas treatment process – including a separation system, a gas dehydration system, a condensate recovery and storage system, and a water treatment system – is

examined through consideration of matters such as fluid property and characteristics.

As the result of the above examinations, the facility construction costs are estimated based on appropriate conditions and assumptions. These costs are estimated using the worldwide industry standard Siemens' Oil and Gas Manager (OGM) software project design tool. OGM is a suite of computer programs for performing field development planning, feasibility studies and cost estimates for oil and gas field development. OGM is used to specify the particular case to be modeled by defining the various production facilities, and then filling in forms to specify the flow connections between each facility, with the estimation results being summarized in a comprehensive database.

One of OGM's major advantages is that the facility design process (including process calculations, utility consumption calculations, conceptual facility design, selection of equipment, cost estimations) can all be processed at the same time through inputting the appropriate data. Accordingly, when compared to the facility design work time, OGM enables effective cost estimation with sufficient accuracy in a short time. Although OGM is widely used internationally in the oil and gas industry, as at February 2015 Japan Oil Engineering Co., Ltd. is the only user in Japan.

The OGM cost estimation procedure using OGM is described below:

Step 1:

In this step the type of the facility necessary for successful gas treatment is specified. Based on the data and information collected in various surveys, the OGM can establish the configurations for the of gas production facility, including for the gas/liquid separation system, the gas dehydration system, the condensate recovery and storage system, and the water separation system.

Step 2:

Input data for the facility configuration established in step 1 is prepared for modeling before running the OGM program. Based on this data, the cost estimation is then carried out utilizing OGM.

The main input data is described below and other data is listed in the Table 27.

- Project construction site information
  Depending on the particular project location, localized data, such as wage levels, are formulated and adjusted by OGM.

- Required facilities (such as the separator, the gas dehydrator, the condensate storage, and the water treatment facilities)
  Facility configuration is entered to model a fluid treatment process. The main equipment in each facility is selected by the OGM database in consideration of the facility specifications and requirements.

- Process conditions
  Process conditions such as flow rate, pressure, temperature and fluid composition are entered so that OGM database may select the proper equipment.

- Gas handling capacity
  By entering a flow rate, simplified sizing for equipment is operated, and the equipment capacity is examined in the software.

- Gas dehydration requirement
  The scale of the gas dehydration facility is examined based on the gas dehydration level specified.

Step 3:

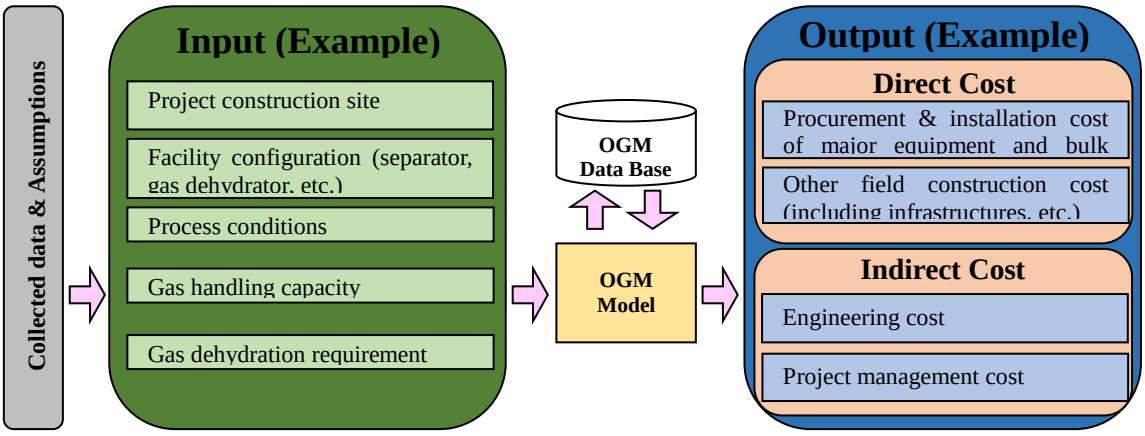
The direct and indirect costs of the total construction costs estimated are analyzed based on the OGM output. The costs breakdown from OGM are as follows:

- Direct costs
  - Procurement and installation costs of main equipment and bulk materials
  - Other field construction costs (including for infrastructure)

- Indirect costs
  - Engineering costs
  - Project management costs

Step 4:
The accuarcy and validity of the OGM cost estimation results is checked in line with data from the previous construction of similar scale gas production facilitiese.

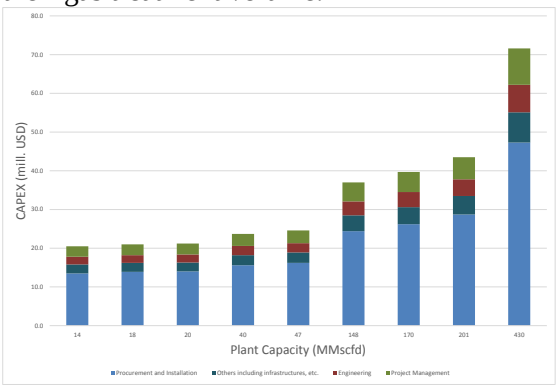
The cost estimation image by OGM is shown in Figure 25.



Source: JICA Survey Team

Figure 25 OGM Output Image

A more detailed cost estimation procedure for a gas production facility modeled using OGM is described below.

	Procedure	Description
Step 1	Preparation of input data	Southeast Asia was designated as the construction site. In relation to the configuration of the gas production facility, five facilities, such as the separation system, the dehydration system, the condensate recovery and storage system, and the water treatment facility, were specified for proper gas treatment. The following were also prepared as the input data: the gas treatment volume, the process conditions (gas composition, pressure, and temperature), the plant capacity, the level of gas dehydration, the number of facility trains, and the equipment required.
Step 2	Modeling the gas production facility and execution of OGM	In modeling the gas production facility, approximately five cases were set at the gas treatment volume within the range of 20 MMscfd to 400 MMscfd in order to cover all the cases at any gas treatment volume established in this study. OGM was used for each of these cases based on the above input data.
Step 3	Review of the OGM output	The OGM output is reviewed as the cost estimation results. In this review, the direct and indirect costs were analyzed separately, and the total construction costs were checked for their gas treatment volume. 
Step 4	Check of the cost estimation results	The accuracy and validity of the OGM output data was checked through comparing it with past construction cost data.

Source: JICA Survey Team

Figure 26 Cost Estimation Image from OGM

(4) Import Gas Development Plan

(a) Construction of a LNG Receiving Terminal

2 x 200,000 kl LNG tanks at south Chittagon is assumed as an initial stage.

(b) Construction of a LNG transmission pipeline

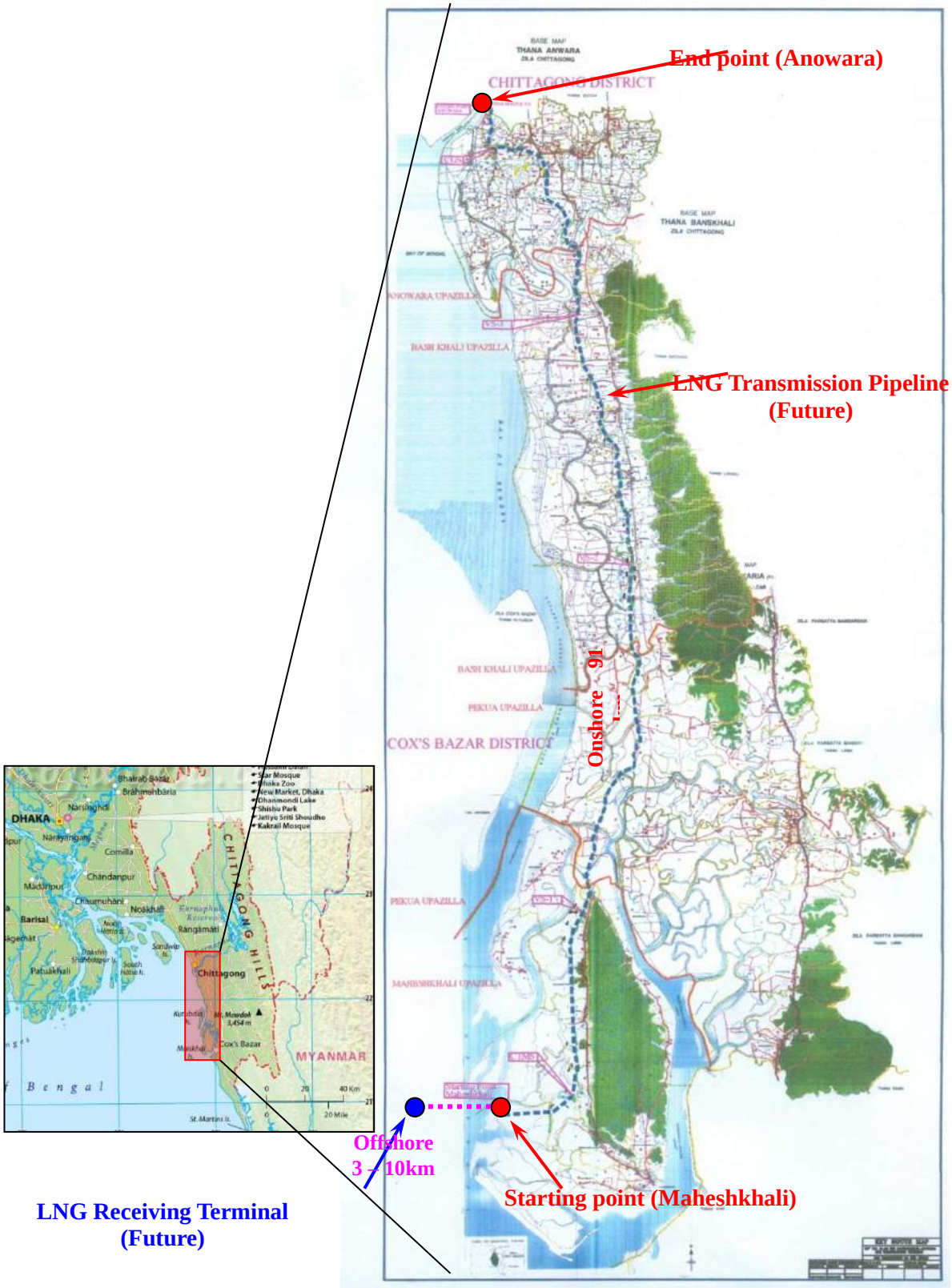
A proposed LNG transmission pipeline is to be constructed as part of a future program to transfer regasified gas of 500 MMscfd from the afore-mentioned proposed offshore LNG receiving terminal to the Chittagong RingMain (Anowara) via Moheshkhali. In this construction project, a 100 km (length) x 30 inch (width) transmission pipeline is to be installed; the pipeline shall be divided into an offshore portion of between 3 km to 10 km and a 91 km onshore portion. Please refer to Figure 27.

The operating conditions for the pipeline have been planned as indicated in Table 97.

Table 97 Operating Condition in LNG Transmission Pipeline

	Location	Flow rate [MMscfd]	Pressure [psig]
Starting point	Moheshkhali	500	1000
End point	Anowara		300

Source: information provided by Petrobangla



Source: information provided by Petrobangla

Figure 27 Pipeline Route Map of LNG Transmission Pipeline

2. Estimation Bases and Assumptions for Exploration Stage

As a part of cost estimation of natural gas development, seismic survey and well drilling costs were roughly estimated based on the information available from the websites of Petrobangla and its subsidiaries and news media.

Oil and gas exploration involves significant cost, time, and also high risk. It is important first step to gather geophysical data to narrow down the target area in the potential gas or oil field prior to start further exploratory activities.

For the last two-three decade, drilling technology has advanced significantly and exploration approach has also changed drastically. Recovery rate of oil and gas has improved due to the technological advancement. Key technological advancements are:

1) 3D seismic survey and 3D modeling technology
2) Directional and horizontal drilling technologies

Oil and gas exploration in Bangladesh started in mid 1950s. Majority of existing wells were designed and installed before 1990, and there may be some room for technological improvement to the existing facilities and also for new potential areas.

(1) Geophysical Survey:

Geophysical survey in the area of oil and gas exploration refers to a gravity survey, a magnetic survey, and a seismic survey. Gravity survey and magnetic survey are called air borne survey and used to identify size and depth of sedimentary basin as a whole and assist in modeling of subsurface structure.

Seismic survey provides more information about subsurface structures and indicates potential of subsurface deposits of crude oil and natural gas in the area. Seismic survey uses artificial seismic energy generated on land by vibrator mounted on specialized trucks if the area is accessible by trucks, otherwise use of explosives in the shallow borehole to generate shock wave. In offshore, air gun is used to generate highly compressed air bubbles which go into the water and transmit seismic wave energy into the subsurface layers.

Seismic waves reflect and refract off subsurface rock formations and travel back to acoustic receivers called geophones (on land) or hydrophones (in water). Based on the travel time data of the returned seismic energy, and also integrated with the existing strata information, feature of subsurface formation will be estimated, such as rock type, relative depth of folding, faulting, depositional environment, and nature of the fluid. This information facilitates to decide the location of prospective drilling targets.

Cost Indication for these activates will be as follows:

Type of Survey	Location	Survey Items	Cost Indication	Major Cost Element
Air Borne Survey	Onshore and Offshore	Gravity	not expensive	Airplane Lease Cost Equipment Lease cost
		Magnetic	not expensive	Airplane Lease Cost Equipment Lease cost
Seismic Survey	Onshore	2D	not expensive	Vibrator Truck Lease Cost Geophone Lease Cost
		3D	not so expensive	Vibrator Truck Lease Cost Geophone Lease Cost
	Offshore	2D	expensive	Survey Ship Day-rate

		3D	very expensive	Survey Ship Day-rate

(2) Drilling Works:

Drilling work for oil and gas exploration is carried out by specialized drilling rigs and experienced personals. These rigs are equipped with all necessary facilities to circulate the drilling fluid, hoist and turn the pipe, control down-hole, remove cuttings from the drilling fluid, safety facilities to prevent blowout events, and generate on-site power for these operations.

Size of the drilling hole in general is 40-36 inch initially and down to 5 inch. Soon after the hole is drilled as per the design, sections of steel pipe called casing, slightly smaller in diameter than the borehole, are placed in the hole. Cement will be placed between the outside of the casing and the borehole (annulus). The casing provides structural integrity to the newly drilled wellbore, in addition to isolating potentially dangerous high pressure zones from each other and from the surface.

Drilling fluid called "Mud" is used to pumped down the inside of the drill pipe and exits at the drill bit for the purpose of cooling the bit, lifting rock cuttings to the surface, preventing destabilization of the rock in the wellbore walls, and overcoming the pressure of fluids inside the rock so that these fluids do not enter the wellbore.
The principal components of drilling fluid are usually water and bentonite and also contain a complex mixture of solids and chemicals that must be carefully tailored to provide the correct physical and chemical characteristics required to safely drill the well. Mud logging is carried out to study the lithology of the formation and monitoring the characteristics of the formation.

Drilling is carried out with following purposes,

1) Exploratory drilling is carried out to gather information about the subsurface around the area of drilling through mud logging analysis.
2) Appraisal well is used to evaluate characteristics (flow rate etc.) of a proven hydrocarbon accumulation.
3) Production well is for production of oil and gas, once the evaluation of the well is completed and commercial production is proven.

Drilling cost is mostly affected by equipment lease cost and also depending on the depth/length (case of directional drilling), field location, and factors. Offshore is more expensive than onshore. General cost element for drilling work is as follows:

1) Hiring cost for geoscientists, geologists, mud loggers, engineers
2) Contractors for logistics and casing /cementing
3) Drilling rig lease cost with operation personals

(3) Drilling Cost

1) Onshore Drilling Cost:
   Typical cost for onshore drilling in US is in the range of USD 0.5 million to 15 million per well and lease day rate for drilling rig capable of drilling most exploratory wells will be USD 10,000-15,000/day.

   Unit drilling cost in Bangladesh is considered in the range of USD 10-20 million per well as shown in the Annural Reports by Petrobangla. Recent driling cost based on a competitive bidding using Best Practice is USD 15 million, and this figure can be used as a benchmrk cost for futre cost estimate.

2) Offshore Drilling cost:

High performance jack up rig lease rate in 2015 is USD 177,000/day in accordance with Rigzone. With the use of similar facility, operating cost in the duration of 100 days can cost USD 30 million, including mobilization and demobilization, but varies to the local factors and location.

3. Construction Cost Estimate

The following assumptions were used for making cost estimate.

(1) Gas Production and Processing Facilities in the Existing Gas Fields

At present there are no new gas fields which are at the development stage. However, in order to increase future domestic gas supply, Petrobangla has a natural gas enhancement program for several of its existing gas fields. These programs run from 2014 to 2017 and are shown in Table 98.

Table 98 Gas Production Enhancement Program (Petrobangla)

Production Enhancement Program (Nov. 2014 – June 2015)

Sl. No.	Gas Fields & Wells	Well type	Flow (MMcfd)	Completion Date
1	Shahbazpur # 4	Development	25	November 2014
2	Bibiyana (sevem wells)	Development	220	Drilling completed, awaiting completion production facilities, will be in production within June 2015 in phases.

Production Enhancement Program (July 2015 - June 2016)

Sl. No.	Gas Fields & Wells	Well type	Flow (MMcfd)	Completion Date
	Titas # 25	Development	20	December 2015
	Kailashtila # 9	Development	25	December 2015
	Kailashtila 1& 5	W/O	15	June 2016
	Titas # 23	Development	20	June 2016
	Begumganj # 4	Development	15	June 2016
	Srikail # 4	Development	20	June 2016
	Titas # 26	Development	20	March 2016
	Salda # 4	Development	15	June 2016

Production Enhancement Program (July 2016 - June 2017)

Sl. No.	Gas Fields & Wells	Well type	Flow (MMcfd)	Completion Date
	Titas # 24	Development	20	September 2016
	Sundalpur # 2	Development	8	December 2016
	Semutang #7	Development	8	December 2016
	Semutang # 8	Development	8	June 2017
	Rashidpur # 9	Development	10	June 2017
	Sylhet # 9	Development	10	December 2016
	Rashidpur # 10, 11	Development	20	December 2017

Source: information provided by Petrobangla (Petrobangla reply to JICA survey team questionnaire).

The production enhancement programs are planned at 17 gas fields, as well as new installations and workovers are being conducted at 25 production wells. In these programs, 23 gas production wells are being newly installed at the existing gas fields, and the workovers of two existing wells being carried out at the Kailashtila gas field in order to improve the present declining gas production rate.

The program outline is shown in Table 99.

Table 99 Production Enhancement Program for the Existing Gas Fields

As at December 2014

Serial No.	Gas Field	Well #	Development Type & Number of Wells		Production Increment [MMscfd]	Completion Date (*2)	Necessity of New Gas Production Facility (*3)
1	Titas	23	Development x 1		20	June 2016	○
		24	Development x 1		20	September 2016	○
		25	Development x 1		20	December 2015	○
		26	Development x 1		20	March 2016	○
4	Kailashtila	1, 15		Workover x 2	15	June 2016	X
		9	Development x 1		25	December 2015	X
5	Rashidpur	9	Development x 1		10	June 2017	X
		10, 11	Development x 2		20	December 2017	X
6	Sylhet	9	Development x 1		10	December 2016	X
12	Shahbazpur	4	Development x 1		25	November 2014	X
13	Semutang	7	Development x 1		8	December 2016	X
		8	Development x 1		8	June 2017	X
17	Bibiyana (*1)	-	Development x 7		220	June 2015	X
19	Sundalpur	2	Development x 1		8	December 2016	X
20	Srikail	4	Development x 1		20	June 2016	X
21	Begumganj	4	Development x 1		15	June 2016	X
Other 1	Salda	4	Development x 1		15	June 2016	X
TOTAL		-	23	2	479	-	-
			25				

Source: Information based on Table 98 Gas Production Enhancement Program (Petrobangla)

NOTE:

*1: In Bibiyana Gas Field, gas of total 220 MMscfd will be additionally produced from seven wells.
*2: "Completion Date" means that construction or workover of the gas production well will be completed at that time.
*3: The information regarding the necessity of a new gas production facility was obtained at the time of the meeting with Petrobangla

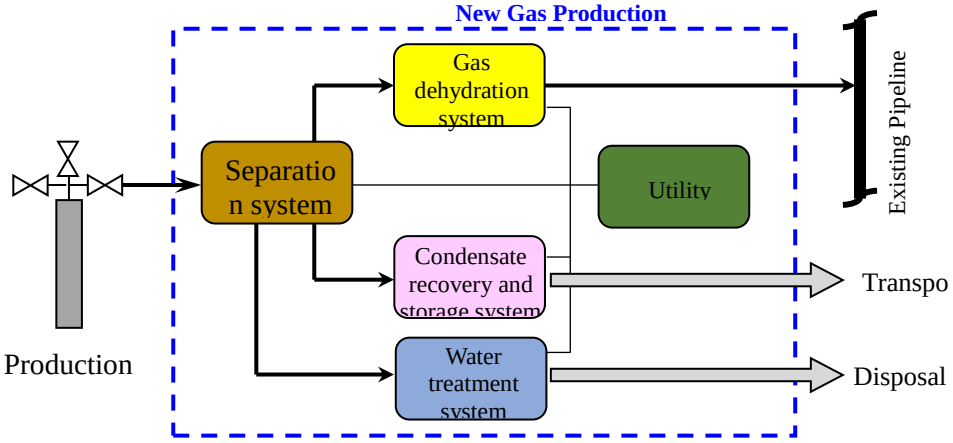
As shown in Table 99, the production enhancement program scheduled until 2017 has been planned, and the gas production wells are expected to be newly completed by and the workover of the existing wells should be carried out up to the date indicated in the table. The gas produced from these wells,

except for that from the Titas Gas Field, is expected to be treatable within the plant capacity of the existing gas treatment facility. Accordingly, the construction of a new gas treatment facility should not be required for those production increments.

Regarding the four wells (23, 24, 25, and 26) in the Titas Gas Field – which should increase production to a total of 80 MMscfd – all the gas produced at these wells is planned to be collected at a site through gathering pipelines and treated in a newly-constructed gas production facility. The construction of this facility will be financed under an ADB project.

To treat produced gas properly, new gas production facility is to be composed of the following five main systems. The typical treatment process is shown in Figure 28 and Table 100.

- ✓ Separation system
- ✓ Gas dehydration system
- ✓ Condensate recovery and storage system
- ✓ Water treatment system
- ✓ Utility system



Source: JICA Survey Team

Figure 28 Typical Gas Treatment Process

Table 100 Function of Gas Treatment System

FACILITY	FUNCTION	PICTURE
Separation system	➢ Separation of gas, liquid and water ➢ Removal of foreign substances in well fluid	
Gas dehydration system	➢ Removes water vapour from the separated gas stream	
Condensate recovery and storage system	➢ Storage and unloading of condensate separated in the separation system	
Water treatment system	➢ Recovery of oil content in produced water using a CPI separator and a flotation unit ➢ Disposal of produced water	
Utility system	➢ Supply of fuel gas, instrument air, cooling water, utility air and water for maintenance, and electrical power.	 （The above picture shows instrument air compressor.）

Source: JICA Survey Team

(2) Parameter for OGM Software of Cost Estimation

(a) Trains at the gas production facility
There shall be no standby train at the proposed new gas production facility.

(b) Equipment standby philosophy
None of the main equipment in the gas production facility will have a standby unit.

(c) Wellhead fluid composition
The gas composition of the Titas Gas Field – Bangladesh's largest gas field – was applied to all cases in this study. This gas composition is shown in Table 101.

Table 101 Typical Wellhead Fluid Composition

Component	mol%
Nitrogen	0.37
Carbon Dioxide	0.31
Methane	96.76
Ethane	1.80
Propane	0.36
i-Butane	0.09
n-Butane	0.05
i-Pentane	0.02
n-Pentane	0.02
n-Hexane	0.04
n-Heptane	0.02
n-Octane	0.01
n-Nonane	0.00
n-Decane+	0.04
H2O	0.11
Total	100.00

Source: Information prepared based on Petrobangla data

Based on the standard gas sales contract in Bangladesh, as allowable water content in treated gas is restricted to below 7 lb/MMscf, this water content value has been applied to the planning of the gas dehydration facility.

(d) Operating conditions at the wellhead
- ✓ Pressure: 1,700 psig
- ✓ Temperature: 142 deg.F

(e) Cost estimation software (OGM) input data
The estimation of the costs for the gas production facility using OGM, was carried out with the input items and the input methods described in Table 27

Table 27 OGM Input Data

No.	Input Item	Input Method
1.	Project Construction Site Information	
1-1	Project Construction Site	The project construction site is specified from major oil/gas production areas worldwide such as the Arabian Gulf, Gulf of Mexico, North Sea, West Africa, Brazil, Venezuela, Southeast Asia, Northeast Asia and Malaysia. In this case, Southeast Asia was specified due to the proximity of Bangladesh. The appropriate wage rate for the specified project construction site was then applied – the same data is inputted for to all the cases regardless of the gas handling capacity.
2.	Required Facilities (Separator, Gas Dehydrator, Condensate Storage, Water Treatment Facilities)	
2-1	Main Facilities	The required main facilities (separator, gas dehydrator, condensate storage tank, and water treatment facility) for gas production are specified. Here, as there are no sour components (H2S) in the gas the general facility configuration for normal gas production was selected. As the facility configuration is the same for all the cases, the same data was inputted regardless of the gas handling capacity.
3.	Process Conditions	
3-1	Gas Production Rate	The gas production rate is specified. In this case, gas handling capacities were specified to cover the wide range of gas production rates in Bangladesh. The facilities required to handle the specified gas production rate are designed in connection with gas handling capacity, and then the costs are estimated.
3-2	Composition Basis	The gas composition is specified and the gas/liquid separation calculation is conducted based on the inputted composition. The facilities required to handle the separated gas and liquid are designed, and then the costs are estimated. The typical gas composition in Bangladesh is inputted in all cases regardless of the gas handling capacity. In case that the toxic substances such as sour component (H2S) and mercury are included in the produced gas, requisite removal facilities will be required. However, as the gas produced in Bangladesh is classified in sweet gas, the installation of such facilities is not

No.	Input Item	Input Method
		necessary.
4.	Separation System	
4-1	Flowing Wellhead Pressure	The wellhead pressure is specified. The pressure level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical wellhead pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.
4-2	Flowing Wellhead Temperature	The wellhead temperature is specified. Temperature level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted temperature, after which the costs are estimated. The typical wellhead temperature in Bangladesh was inputted in all the cases regardless of the gas handling capacity.
4-3	Production Manifold Design Pressure	The manifold design pressure is specified. The pressure level at the manifold is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure was inputted in all the cases regardless of the gas handling capacity.
4-4	Production Separator Design Pressure	The separator design pressure is specified. The pressure level of the separator is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure was inputted in all the cases regardless of the gas handling capacity.
4-5	Production Separator Operating Pressure	The separator operating pressure is specified. The gas/liquid separation calculation is conducted based on the inputted pressure, then the separator size and wall thickness required to handle the separated gas and liquid are designed, after which the costs are estimated. The typical separator operating pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.
4-6	Test Separator	The necessity of the test separator is specified. The test separator is normally required to monitor the production rate of one well and to manage the gas reservoir. “Allocated” was selected for all the cases regardless of the gas handling capacity.

No.	Input Item	Input Method
4-7	Residence Time	The oil/condensate residence time in a separator that is required to segregate water droplets from oil/condensate phase was inputted. The As the separator is designed based on the residence time, the typical residence time is inputted in all the cases regardless of the gas handling capacity.
4-8	Separator per Stage	The number of separators per stage is inputted. Normally, vessels such as separators do not have any spares. Also, as the facility configuration without any spares is a design premise in the study, the number of train was inputted as one for all the cases regardless of the gas handling capacity.
4-9	Percent Flow per Separator	In relation to the "separator per stage", the percentage of the handling flow rate per train in the total flow rate was inputted. As the facility configuration without any spares is a design premise in the study, the percent flow per separator is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
4-10	Water Separation Option	The necessity of water separation in a separator is specified. The produced water is normally removed from the oil/condensate and gas. "Allocated" was selected for all the cases regardless of the gas handling capacity.
5.	Gas Dehydration System	
5-1	Gas Dehydration Medium	The gas dehydration medium is specified. "Glycol" is specified as a typical medium (chemical) used in gas dehydration process for all the cases regardless of the gas handling capacity.
5-2	Number of Gas Dehydration Trains	The number of gas dehydration trains is inputted. Vessels such as gas dehydration facility normally do not have any spares, and facility configuration without any spare is a design premise in the study, therefore number of train is inputted as one for all the cases regardless of gas handling capacity.
5-3	Percent Flow per Dehydration Train	In relation to the "number of gas dehydration trains", the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spares is a design premise in the study, the percent flow per gas dehydration train is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
5-4	Outlet Water Dew Point Temperature	The outlet water dew point temperature for the gas dehydration is inputted. The water dew point temperature of 32 F corresponding to 7 lb water in 1 MMscf gas, as regulated in the standard sales gas

No.	Input Item	Input Method
		contract in Bangladesh, is inputted for all the cases regardless of the gas handling capacity.
5-5	Dehydrator Column Design Pressure	The gas dehydrator column design pressure is specified. The pressure level of the dehydrator column is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical design pressure is inputtedfor all the cases regardless of the gas handling capacity.
6.	Condensate Recovery and Storage System	
6-1	Oil/Condensate Tank Capacity	The oil/condensate tank capacity is specified. The required oil/condensate storage facilities are designed for the inputted tank capacity, then the costs are estimated.
6-2	Oil Pump Outlet Pressure	The oil pump outlet pressure required for shipping is specified. The Pressure level of the pump is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure is inputted for all the cases regardless of the gas handling capacity.
6-3	Number of Pumps	The number of pumps is inputted. As the facility configuration without any spares is a design premise in the study, the number of trains is inputted as one for all the cases regardless of the gas handling capacity.
6-4	Percent Flow per Pump	In relation to “number of pumps”, the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spare is a design premise in the study, thepercent flow per pump is inputted in common as one hundred (100%) for all the cases regardless of the gas handling capacity.
7.	Water Treatment System	
7-1	Produced Water Design Rate	The produced water design rate is specified. The facilities required to handle the specified water rate are designed in connection with the produced water design rate, then the costs are estimated.
7-2	Sour Water Stripping Option	The necessity of a sour (H_2S) component stripping facility as one the of water treatment systems is specified. As gas produced from Bangladesh is classified as sweet gas a without sour (H_2S) component, the installation of such a facility is not required. “Not allocated” was selected for all the cases regardless of the gas handling capacity.

No.	Input Item	Input Method
7-3	CPI Unit	The necessity of a CPI unit as the first stage of water treatment is specified. A CPI unit is normally used in the water treatment. "Allocated" was selected for all the cases regardless of the gas handling capacity.
7-4	Floatation/Hydrocyclone Unit	The necessity of a floatation/hydrocyclone unit as the second stage of water treatment is specified. A floatation/hydrocyclone unit is normally used in the water treatment. "Allocated" was selected for all the cases regardless of the gas handling capacity.
8.	Utility System	
8-1	Type of Main Power Generator	The type of main power generator driver is specified. "Turbine" was specified as the typical most proven type of driver for all the cases regardless of the gas handling capacity.
8-2	Number of Main Power Generators	The number of main power generators is inputted. As the facility configuration without any spares is a design premise in the study, thethe number of trains was inputted as one for all the cases regardless of the gas handling capacity.
8-3	Percent of Main Power Load	In relation to the "number of main power generators", the percentage of power generation per train in the total power generation is inputted. As the facility configuration without any spares is a design premise in the study, the percent of the main power load was inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
8-4	Power Generator Selection	The manufacturer's model of the main power generator is specified. In this case, the required power for all the facilities was internally calculated in the software by specifying "internally determined" for all the cases regardless of the gas handling capacity. Also, the type of main power generator was automatically selected to cover the power demand required.
9.	Other Related Facilities	
9-1	Number of People in Operation Camp	The number of people to be accommodated in the operation camp is inputted. Based on three shift of eight hours , the number of people – including operators, supervisors, maintenance workers, administrators, and guests – are assumed for the required accommodation, then the costs are estimated.
9-2	Number of People in Construction Camp	The number of people to be accommodated in construction camp is inputted. The number of people is assumed for the required accommodation, then the costs are estimated.

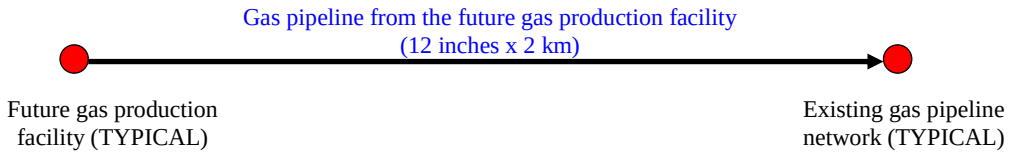
Source: JICA Survey Team

(3) Gas Transmission Pipelines for Already-discovered Domestic Natural Gas

For the costs estimation, the following conditions were uniformly applied for all the gas pipelines to be newly laid between the future gas production facility and the existing pipeline network.

- Pipe material: API5L Gr.X60 with 3LPE coating
- Nominal pipe size: 12 inches
- Wall thickness: 0.312 inches
- Pipeline length: 2 km (per each pipeline)
- Concrete coating: Not required
- Construction cost: 0.5 million USD/km

The overall view of the pipeline is as follows.

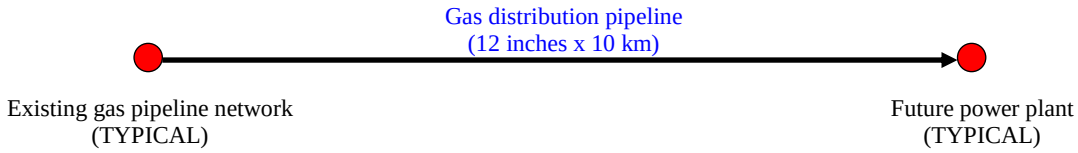


(4) Gas distribution pipelines for future power plants

For the costs estimation, the following conditions were uniformly applied for all the gas distribution pipelines to be newly laid for future power plants which will be constructed for the power supply increment.

- Pipe material: API5L Gr.X60 with 3LPE coating
- Nominal pipe size: 12 inches
- Wall thickness: 0.312 inches
- Pipeline length: 10 km (per each pipeline)
- Concrete coating: Not required
- Construction cost: 0.5 million USD/km

The overall view of the pipeline is as follows.



(5) Import Gas Development Cost

(a) LNG Receiving Terminal

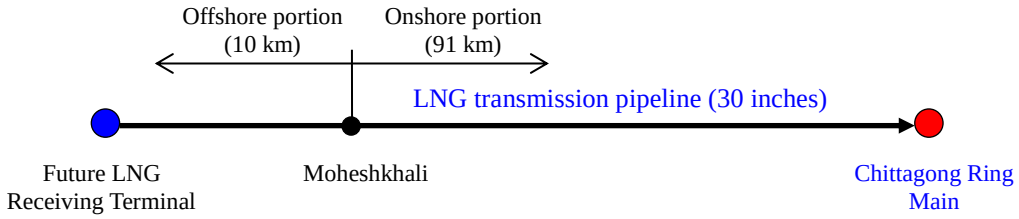
Cost for LNG Receiving terminal inclusive of Jetty and Loading facilities, 2 x 200,000 kl tanks and re-gasification facilities are estimated USD 500 million.

(b) LNG Transmission Pipeline

For the costs estimation, the following conditions were applied for the LNG transmission pipeline to be newly laid between the LNG receiving terminal to the Chittagong ring main.

- Pipe material: API5L Gr.X60 with 3LPE coating
- Nominal pipe size: 30 inches
- Wall thickness: 0.562 inches
- Pipeline length: 10/91 km (Offshore/Onshore)
- Concrete coating: Required for the offshore portion
- Construction cost: 1.5 million USD/km (Offshore)
  1.1 million USD//km (Onshore)

Overall view of the pipeline is shown as follows.



4. Results of Cost Estimate

Cost estimate for future gas exploration and production, and also cost for LNG introduction ware carried out based on various assumptions as mentioned in the previous sections.

(1) Exploration and Drilling Cost (Remaining reserves 2P)

Seismic survey and well drilling costs were roughly estimated based on the information available from the websites of Petrobangla and its subsidiaries and news media.

1) Seismic Survey Cost

(a) Seismic Data Acquisition

There are two different types of methods for the data acquisition in seismic surveys: two-dimensional (2D) seismic survey and three-dimensional (3D) seismic survey. A 2D seismic survey is conducted mainly in the exploration phase, and if promising amounts of oil and gas are confirmed by exploration drilling, a 3D seismic survey is conducted for confirming the size and structure of the field in the appraisal and development phases. In addition, a 3D seismic survey may be also conducted for better reservoir management in the field development phase.

The method for the cost estimation of a seismic survey depends on the type of survey: 2D or 3D survey. A total cost of seismic survey can be roughly estimated based on the seismic line length (line-km) for 2D seismic survey and survey area (km2) for 3D seismic survey, respectively. It should be noted that, for example, the specifications can be different depending on the environmental conditions of given area or location, and this makes it difficult to estimate the cost based on a given survey line length or survey area only.

(b) Cost Analysis of Seismic Survey

Regarding the seismic surveys conducted in recent 4 or 5 years in Bangladesh, the available data was organized in order to examine the relationships between the survey costs and the survey line length for

a given 2D seismic survey and a survey area for a 3D seismic survey, respectively (Table 103). In addition, based on the collected data, rough estimates of the costs per line-km for 2D and per sq. km for 3D seismic surveys were also carried out, respectively (Table 103).
The data such as name of field/area, survey line length (2D seismic survey) and area (3D seismic survey), survey period and total survey cost is shown in Table 103.
In addition, as shown in the table, the surveys for which necessary data for cost analysis were available are three projects only, of which one project was 2D seismic survey and two projects were 3D seismic surveys. From the viewpoint of analysis of seismic survey cost, the data is considered to be insufficient for 2D seismic survey.
The results of the cost analysis of seismic surveys are summarized below, as also shown in Table 103:

- 2D seismic survey: US$5.1 thousand/line-km
- 3D seismic survey: US$12.0 to 18.5 thousand/km^2

Table 103 Analysis of Seismic Survey Costs

As of October 2015

Field/Area	Length	Area	Survey Period	Estimated Survey Cost		Cost Analysis		Remarks
						Cost per line-km	Cost per sq km	
	(line-km)	(sq km)		M BDT	M USD	K USD	K USD	
Dhaka, Manikganj, Shariatpur, Faridpur, Gopalganj, Madaripur, Khulna, Netrokona, Kishoreganj, Sunamganj, Habiganj, Sylhet, Maulavibazar and Bhola	1,800	—	Dec. 2012 (?) - (Underway)	711.3	9.15	5.1	—	
Titas	—	335	2010 - 2012 (Details unknown)	784.5 (for 2 fields)	10.09 (for 2 fields)	—	18.5	• Appraisal of Gas Field (3D Seismic) (Titas, Bakhrabad, Sylhet, Kailashtila and Rashidpur) Project (Revised)
Bakhrabad	—	210						
Rashidpur	—	325		859.5 (for 3 fields)	11.05 (for 3 fields)	—	15.7	
Kailashtila	—	190						
Sylhet	—	190						
Sunetra	—	260	May 2013 (?) - (Underway)	1,825.0 (for 6 fields/area, 1,950 sq km in total)	23.47 (for 6 fields/area, 1,950 sq km in total)	—	12.0	
Shahbazpur	—	600						
Sundalpur-Begumganj	—	440						
Srikail	—	150						
Narshingdi	—	250?						
Habiganj	—	250?						

Note: The BDT to USD exchange rate on January 1, 2015 (1 BDT = US$ 0.01286) is used.

Source: Prepared based on Petrobangla Annual Report 2012 and BAPEX Annual Reports 2013 and 2014

2) Well Drilling Cost

(a) Well Type

Two types of wells, exploration (or exploratory) and appraisal wells, are drilled in the exploration phase. An exploration or exploratory well is usually drilled in an area where any oil or gas has not been discovered yet. However, if a well is targeted for new oil or gas pool, for example, in a deeper horizon in the existing oil or gas field, the well is also called as exploration well. If promising oil and/or gas are discovered by exploration drilling, then an appraisal well will be drilled for confirming the size of the discovered oil and/or gas reservoir(s) in the next phase. Most of the wells to be drilled in the development phase are defined as development well.

(b) Factors Affecting Well Drilling Cost

The cost of a well depends mainly on the daily rate of the drilling rig and a well operation period in days, and a well drilling cost is basically determined by multiplying the rig day rate by duration of drilling operations in days. In the viewpoint of the estimation of a well drilling cost, the difference in types of wells shown above are not significant.
There are various factors affecting the duration of the well operations, and in general, for example, the factors are as follows:

However, the information on the factors except for well depth is not available or insufficient, those factors are not examined in this survey.

- Drilling depth
- Subsurface geological conditions
- Subsurface pressure and temperature conditions
- Well type (vertical, directional, horizontal)
- Duration of well test

However, the information on the factors except for well depth is not available or insufficient, those factors are not examined in this survey.

3) Well Drilling Cost Analysis

Based on the description in the above section, the cost analysis was performed on the wells which show the data of relatively high reliability listed below.

- Estimated cost per well
- Well depth (total depth)
- Well type (vertical or directional)
- Duration of drilling operations

Regarding the wells whose cost analysis was conducted, the data such as well name, well type, well drilling cost, well depth (drilling depth) and duration of drilling operations are shown in Table 104. The number of the wells whose cost analyses have been done to date is only 10. These wells consist of nine vertical wells (including wells whose types have not been confirmed yet) and one directional well. The relationship between well drilling cost and well depth for these wells are shown in Figure 29 in which the well types are classified. Proposed well depths should be used as well depths in this type of plot because the estimated well drilling costs are only available. However, regarding the wells where the actual well depths are not available, the actual well depths were used instead of the proposed well depths in the plot.

In general, it is empirically known that a well drilling cost can be described as an exponential function of depth. Therefore, if a well depth is given, the corresponding well drilling cost can be roughly estimated. However, unfortunately such a relationship is not apparent in Figure 29. This is due to the following reasons:

- A small amount of data set
- Relatively narrow range of well depths (about 2,900 to 3,700 m)

In addition, it should be noted that the estimated well drilling cost varies largely depending on different drilling contractors in Bangladesh. Recently, Gazprom, a Russian company, was involved in the drilling of the wells in Bangladesh. The costs of the wells drilled by Gazprom are at least twice as high as compared with those of the wells drilled by BAPEX. For example, as shown in Table 104, Well Rashidpur-8, where the drilling operations were undertaken by Gazprom, was drilled to a proposed total depth of 2,902 m at an estimated cost of US$ 22.0 million. On the other hand, Well

Fenchuganj-5, where drilling operations were undertaken by BAPEX, was drilled to a proposed total depth of 3,100 m at an estimated cost of US$ 9.8 million.

4) Estimates of Well Drilling Cost for Model Wells

Based on the results shown in the section (3), the estimated well drilling costs are tentatively proposed for two model cases having the well depths of 3,000 m and 4,500 m, respectively. The model well with a total depth of 3,000 m can be used as one of the model wells for estimating a well drilling cost in Bangladesh, taking into account the range of the well depths. The other model well with a total depth of 4,500 m is proposed based on the fact that the exploration well Mubarakpur-1 currently being drilled has a proposed total depth of 4,500 (+) m, indicating that the well is to be drilled at least to a total depth of 4,500 m, and the proposed total depth of the exploration well Sunetra-1 was also 4,500 m (actual total depth of 4,683 m).

- Model well with a total depth of 3,000 m:
  The cost of the model well having a total depth of 3,000 m is about US$ 9.5 million by calculation using the estimated cost of Well Fenchuganj-5 shown in Table 104.
- Model well with a total depth of 4,500 m:
  The cost of the model well having a total depth of 4,500 m is about US$ 10.9 million by averaging the estimated costs of both wells Mubarakpur-1 and Sunetra-1 shown in Table 104,

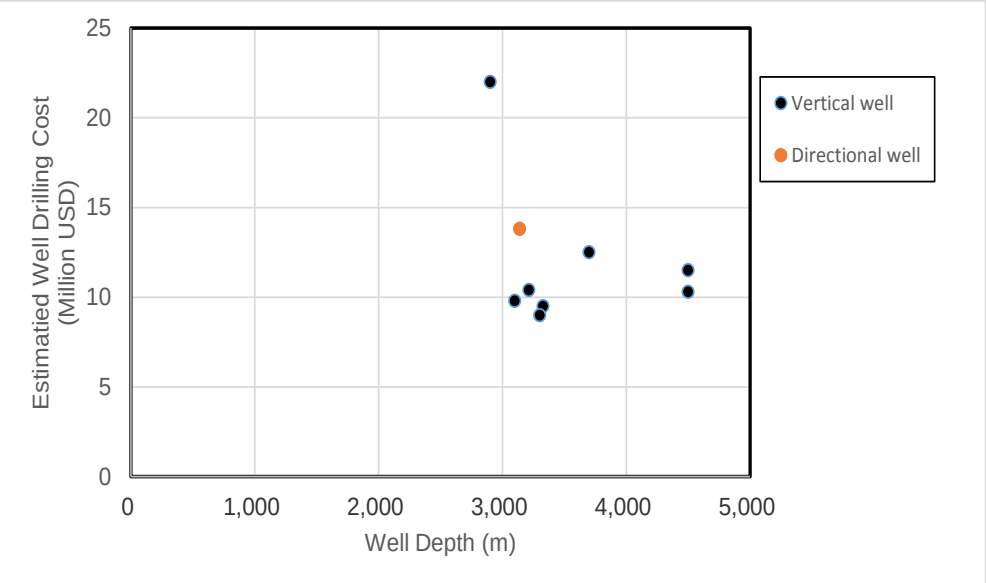
In this study, 4 development wells are assumed and converted to production wells at the later stage.Recent case shows that total cost of drilling of 4 wells in Bangladesh is assumed USD 60 million.

Table 104 Analysis of Well Drilling Costs

As of October 2015

Well Name	Expl./ Appr./ Dev.	Well Type	Well Depth (m)		Operation Period	Estimated Well Drilling Cost		Remarks
			Proposed	Actual		M BDT	M USD	
Titas-27	Dev.	Directional	(N/A)	3,138	Nov. 19, 2013 - Apr. 11, 2014	1,070.0	13.8	
Mubarakpur-1	Expl.	Vertical?	4,500 (+)	(Underway)	Aug. 22, 2014 - (Underway)	892.6	11.5	• Mubarakpur Oil/Gas Exploration Well Drilling Project
Sundalpur-1	Expl.	Vertical?	(N/A)	3,327	Dec. 21, 2010 - Mar. 11, 2011	736.5	9.5	• Discovery well
Kapasia-1	Expl.	Vertical?	(N/A)	3,301	Feb. 6, 2012 - Apr. 13, 2012	701.7	9.0	• Kapasia Oil/Gas Exploration Well Drilling (Revised) • Dry
Srikail-2	Appr.	Vertical?	(N/A)	3,214	May 5, 2012 - June 29, 2012	811.2	10.4	• Srikail Oil/Gas Exploration Well Drilling Project (Well #2) • Discovery well
Fenchuganj-5	Dev.	Vertical	3,100	3,137	Sept. 27, 2013 - (?)	760	9.8	• A part of Salda # 3, 4 & Fenchuganj # 4, 5 Gas Fields Development Project • Dry
Sunetra-1	Expl.	Vetical	4,500	4,683	Aug. 10, 2012 - Mar. 18, 2013	802.5	10.3	• Sunetra Oil/Gas Exploration Well Drilling Project • Dry
Rashidpur-8	Dev.	Vertical	2,902	2,990	(?) - Aug. 27, 2014	1,705.0	21.9	• Drilliing was undertaken by Gazprom.
Rupganj-1	Expl.	Vertical	3,700	3,615	May 19, 2013 - (?)	970.0	12.5	• Discovery well
Sundalpur-2	Dev.	Vertical?	3,250	—	—	754.5	9.7	• Well has not been drilled yet.

Note: The BDT to USD exchange rate on January 1, 2015 (1 BDT = 0.01286 USD) is used.



Source: Prepared based on Petrobangla Annual Reports 2012 and 2013, etc.

Figure 29 Estimated Well Drilling Cost vs. Well Depth Plot

(2) Facility Construction Costs

The facility construction costs necessary for supplying incremental gas in the future was estimated below in items 1) to 3).

(a) Gas Production Facilities

Gas production facilities for already-discovered domestic natural gas described earlier, there are no new gas fields which will move to the development stage in Bangladesh. Also, although several gas field enhancement plans have been scheduled at the existing gas fields, most of them do not require the construction of new gas production facilities because the increased gas should be able to be treated in the existing facilities. In relation to the Titas gas field requiring an additional gas production facility, the production of gas of 80 MMscfd is anticipated to be increased in the near future.

However, at present these plans have been scheduled only up until 2017; there is still no specific gas development plan for after 2018. Accordingly, it is difficult to frame a financial plan for the gas field development based on such a short term plan. Nevertheless, in December 2012 the World Bank published a long term production forecast for each gas field up until 2030 in its report entitled "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development". Thus, a financial plan can be made based on this long term plan.

In this study, as a yearly financial plan is required to properly conduct economic and financial analyses, the construction costs of gas production facility for future gas development were estimated based on the said long term production forecasts.

The future field wise gas production forecast is indicated in Table 105.

Table 105 Field Wise Gas Field Enhancement Plan

Field wise predicted production

Titas

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		450	450	480	600	600	600	600	600	600	500	500	450	400	300	250	250	250	200	200
Yearly Production, tcf		0.1643	0.1643	0.1752	0.219	0.219	0.219	0.219	0.219	0.219	0.1825	0.1825	0.1643	0.146	0.1095	0.0913	0.091	0.091	0.073	0.073
Remaining Reserve, tcf	3.073	2.9088	2.7445	2.5693	2.3503	2.1313	1.9123	1.6933	1.4743	1.2553	1.0728	0.8903	0.7261	0.5801	0.4706	0.3793	0.288	0.197	0.1238	0.051

Habiganj

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		250	250	250	250	200	200	100	100	50	50	50	50	50	50	50	50	50	50	20
Yearly Production, tcf		0.0913	0.0913	0.09125	0.0913	0.073	0.073	0.0365	0.0365	0.01825	0.0183	0.0183	0.0183	0.0183	0.0183	0.0183	0.018	0.018	0.0183	0.007
Remaining Reserve, tcf	0.8363	0.7451	0.6538	0.56255	0.4713	0.3983	0.3253	0.2888	0.2523	0.23405	0.2158	0.1976	0.1793	0.1611	0.1428	0.1246	0.106	0.088	0.0698	0.063

Bakhrabad

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		30	30	30	50	50	80	80	80	80	80	80	80	70	70	50	50	50	50	20
Yearly Production, tcf		0.011	0.011	0.01095	0.0183	0.01825	0.0292	0.0292	0.0292	0.0292	0.0292	0.0292	0.0292	0.0256	0.0256	0.0183	0.018	0.018	0.0183	0.007
Remaining Reserve, tcf	0.514	0.5031	0.4921	0.48115	0.4629	0.44465	0.4155	0.38625	0.3571	0.32785	0.2987	0.2695	0.2403	0.2147	0.1892	0.1709	0.153	0.134	0.1162	0.109

Meghna

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		10	10	10	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0037	0.0037	0.00365	0.0037	0.00365	0.0037	0.00365	0	0	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.0312	0.0276	0.0239	0.02025	0.0166	0.01295	0.0093	0.00565	0.0057	0.00565	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.006	0.006	0.0057	0.006

Narsingdi

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		30	30	30	30	30	30	30	30	20	20	20	20	20	20	15	15	10	0	0
Yearly Production, tcf		0.011	0.011	0.01095	0.011	0.01095	0.011	0.01095	0.011	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0055	0.005	0.004	0	0
Remaining Reserve, tcf	0.1547	0.1438	0.1328	0.12185	0.1109	0.09995	0.089	0.07805	0.0671	0.0598	0.0525	0.0452	0.0379	0.0306	0.0233	0.0178	0.012	0.009	0.0087	0.009

Sylhet

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		10	10	10	25	25	25	25	25	25	25	20	20	20	20	15	10	10	0	0
Yearly Production, tcf		0.0037	0.0037	0.00365	0.0091	0.009125	0.0091	0.00913	0.0091	0.00913	0.0091	0.0073	0.0073	0.0073	0.0073	0.0055	0.004	0.004	0	0
Remaining Reserve, tcf	0.1255	0.1219	0.1182	0.11455	0.1054	0.0963	0.0872	0.07805	0.0689	0.0598	0.0507	0.0434	0.0361	0.0288	0.0215	0.016	0.012	0.009	0.0087	0.009

Beanibazar

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		14	14	14	14	14	14	14	14	14	14	14	14	10	10	10	0	0	0	0
Yearly Production, tcf		0.0051	0.0051	0.00511	0.0051	0.00511	0.0051	0.00511	0.0051	0.00511	0.0051	0.0051	0.0051	0.0037	0.0037	0.0037	0	0	0	0
Remaining Reserve, tcf	0.136	0.1309	0.1258	0.12067	0.1156	0.11045	0.1053	0.10023	0.0951	0.09001	0.0849	0.0798	0.0747	0.071	0.0674	0.0637	0.064	0.064	0.0637	0.064

Rashidpur

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		50	70	70	100	150	200	200	250	250	250	250	250	250	250	250	200	200	200	200
Yearly Production, tcf		0.0183	0.0256	0.02555	0.0365	0.05475	0.073	0.073	0.0913	0.09125	0.0913	0.0913	0.0913	0.0913	0.0913	0.0913	0.073	0.073	0.073	0.073
Remaining Reserve, tcf	1.949	1.9308	1.9052	1.87965	1.8432	1.7884	1.7154	1.6424	1.5512	1.4599	1.3687	1.2774	1.1862	1.0949	1.00	0.9124	0.839	0.766	0.6934	0.62

Kailashtilla

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		100	100	100	150	150	200	200	250	250	250	250	250	250	250	250	200	200	200	200
Yearly Production, tcf		0.0365	0.0365	0.0365	0.0548	0.05475	0.073	0.073	0.0913	0.09125	0.0913	0.0913	0.0913	0.0913	0.0913	0.0913	0.073	0.073	0.073	0.073
Remaining Reserve, tcf	2.2229	2.1864	2.1499	2.1134	2.0587	2.0039	1.9309	1.8579	1.7667	1.6754	1.5842	1.4929	1.4017	1.3104	1.22	1.1279	1.055	0.982	0.9089	0.836

Field wise predicted production

Saldanadi

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		20	25	20	18	15	14	10	9	7	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0073	0.0091	0.0073	0.0066	0.005475	0.0051	0.00365	0.0033	0.00256	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.2149	0.2076	0.1985	0.19118	0.1846	0.17913	0.174	0.17037	0.1671	0.16453	0.1645	0.1645	0.1645	0.1645	0.16	0.1645	0.165	0.165	0.1645	0.165

Fenchuganj

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		35	50	60	60	55	50	45	40	40	35	35	25	20	0	0	0	0	0	0
Yearly Production, tcf		0.0128	0.0183	0.0219	0.0219	0.020075	0.0183	0.01643	0.0146	0.0146	0.0128	0.0128	0.0091	0.0073	0	0	0	0	0	0
Remaining Reserve, tcf	0.30	0.2902	0.272	0.25008	0.2282	0.2081	0.1899	0.17343	0.1588	0.14423	0.1315	0.1187	0.1096	0.1023	0.10	0.1023	0.102	0.102	0.1023	0.102

Shahbazpur

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		8	50	50	60	60	60	70	70	70	60	55	50	40	30	0	0	0	0	0
Yearly Production, tcf		0.0029	0.0183	0.01825	0.0219	0.0219	0.0219	0.02555	0.0256	0.02555	0.0219	0.0201	0.0183	0.0146	0.011	0	0	0	0	0
Remaining Reserve, tcf	0.27	0.2671	0.2488	0.23058	0.2087	0.18678	0.1649	0.13933	0.1138	0.08823	0.0663	0.0463	0.028	0.0134	0.002	0.002	0.002	0.002	0.0025	0.002

Semutang

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		12	10	20	25	25	25	30	30	30	25	25	20	15	15	12	12	10	10	10
Yearly Production, tcf		0.0044	0.0037	0.0073	0.0091	0.009125	0.0091	0.01095	0.011	0.01095	0.0091	0.0091	0.0073	0.0055	0.0055	0.0044	0.004	0.004	0.0037	0.004
Remaining Reserve, tcf	0.3173	0.3129	0.3093	0.30197	0.2928	0.28372	0.2746	0.26365	0.2527	0.24175	0.2326	0.2235	0.2162	0.2107	0.205	0.201	0.196	0.193	0.1892	0.186

Jalalabad

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		180	180	230	230	200	200	100	0	0	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0657	0.0657	0.08395	0.084	0.073	0.073	0.0365	0	0	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.565	0.4993	0.4336	0.34965	0.2657	0.1927	0.1197	0.0832	0.0832	0.0832	0.0832	0.0832	0.0832	0.0832	0.083	0.083	0.083	0.083	0.0832	0.083

Maulavibazar

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	0	0	0
Yearly Production, tcf		0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.015	0	0	0
Remaining Reserve, tcf	0.249	0.2344	0.2198	0.2052	0.1906	0.176	0.1614	0.1468	0.1322	0.1176	0.103	0.0884	0.0738	0.0592	0.045	0.030	0.015	0.015	0.0154	0.015

Bibiana

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		760	760	1000	1000	1000	1200	1200	1200	1200	1200	800	600	400	200	150	100	100	100	50
Yearly Production, tcf		0.2774	0.2774	0.365	0.365	0.365	0.438	0.438	0.438	0.438	0.438	0.292	0.219	0.146	0.073	0.0548	0.037	0.037	0.0365	0.018
Remaining Reserve, tcf	4.8998	4.6224	4.345	3.98	3.615	3.25	2.812	2.374	1.936	1.498	1.06	0.768	0.549	0.403	0.330	0.275	0.239	0.202	0.1657	0.147

Sangu

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		9	8	8	8	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0033	0.0029	0.00292	0.0029	0.00292	0.0029	0.00292	0.0029	0	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.1	0.0967	0.0938	0.09088	0.088	0.085035	0.0821	0.0792	0.0763	0.07628	0.0763	0.0763	0.0763	0.0763	0.076	0.076	0.076	0.076	0.0763	0.076

Bangura

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		103	100	100	100	100	100	100	70	50	40	30	20	10	10	0	0	0	0	0
Yearly Production, tcf		0.0376	0.0365	0.0365	0.0365	0.0365	0.0365	0.0365	0.0256	0.01825	0.0146	0.011	0.0073	0.0037	0.0037	0	0	0	0	0
Remaining Reserve, tcf	0.364	0.3264	0.2899	0.25341	0.2169	0.180405	0.1439	0.10741	0.0819	0.06361	0.049	0.0381	0.0308	0.0271	0.023	0.023	0.023	0.023	0.0235	0.023

Source: Annexure 3, FINAL REPORT "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development」 (prepared in December 2012)

In Table 106, the production enhancement plan for the existing gas fields is comparatively recent information that was reported in December 2012; the contents of the plan were approved by Petrobangla with certain corrections. Hence the investment costs were estimated on the assumption that the existing gas production facilities would be expanded in accordance with the plan.

In Annexure 3 of the said World Bank report, the field wise daily production rate and timing of the field expansion has been predicted up until 2030. Thus "the peak production rate (a)" and the peak production year may be for each gas field. Data for the field wise "current plant capacity (b)" is available in the Petrobangla Annual Report 2012. (Please refer to Appendix 3 for this.)

The value of (a) and (b) are listed in Table 106.

Table 106 Predicted Peak Production Rate versus Current Plant Capacity

Serial No.	Gas Field	Operating Company	Predicted Peak Production Rate (a) [MMscfd]	Current Plant Capacity (b) [MMscfd]	Additional Capacity Required (a – b) [MMscfd]	Peak Production Year [MMscfd] (See Note *2)
1	Titas	BGFCL	600	452	148	2015
2	Habiganj	Ditto	250	240	0 (See Note *1)	2012
3	Bakhrabad	Ditto	80	33	47	2017
4	Kailashtila	Ditto	250	80	170	2019
5	Rashidpur	Ditto	250	49	201	2019
6	Sylhet	SGFL	25	11	14	2015
7	Meghna	Ditto	10	11	0 (See Note *1)	2012
8	Narshingdi	Ditto	30	30	0	2012
9	Beanibazar	Ditto	14	14	0	2012
10	Fenchuganj	Ditto	60	40	20	2014
11	Saldanadi	BAPEX	25	20	0 (See Note *1)	2013
12	Shahbazpur	Ditto	70	30	40	2018
13	Semutang	Ditto	30	12	18	2018
14	Sangu	SANTOS	9	9	0	2012
15	Jalalabad	CHEVRON	230	230	0	2014
16	Moulavibazar	Ditto	40	60	0	2012
17	Bibiyana	Ditto	1200	770	430	2017
18	Bangura	TULLOW	103	100	0 (See Note *1)	2012

Source: information based on Petrobangla Annual Report 2012 and FINAL REPORT "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development" reported in December 2012

Note:

*1: Since the predicted peak production rate (a) is almost same as the current plant capacity (b), further investment for the gas field is not be considered.

*2: The peak production year in each gas field is scheduled as in 2012.

As shown in Table 106, if gas at "predicted peak production rate (a)" is produced in future in excess of the "current plant capacity (b)", the construction of new facility will be required to treat the excess volume of gas. Since the new facility must be able to treat the "additional capacity required (a minus b)" in the above table, this costs estimation is carried out based on the additional capacity required for the respective nine gas fields – Titas, Bakhrabad, Sylhet, Kailashtila, Rashidpur, Fenchuganj, Shahbazpur, Semutang, and Bibiyana). As for other gas fields, since the "predicted peak production rate (a)" is smaller than the "current plant capacity (b)" or almost same as (b), further investment for the gas field is not be considered.

For the Titas gas field, a new production facility having a capacity of 80 MMscfd will be constructed in the near future as mentioned in Paragraph 2.1.2 (1). It can be considered that the 148 MMscfd of "additional capacity required (a minus b)" in Table 106 includes the planned capacity of 80 MMscfd because the "predicted peak production rate (a)" of 600 MMscfd was forecasted before 2012. Accordingly, his means that the gas development plan for producing a part of the 148 MMscfd has now moved to its implementation stage as a construction project. Therefore, the construction costs of the new facility in the Titas gas field were estimated at 148 MMscfd.

Construction cost of the future gas production facilities which will be installed in each gas field is estimated as described below.

In Table 107, there is great variation in the "additional capacity required (a minus b)" between minimum 14 MMscfd and maximum 430 MMscfd. Typically, in plant construction the "six-tenths factor rule", as a simplified calculation method, is often utilized for estimating approximate construction costs. In term of the rule, there is an empirical relationship between the cost and the size of a manufacturing facility; as the size increases, cost the increases by an exponent of six-tenths, that is cost1/cost2 = (size1/size2) 0.6.

However, in this study, a typical gas production facility with specific plant capacity of 20, 40, 150, 200 and 400 MMscfd was estimated using OGM and in-house cost data Also, the construction costs of the future gas production facilities stated above were estimated based on the costs estimation results for a typical gas production facility.

At first, construction cost of the plant capacity; 20, 40, 150, 200 and 400 MMscfd, was estimated using OGM. In the case of applying the input data in Table 117 (as attached on the last page of this chapter) the construction costs were estimated as listed in Table 107.

Table 107 OGM Output for Construction Costs of Gas Production Facility (20, 40, 150, 200 and 400 MMscfd)

Cost Item	Plant Capacity (MMscfd)				
	20	40	150	200	400
Procurement & Fabrication, Installation	**14,003.2**	**15,769.4**	**24,244.8**	**27,872.2**	**45,424.6**
Separation System	1,221.3	1,639.0	4,349.5	6,181.9	12,935.2
Production Manifold	464.3	738.3	1,505.1	2,268.7	5,143.8
Separation	757.0	900.7	2,844.4	3,913.2	7,791.4
Gas Dehydration System	1,655.1	2,506.3	5,989.6	6,982.3	13,717.5
GasDehydration1	1,655.1	2,506.3	5,989.6	6,982.3	13,717.5
Condensate Recovery & Storage System	3,256.3	3,488.5	4,504.9	4,881.8	6,300.2
Crude Metering & Export	137.6	132.2	123.3	123.3	121.5
Tankage	3,118.7	3,356.3	4,381.6	4,758.5	6,178.7
Water Treatment System	550.1	581.6	784.0	857.0	1,158.4
Produced Water	151.1	155.0	190.5	195.3	286.7
Drain Effluent Water	399.0	426.6	593.5	661.7	871.7
Utility & Support Systems, Others	7,320.4	7,554.0	8,616.8	8,969.2	11,313.3
GasCompression1	356.2	376.4	387.0	391.7	410.2
Relief	217.3	261.3	577.8	649.2	709.3
Flare	160.0	175.9	263.1	302.8	461.4
Power Generation	1,100.8	1,100.8	1,100.8	1,100.8	1,100.8
Power Distribution	1,273.3	1,330.2	1,283.7	1,303.4	1,383.4
Heating Medium	0.0	0.0	196.3	205.0	309.4
Instrument Air	295.8	298.3	312.2	330.6	363.8
Utility Air	70.4	73.3	89.2	95.0	109.6
Fuel Gas	97.8	99.8	128.0	131.8	141.5
Diesel Fuel	213.9	217.0	233.3	239.2	254.2
Fire Protection	729.9	741.7	841.0	884.8	982.5
Control Center	1,472.5	1,472.5	1,472.5	1,472.5	2,667.8
Buildings	576.6	583.6	583.0	584.3	602.3
Site Preparation	100.0	107.7	154.7	173.5	227.4
Site Mgt	655.9	715.5	994.2	1,104.6	1,589.7
Infrastructure & Other Cost	**2,735.5**	**2,762.0**	**4,389.2**	**4,443.6**	**7,206.8**
Infrastructure	2,500.0	2,500.0	4,000.0	4,000.0	6,500.0
Construction Camp	1,000.0	1,000.0	2,000.0	2,000.0	4,000.0
Operations Camp	1,500.0	1,500.0	2,000.0	2,000.0	2,500.0
Other Cost	235.5	262.0	389.2	443.6	706.8
Certification	70.0	78.8	121.2	139.4	227.1
Insurance	140.0	157.7	242.5	278.7	454.2
Land	25.5	25.5	25.5	25.5	25.5
Engineering & Project Management	**4,901.1**	**5,519.2**	**8,485.7**	**9,755.3**	**15,898.6**
Engineering	2,100.5	2,365.4	3,636.7	4,180.8	6,813.7
Project Management	2,800.6	3,153.8	4,849.0	5,574.5	9,084.9
CAPEX	**21,639.8**	**24,050.6**	**37,119.7**	**42,071.1**	**68,530.0**

Source: JICA Survey Team

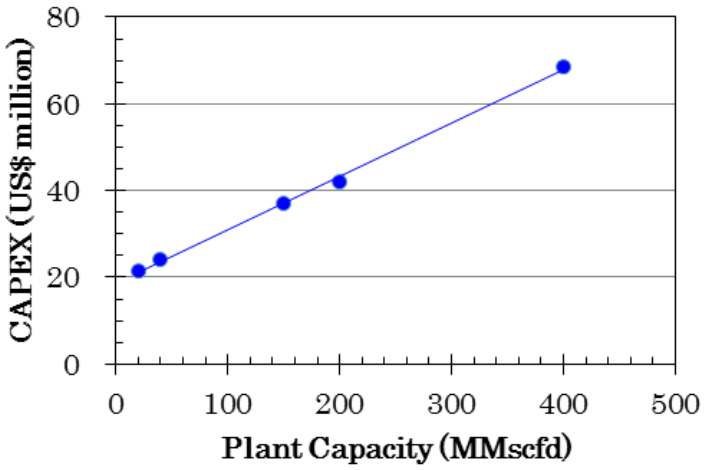
The OGM output in Table 107 may also be arranged by the principal cost items as listed in Table 108.

Table 108 Construction Costs of Gas Production Facility (20, 40, 150, 200 and 400 MMscfd)

Plant Capacity (MMscfd)	Total Construction Cost (million USD)	Cost Breakdown (mill. USD)			
		Direct Cost		Indirect Cost	
		Procurement and installation	Other field construction including infrastructures	Engineering	Project management
20	21.6	14.0	2.7	2.1	2.8
40	24.1	15.8	2.8	2.4	3.1
150	37.1	24.2	4.4	3.6	4.9
200	42.1	27.9	4.4	4.2	5.6
400	68.5	45.4	7.2	6.8	9.1

Source: JICA Survey Team

According to Table 108, the OGM costs estimation results for the typical gas production facilities can be plotted as shown in Figure 30.



Source: JICA Survey Team

Figure 30 Construction Cost of Gas Production Facility (20, 40, 150, 200 and 400 MMscfd)

As shown in Figure 30, it can be said that as the plant capacity increases CAPEX is also likely to increase by a certain percentage. As stated above, construction costs of the future gas production facilities can be predicted. The cost of the nine gas production facilities with the "additional capacity required (a minus b)" in Table 109 may be estimated.

Table 109 Construction Costs of the Gas Production Facility for Already-Discovered Domestic Natural Gas (Predicted Cost based on OGM output)

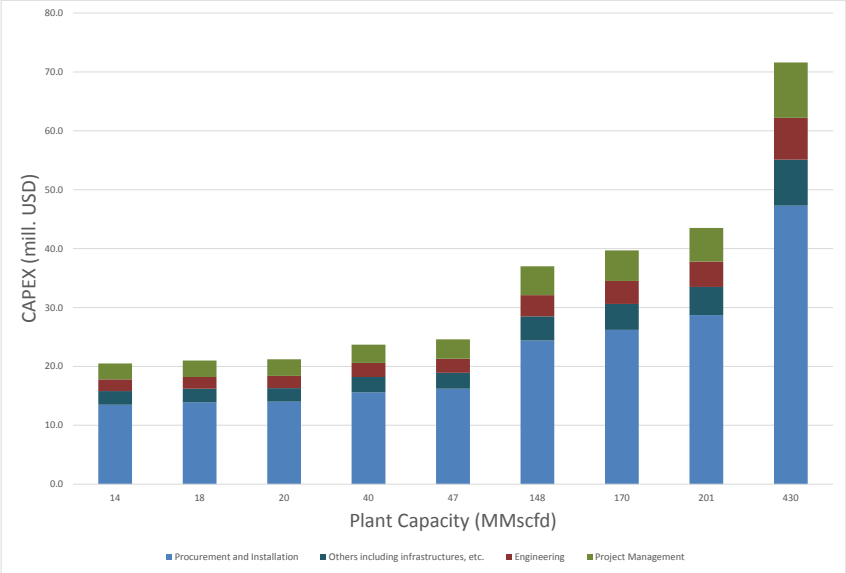
Field Name	Sylhet	Semutung	Fenchuganj	Shahbazpur	Bakhrabad	Titas	Kailashtila	Rashidpur	Bibiyana
Gas Production Rate (MMscfd)	14	18	20	40	47	148	170	201	430
Procurement & Fabrication, Installation	**13,533.4**	**13,857.6**	**14,019.7**	**15,640.7**	**16,208.0**	**24,393.9**	**26,176.9**	**28,689.4**	**47,249.4**
Separation System	1,180.3	1,208.6	1,222.7	1,625.6	1,684.5	4,376.2	4,696.1	6,363.2	13,454.9
Production Manifold	448.7	459.4	464.8	732.2	758.8	1,514.4	1,625.1	2,335.2	5,350.5
Separation	731.6	749.2	757.9	893.4	925.8	2,861.9	3,071.1	4,028.0	8,104.4
Gas Dehydration System	1,599.6	1,637.9	1,657.1	2,485.8	2,576.0	6,026.4	6,466.9	7,187.0	14,268.6
GasDehydration1	1,599.6	1,637.9	1,657.1	2,485.8	2,576.0	6,026.4	6,466.9	7,187.0	14,268.6
Condensate Recovery & Storage System	3,147.0	3,222.4	3,260.1	3,460.0	3,585.5	4,532.6	4,863.9	5,024.9	6,553.3
Crude Metering & Export	132.9	136.1	137.7	131.1	135.9	124.0	133.1	126.9	126.4
Tankage	3,014.1	3,086.3	3,122.4	3,328.9	3,449.6	4,408.6	4,730.8	4,898.0	6,426.9
Water Treatment System	531.6	544.4	550.7	576.8	597.8	788.8	846.5	882.1	1,205.0
Produced Water	146.0	149.5	151.3	153.7	159.3	191.6	205.6	201.0	298.3
Drain Effluent Water	385.6	394.8	399.4	423.1	438.4	597.2	640.9	681.1	906.7
Utility & Support Systems, Others	7,074.9	7,244.3	7,329.1	7,492.4	7,764.2	8,669.8	9,303.5	9,232.2	11,767.7
GasCompression1	344.3	352.5	356.7	373.3	386.9	389.3	417.8	403.2	426.7
Relief	210.0	215.1	217.6	259.2	268.6	581.3	623.8	668.2	737.8
Flare	154.6	158.3	160.2	174.4	180.8	264.7	284.1	311.6	479.9
Power Generation	1,063.9	1,089.4	1,102.1	1,091.8	1,131.4	1,107.6	1,188.5	1,133.1	1,145.0
Power Distribution	1,230.6	1,260.1	1,274.8	1,319.4	1,367.3	1,291.7	1,386.1	1,341.7	1,439.0
Heating Medium	0.0	0.0	0.0	0.0	0.0	197.5	211.9	211.0	321.8
Instrument Air	285.8	292.7	296.1	295.9	306.6	314.1	337.0	340.3	378.4
Utility Air	68.0	69.6	70.4	72.7	75.4	89.8	96.3	97.7	114.0
Fuel Gas	94.5	96.7	97.9	98.9	102.5	128.7	138.1	135.6	147.2
Diesel Fuel	206.8	211.7	214.2	215.2	223.0	234.7	251.9	246.2	264.4
Fire Protection	705.4	722.3	730.7	735.7	762.3	846.2	908.0	910.7	1,021.9
Control Center	1,423.2	1,457.3	1,474.4	1,460.6	1,513.6	1,481.7	1,590.0	1,515.8	2,775.1
Buildings	557.2	570.6	577.3	578.8	599.8	586.6	629.5	601.4	626.4
Site Preparation	96.6	99.0	100.1	106.8	110.7	155.7	167.0	178.6	236.5
Site Mgt	633.9	649.1	656.7	709.7	735.4	1,000.3	1,073.4	1,137.1	1,653.6
Infrastructure & Other Cost	**2,255.6**	**2,309.6**	**2,336.6**	**2,606.8**	**2,701.3**	**4,065.6**	**4,362.8**	**4,781.6**	**7,874.9**
Infrastructure	2,061.4	2,110.7	2,135.4	2,359.5	2,445.1	3,705.2	3,976.0	4,304.2	7,102.5
Construction Camp	824.5	844.3	854.2	943.8	978.0	1,852.6	1,988.0	2,152.1	4,370.8
Operations Camp	1,236.8	1,266.4	1,281.3	1,415.7	1,467.0	1,852.6	1,988.0	2,152.1	2,731.7
Other Cost	194.2	198.9	201.2	247.3	256.3	360.5	386.8	477.3	772.4
Certification	57.7	59.1	59.8	74.4	77.1	112.3	120.5	150.0	248.2
Insurance	115.5	118.2	119.6	148.8	154.2	224.6	241.0	299.9	496.4
Land	21.0	21.5	21.8	24.1	24.9	23.6	25.3	27.4	27.9
Engineering & Project Management	**4,716.2**	**4,829.2**	**4,885.7**	**5,450.5**	**5,648.2**	**8,500.9**	**9,122.3**	**9,997.8**	**16,465.7**
Engineering	2,021.2	2,069.6	2,093.9	2,335.9	2,420.7	3,643.2	3,909.5	4,284.8	7,056.7
Project Management	2,695.0	2,759.5	2,791.8	3,114.6	3,227.6	4,857.7	5,212.7	5,713.0	9,409.0
CAPEX	**20,505.2**	**20,996.4**	**21,242.0**	**23,698.0**	**24,557.6**	**36,960.4**	**39,662.0**	**43,468.8**	**71,590.0**

Then, the predicted costs in Table 109 can be arranged by the principal cost items as shown in Table 110.

Table 110 Construction Costs of the Gas Production Facility for Already-Discovered Domestic Natural Gas

Serial No.	Gas Field	Additional Capacity Required (MMscfd)	Total Construction Cost (mill. USD)	Cost Breakdown (mill. USD)			
				Direct Cost		Indirect Cost	
				Procurement and installation	Other field construction including infrastructures	Engineering	Project management
1	Titas	148	37.0	24.4	4.1	3.6	4.9
3	Bakhrabad	47	24.6	16.2	2.7	2.4	3.3
4	Kailashtila	170	39.7	26.2	4.4	3.9	5.2
5	Rashidpur	201	43.5	28.7	4.8	4.3	5.7
6	Sylhet	14	20.5	13.5	2.3	2.0	2.7
10	Fenchuganj	20	21.2	14.0	2.3	2.1	2.8
12	Shahbazpur	40	23.7	15.6	2.6	2.4	3.1
13	Semutang	18	21.0	13.9	2.3	2.0	2.8
17	Bibiyana	430	71.6	47.3	7.8	7.1	9.4
Total		1088	302.8	199.8	33.3	29.8	39.9

Source: JICA Survey Team



Source: JICA Survey Team

Figure 31 Construction Costs Breakdown of the Gas Production Facility for Already-Discovered Domestic Natural Gas

As shown in Figure 31, the construction cost of gas production facility varies according to the plant capacity. Even if the plant capacity is small, facility configuration required for the proposed gas treatment is same, and only the scale of the facility is reduced in connection with gas treatment volume. Therefore, approximately minimum 20 million USD is necessary even for Sylhet gas field case, which has the smallest facility scale (14 MMscfd) of the nine gas fields. The plant capacity of 14 MMscfd is

classified in the minimum plant scale in regular gas development projects, and it is considered that the approximately 20 million USD is “base cost” of gas production facilities that are planned to be constructed in each gas field. Accordingly, the facility construction cost in each gas field may be estimated by adding this “base cost” and facility costs escalated by the increase of plant capacity.

The construction cost estimated in Table 110 includes not only the five main systems stated earlier, but also the related facilities such as: power generation and distribution systems, fuel gas systems, tankage systems, drain/effluent water systems, relief/flare systems, fire protection systems, instrument air systems, and buildings.

For the above costs estimation, the validity of the finally estimated costs for the future gas production facilities in Table 110 was checked below in comparison with past construction data. As stated above, since all the costs in these nine gas fields were predicted based on CAPEX increasing (indicated in Figure 30, the validity was checked in relation to the original costs shown in in Figure 30.

According to the past construction data, the total construction costs of gas production facilities having 45 MMscfd capacity was estimated at approximately 22.1 million USD whne applying the current exchange rate (1 USD = 117 YEN). In response, CAPEX of the facility with the same plant capacity can be considered at around 24.3 million USD in Figure 30. Thus it can be said that CAPEX in Figure 30 is almost same as that of the past construction experience, and that CAPEX in Table 110 also has sufficient validity in terms of its accuracy.

(b) Gas transmission pipelines from the gas production facilities for already-discovered domestic natural gas

It is proposed that nine gas pipelines shall be constructed to transfer gas treated in the future gas production facilities that are to be built in the gas fields shown in Table 111, and that this gas will be sent to the existing pipeline network for future incremental gas supply. Each pipeline will be tied-in to the nearest valve station and/or city gate station on the existing pipeline network.

Based on the pipeline data described in the paragraph 3(3), the unit costs of 0.5 million USD/km are applied, the total construction costs for the above pipelines is estimated at approximately 9 million USD. Please refer to Table 111.

Table 111 Construction Cost of the Gas Transmission Pipelines from the Gas Production Facilities for Domestic Natural Gas which has Already Been Discovered

Serial No.	Starting point	Length (km)	Unit cost (mill. USD/km)	Total cost (mill. USD)
1	Titas gas field	2	0.5	1.0
3	Bakhrabad gas field	2	0.5	1.0
4	Kailashtila gas field	2	0.5	1.0
5	Rashidpur gas field	2	0.5	1.0
6	Sylhet gas field	2	0.5	1.0
10	Fenchuganj gas field	2	0.5	1.0
12	Shahbazpur gas field	2	0.5	1.0
13	Semutang gas field	2	0.5	1.0
17	Bibiyana gas field	2	0.5	1.0
	Total	18	-	9.0

Source: JICA Survey Team

(c) Gas distribution pipelines for future power plants

It is proposed that gas distribution pipelines will be constructed to supply gas for future power plants which will be newly required based on an examination of the domestic power balance between supply and demand. Each pipeline it expected to be branched at the nearest valve station and/or city gate station on the existing pipeline network and tied-in to the respective appropriate delivery points in the future power plants.

Based on the pipeline data described in Paragraph 3 (4) if the unit costs of 0.5 million USD/km are applied, the construction costs for the 12 inch x 10 km pipeline is estimated at 5 million. Please refer to Table 112.

Table 112 Construction Cost of Gas Distribution Pipeline

Delivery point	Length (km)	Unit cost (mill. USD/km)	Total cost (mill. USD)
xxx power plant	10	0.5	5.0
Total	10	-	5.0

Source: JICA Survey Team

As a result, the estimated investment costs for the the future gas development is summarized as shown in Table 113.

Table 113 Investment Cost for Gas Field Development

Item			Predicted Peak Production Rate (a) [MMscfd]	Current Plant Capacity (b) [MMscfd]	Additional Capacity Required (a) – (b) [MMscfd]	Completion of New Facility Construction [Year]	Investment Cost											Total [mill. USD]
							Drilling				Facility construction			Pipeline				
							Quantity	Specification	Unit cost [mill. USD/well]	Subtotal [mill. USD]	Quantity [MMscfd]	Specification	Subtotal [mill. USD]	Quantity [km]	Specification	Unit cost [mill. USD/km]	Subtotal [mill. USD]	
Serial No.	1.	**Construction cost of gas production facilities for domestic gas which have already been discovered**																
1		Titas	600	452	148	2015				0	148	Wellhead press./temp.: 1,700psig/142 deg.F	37.0	2	API5L Gr.X60 w/3LPE coating, 12" x 0.312"wt	0.5	1.0	38.0
3		Bakhrabad	80	33	47	2017				0	47	Ditto	24.6	2	Ditto	0.5	1.0	25.6
4		Kailashtila	250	80	170	2019				0	170	Ditto	39.7	2	Ditto	0.5	1.0	40.7
5		Rashidpur	250	49	201	2019				0	201	Ditto	43.5	2	Ditto	0.5	1.0	44.5
6		Sylhet	25	11	14	2015				0	14	Ditto	20.5	2	Ditto	0.5	1.0	21.5
10		Fenchuganj	60	40	20	2014				0	20	Ditto	21.2	2	Ditto	0.5	1.0	22.2
12		Shahbazpur	70	30	40	2018				0	40	Ditto	23.7	2	Ditto	0.5	1.0	24.7
13		Semutung	30	12	18	2018				0	18	Ditto	21.0	2	Ditto	0.5	1.0	22.0
17		Bibiyana	1200	770	430	2017				0	430	Ditto	71.6	2	Ditto	0.5	1.0	72.6
		Subtotal (1)					0.0			0.0	1088	-	302.8	18	-	-	9.0	311.8
	2.	**Construction cost of gas production facilities for domestic gas which have not been discovered**																
			-	-	-					0							0	0
			-	-	-					0							0	0
		Subtotal (2)					0.0			0.0		-	0.0	0	-	-	0.0	0.0
	3.	**Gas distribution pipelines for future power plants**																
			-	-	-		-	-	-		-	-		10	API5L Gr.X60 w/3LPE coating, 12" x 0.312"wt	0.5	5.0	5
			-	-	-		-	-	-		-	-					0	0
		Subtotal (3)					-				-	-		10	-	-	5.0	5.0
		Total					-	-	-	0.0	-	-	302.8	-	-	-	14.0	316.8

Source: JICA Survey Team

Table 114 Investment Plan for Gas Field Development

Item			Predicted Max. Production Rate [MMscfd]	Current Plant Capacity [MMscfd]	Additional Capacity Required [MMscfd]	Completion of New Facility Construction	Investment Cost [mill. USD]																										
							Fisical Year																										
							2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	Total Cost
Serial No.	**1.**	**Gas production facilities for domestic gas which have already been discovered**																															
1		Titas	600	452	148	2015		38.0																									38.0
3		Bakhrabad	80	33	47	2017				25.6																							25.6
4		Kailashtila	250	80	170	2019						40.7																					40.7
5		Rashidpur	250	49	201	2019						44.5																					44.5
6		Sylhet	25	11	14	2015		21.5																									21.5
10		Fenchuganj	60	40	20	2014	22.2																										22.2
12		Shahbazpur	70	30	40	2018					24.7																						24.7
13		Semutung	30	12	18	2018					22.0																						22.0
17		Bibiyana	1200	770	430	2017				72.6																							72.6
		Subtotal (1)					22.2	59.5	0.0	98.2	46.7	85.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	311.8
	2.	**Gas production facilities for domestic gas which have not been discovered**																															
			-	-	-																												0.0
			-	-	-																												0.0
		Subtotal (2)					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3.	**Gas distribution pipelines for future power plants**																															
			-	-	-																												0.0
			-	-	-																												0.0
		Subtotal (3)					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total					22.2	59.5	0.0	98.2	46.7	85.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	311.8

Source: JICA Survey Team

(3) Import Gas Development Cost

(a) LNG Receiving terminal

LNG Receiving Onshore terminal assumes 2x 200,000 M3 LNG tanks at the initial phase, with jetty and re-gasification facilities. Total estimated cost is USD 500 million.

(b) LNG transmission pipeline

Based on the pipeline data described in Paragraph 3 (5), if the onshore unit costs of 1.5 million USD/km and offshore unit costs of 1.1 million USD are applied, the total construction cost for the pipeline is estimated at approximately 115.1 million USD. Refer to Table 115.

Table 115 Construction Cost of LNG Transmission Pipeline

	Length (km)	Unit cost (mill. USD/km)	Total cost (mill. USD)
Offshore portion	10	1.5	15.0
Onshore portion	91	1.1	100.1
Total	101	-	115.1

Source: JICA Survey Team

5. Total Investment Cost

Some area is not covered by the Software and these are assumed based on the following figures:

1) Significant labor works and time/cost will be required to identify oil and gas deposit in the green field in general, and cost for these area will also differ from country to country and also to the local conditions. In case of Bangladesh, it is assumed that potential of gas borne area is identified already, and actual cost information used for particular field is used as a benchmark cost, i.e., 2D Seismic Survey: USD 3 million (80 L Km), 3D Seismic Survey: USD 28 million (400 km2)

2) Drilling cost assumes four development wells and used as a production well at later stage. Based on the recent experience by BGFCL, total of 4 wells cost USD 60 million.

3) Assuming that production rate from future onshore wells is 500 mmscfd, cost for production facilities will be assumed USD 90 million as per SIMENS Cost Estimate Software.

Table 116 Total Investment Costs for Gas Development till 2027

	Item	Cost [mill. USD]
A	**Domestic Gas Development Costs for the Remaining Reserves 2P**	
A1	Field Exploration Costs	*30*
A2	Field Development Costs	
A2.1	Drilling Costs	*60*
A2.2	Facility Construction Costs	
(1)	Facility construction costs for domestic gas which has already been discovered	302.8
(2)	Gas transmission pipelines from gas production facilities for domestic gas which has already been discovered	9.0
(3)	Facility construction costs for domestic gas which has not been discovered	*90*
(4)	Gas distribution pipelines for future power plants	5.0
	Subtotal (A)	*496.8*
B	**Import Gas Development Costs**	
B1	Facility Construction Costs	
(1)	LNG Receiving Terminal	*760*
(2)	LNG transmission pipeline	115.1
	Subtotal (B)	*875.1*
C	**Contingency (= (A+B) x 50%)**	
	Subtotal (C)	*686*
	Total (A+B+C)	***2057.9***

Source: JICA Survey Team

Numbers of assumptions were made to make cost estimate and the result is not necessarily close enough to predict future cost.

(1) Reinforcement cost for Existing Pipeline Infrastructure is not included in the cost estimate.

(2) Impact of LNG introduction to existing gas infrastructure and to gas field processing facilities/wellhead compressors is not included.

(3) All the cost data and assumed infrastructure models used for cost estimate to be reviewed.

Table 117 OGM Input Data for Plant Capacity (20, 40, 150, 200 and 400 MMscfd)

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
1. Project Construction Site								
1-1	Project Construction Site	Southeast Asia	Southeast Asia	Southeast Asia	Southeast Asia	Southeast Asia	Large	The project construction site is specified from major oil/gas production areas worldwide such as the Arabian Gulf, Gulf of Mexico, North Sea, West Africa, Brazil, Venezuela, Southeast Asia, North East Asia and Malaysia. In this case, Southeast Asia was specified due to the proximity of Bangladesh. The appropriate wage rate for the specified project construction site was then applied –the same data is inputted for to all the cases regardless of the gas handling capacity
2. Required Facilities (Separator, Gas Dehydrator, Condensate Storage, Water Treatment Facilities)								
2-1	Main Facilities	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Large	The required main facilities (separator, gas dehydrator, condensate storage tank, and water treatment facility) for gas production are specified. Here, as there are no sour components (H2S) in the gas the general facility configuration for normal gas production was selected. As the facility configuration is the same for all the cases, the same data was inputted regardless of the gas handling capacity.
3. Process Conditions								
3-1	Gas Production Rate	20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd	Large	The gas production rate is specified. In this case, gas handling capacities is specified to covers the wide range of gas production rates in Bangladesh. The facilities required to handle the specified gas production rate are designed in connection with gas handling capacity,then the costs are estimated.

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
3-2	Composition Basis	Mole %	Mole %	Mole %	Mole %	Mole %	Large	The gas composition is specified and the gas/liquid separation calculation is conducted based on the inputted composition. The facilities required to handle the separated gas and liquid are designed, and then the costs are estimated. The typical gas composition in Bangladesh is inputted in all cases regardless of the gas handling capacity. In case that the toxic substances such as sour component (H2S) and mercury are included in the produced gas, requisite removal facilities will be required. However, as the gas produced in Bangladesh is classified in sweet gas, the installation of such facilities is not necessary. Due to the limitations of the software inputs, the heavier components of n-Hexane (and above) were inputted into all the cases as n-Hexane+
	Nitrogen (N2)	0.37	0.37	0.37	0.37	0.37		
	Carbon Dioxide (CO2)	0.31	0.31	0.31	0.31	0.31		
	Hydrogen Sulfide (H2S)	0.00	0.00	0.00	0.00	0.00		
	Methane (C1)	96.76	96.76	96.76	96.76	96.76		
	Ethane (C2)	1.80	1.80	1.80	1.80	1.80		
	Propane (C3)	0.36	0.36	0.36	0.36	0.36		
	i-Butane (iC4)	0.09	0.09	0.09	0.09	0.09		
	n-Butane (nC4)	0.05	0.05	0.05	0.05	0.05		
	i-Pentane (iC5)	0.02	0.02	0.02	0.02	0.02		
	n-Pentane (nC5)	0.02	0.02	0.02	0.02	0.02		
	n-Hexane+ (nC5+)	0.22	0.22	0.22	0.22	0.22		
4. Separation System								
4-1	Flowing Wellhead Pressure	1,700 psig	1,700 psig	1,700 psig	1,700 psig	1,700 psig	Medium	The wellhead pressure is specified. The pressure level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical wellhead pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.The normal range of wellhead pressure at the gas fields is approximately 500 to 3,000 psig.
4-2	Flowing Wellhead Temperature	142 F	142 F	142 F	142 F	142 F	Small	The wellhead temperature is specified. Temperature level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								temperature, after which the costs are estimated. The typical wellhead temperature in Bangladesh was inputted in all the cases regardless of the gas handling capacity. The normal range of the wellhead temperature is approximately 100 to 180 F
4-3	Prod. Manifold Design Pressure	1,100 psig	1,100 psig	1,100 psig	1,100 psig	1,100 psig	Medium	The manifold design pressure is specified. The pressure level at the manifold is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure was inputted in all the cases regardless of the gas handling capacity.The normal range of the manifold design pressure is approximately 500 to 1,500 psig.
4-4	Prod. Separator Design Pressure	1,100 psig	1,100 psig	1,100 psig	1,100 psig	1,100 psig	Medium	The separator operating pressure is specified. The gas/liquid separation calculation is conducted based on the inputted pressure, then the separator size and wall thickness required to handle the separated gas and liquid are designed, after which the costs are estimated. The typical separator operating pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.The normal range of the separator design pressure is approximately 500 to 1,500 psig.

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
4-5	Prod. Separator Operating Pressure	1,000 psig	1,000 psig	1,000 psig	1,000 psig	1,000 psig	Medium	The separator operating pressure is specified. The gas/liquid separation calculation is conducted based on the inputted pressure, then the separator size and wall thickness required to handle the separated gas and liquid are designed, after which the costs are estimated. The typical separator operating pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.The normal range of the separator operating pressure is approximately 500 to 1,500 psig.
4-6	Test Separator	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of the test separator is specified. The test separator is normally required to monitor the production rate of one well and to manage the gas reservoir. “Allocated” was selected for all the cases regardless of the gas handling capacity.
4-7	Residence Time	3 min.	3 min.	3 min.	3 min.	3 min.	Small	The oil/condensate residence time in a separator that is required to segregate water droplets from oil/condensate phase was inputted. The As the separator is designed based on the residence time, the typical residence time is inputted in all the cases regardless of the gas handling capacity.The normal value of the oil/condensate residence time is approximately 3 minutes.
4-8	Separator per Stage	1	1	1	1	1	Medium	The number of separators per stage is inputted. Normally, vessels such as separators do not have any spares. Also, as the facility configuration without any spares is a design premise in the study, the number of train was inputted as one for all the cases regardless of the gas handling capacity.
4-9	Percent Flow per Separator	100%	100%	100%	100%	100%	Medium	In relation to the “separator per stage”, the percentage of the handling flow rate per train in the total flow rate was inputted. As the facility

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								configuration without any spares is a design premise in the study, the percent flow per separator is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
4-10	Water Separation Option	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of water separation in a separator is specified. The produced water is normally removed from the oil/condensate and gas. "Allocated" was selected for all the cases regardless of the gas handling capacity.
5. Gas Dehydration System								
5-1	Gas Dehydration Medium	Glycol	Glycol	Glycol	Glycol	Glycol	Medium	The gas dehydration medium is specified. "Glycol" is specified as a typical medium (chemical) used in gas dehydration process for all the cases regardless of the gas handling capacity.
5-2	Number of Gas Dehydration Train	1	1	1	1	1	Medium	The number of gas dehydration trains is inputted. Vessels such as gas dehydration facility normally do not have any spares, and facility configuration without any spare is a design premise in the study, therefore number of train is inputted as one for all the cases regardless of gas handling capacity.
5-3	Percent Flow per Dehydration Train	100%	100%	100%	100%	100%	Medium	In relation to the "number of gas dehydration trains", the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spares is a design premise in the study, the percent flow per gas dehydration train is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
5-4	Outlet Water Dew Point Temperature	32 deg.F	32 deg.F	32 deg.F	32 deg.F	32 deg.F	Medium	The outlet water dew point temperature for the gas dehydration is inputted. The water dew point temperature of 32 F corresponding to 7 lb water in 1 MMscf gas, as regulated in the standard sales gas contract in Bangladesh, is inputted for all the cases regardless of the gas handling capacity.
5-5	Dehydrator Column Design Pressure	1,100 psig	1,100 psig	1,100 psig	1,100 psig	1,100 psig	Medium	The gas dehydrator column design pressure is specified. The pressure level of the dehydrator column is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical design pressure is inputtedfor all the cases regardless of the gas handling capacity.The normal range of the dehydrator column design pressure is approximately 500 to 1,500 psig.
6. Condensate Recovery and Storage System								
6-1	Oil/Condensate Tank Capacity	15 kbbl	20 kbbl	40 kbbl	50 kbbl	100 kbbl	Large	The oil/condensate tank capacity is specified. The tank capacities for above 150 MMscfd cases were determined and inputted in proportion to the actual gas field development/construction record (25 kbbl for 90 MMscfd). Regardign the tank capacities for small development cases (20 and 40 MMscfd), appropriate capacities were inputted so as to reduce the shipping frequency of the condensate stored. The required oil/condensate storage facilities are designed for the inputted tank capacity, then the costs are estimated.
6-2	Oil Pump Outlet Pressure	100 psig	100 psig	100 psig	100 psig	100 psig	Medium	The oil pump outlet pressure required for shipping is specified. The Pressure level of the pump is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure is inputted for all the cases regardless of

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								the gas handling capacity.
6-3	Number of Pumps	1	1	1	1	1	Medium	The number of pumps is inputted. As the facility configuration without any spares is a design premise in the study, the number of trains is inputted as one for all the cases regardless of the gas handling capacity.
6-4	Percent Flow per Pump	100%	100%	100%	100%	100%	Medium	In relation to "number of pumps", the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spare is a design premise in the study, thepercent flow per pump is inputted in common as one hundred (100%) for all the cases regardless of the gas handling capacity.
7. Water Treatment System								
7-1	Produced Water Design Rate	0.2 kbpd	0.4 kbpd	1.5 kbpd	2 kbpd	4 kbpd	Large	The produced water design rate is specified. The facilities required to handle the specified water rate are designed in connection with the produced water design rate, then the costs are estimated. 10 bbl of water was assumed to be produced with 1 MMscf gas.
7-2	Sour Water Stripping Option	Not Allocated	Not Allocated	Not Allocated	Not Allocated	Not Allocated	Medium	The necessity of a sour (H2S) component stripping facility as one the of water treatment systems is specified. As gas produced from Bangladesh is classified as sweet gas a without sour (H2S) component, the installation of such a facility is not required. "Not allocated" was selected for all the cases regardless of the gas handling capacity.
7-3	CPI Unit	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of a CPI unit as the first stage of water treatment is specified. A CPI unit is normally used in the water treatment. "Allocated"

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								was selected for all the cases regardless of the gas handling capacity.
7-4	Floatation/Hydrocyclone Unit	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of a floatation/hydrocyclone unit as the second stage of water treatment is specified. A floatation/hydrocyclone unit is normally used in the water treatment. "Allocated" was selected for all the cases regardless of the gas handling capacity.
8. Utility System								
8-1	Type of Main Power Generator	Turbine	Turbine	Turbine	Turbine	Turbine	Small	The type of main power generator driver is specified. "Turbine" was specified as the typical most proven type of driver for all the cases regardless of the gas handling capacity.
8-2	Number of Main Power Generators	1	1	1	1	1	Medium	The number of main power generators is inputted. As the facility configuration without any spares is a design premise in the study, the number of trains was inputted as one for all the cases regardless of the gas handling capacity.
8-3	Percent of Main Power Load	100%	100%	100%	100%	100%	Medium	In relation to the "number of main power generators", the percentage of power generation per train in the total power generation is inputted. As the facility configuration without any spares is a design premise in the study, the percent of the main power load was inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
8-4	Power Generator Selection	Internally Determined	Internally Determined	Internally Determined	Internally Determined	Internally Determined	Medium	The manufacturer's model of the main power generator is specified. In this case, the required power for all the facilities was internally calculated in the software by specifying "internally determined" for all the cases

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								regardless of the gas handling capacity. Also, the type of main power generator was automatically selected to cover the power demand required.
9. Other Related Facilities								
9-1	Number of People in Operation Camp	30	30	40	40	50	Medium	The number of people to be accommodated in the operation camp is inputted. Based on three shift of eight hours , the number of people – including operators, supervisors, maintenance workers, administrators, and guests – are assumed for the required accommodation, then the costs are estimated.
9-2	Number of People in Construction Camp	50	50	100	100	200	Medium	The number of people to be accommodated in construction camp is inputted. The number of people is assumed for the required accommodation, then the costs are estimated.

Source: JICA Survey Team

Chapter 8 Liquefied Natural Gas Supply

8.1 Background of LNG Import in Bangladesh

According to the natural gas supply and demand balance forecast study from 2009 to 2030 in Bangladesh by PSMP2010, the tremendous shortage data of natural gas supply from the domestic gas well in 2015 onward was shown to us.
In the present study, as one of the solutions to compensate the huge gap between natural gas supply and demand, onshore LNG receiving terminal will be studied and the technical challenges at the earliest stage will be shown.
In the process of the study, the main objective is to pursue the stable natural gas supply to bulk users like power station and fertilizer nearby and we will find the technical challenges to have an economic and energy effective LNG receiving terminal, while looking at the design, construction, and O&M procedure of LNG receiving terminal in Japan and studying the gas tie-in condition with the local gas pipeline.



Source: Osaka Gas Brochure

Figure 8-1 Overview of LNG Receiving Terminal Owned by Osaka Gas

8.2 Overview of LNG Terminal Development Plans

Until 2041, approximately 5,900mmscfd gas will be required, out of which 4,000mmscfd will be supplied from newly constructed LNG terminals (refer to the below Table). In addition to the terminals, 125mmscfd (up to 250 mmscfd) will be supplied mainly in Khulna, through an international gas pipeline to be connected to a newly constructed FSRU in West Bengal (further details can be referred in section 8.7 .).

Table 8-1 LNG Terminal Development Plans

FY	Type of Terminal	Capacity (mmcfd)	Remarks
2018	*FSRU*	*500*	*On-going project by Petrobangla*
2023	FSRU	500	To be planned
2027	Onshore	500	Moheshkhali and/or Payra
2029	Onshore	500	Moheshkhali and/or Payra
2036	Onshore	500	Moheshkhali and/or Payra
2039	Onshore	500	Moheshkhali and/or Payra
2040	Onshore	500	To be planned
2041	Onshore	500	To be planned
Total Capacity		4,000	

Source: JICA Survey Team

The FSRU project by Petrobangla makes the first move and three other LNG projects follow.

Table 8-2 Four Immediate Future LNG Import Projects

Project	Location	Capacity (mmscfd)	Leading Agency	Operating Entity	Status and/or Commercial Operation	Project Operation
FSRU	Moheshkhali	500	Petrobangla	Excelerate Energy Bangladesh	2018	BOOT
Land Based LNG	Moheshkhali	LNG for 3,000 MW of IPPs	Power Cell	SPV of BPDB/ ICF Infra Venture/	Expression of Interest (EoI) for FS released.	BOO
Land Based LNG	Moheshkhali	1000	Petrobangla	Petrobangla companies	EoI for FS released. Await for anouncement for Request for Proposal (RfP)	not finalized yet
Land Based LNG	Payra	1000				

Source: JICA Survey Team based on the publically available information

From the next section, these four projects will be described.

8.3 Status of FSRU Planning in Bangladesh

The Bangladeshi Government has focused on the LNG supply technology of FSRU to recover quickly the natural gas supply and demand gap and agreed the charter party of one unit of FSRU in 2014.

DHAKA, BANGLADESH – Excelerate Energy and Petrobangla have reached agreement on terms for the development and operation of Bangladesh's first LNG import terminal. The agreement includes the provision of one of Excelerate's existing floating storage and regasification units (FSRU) under a 15-year long-term charter, as well as the design and construction of the facility. Located offshore near Moheshkhali Island in the Bay of Bengal, the terminal will provide much needed natural gas to the southeastern Chittagong region of Bangladesh.

The facility will include the installation of a subsea buoy system anchored offshore. The buoy system will act as both the mooring mechanism for the FSRU and as the conduit through which natural gas is delivered to shore through a subsea pipeline. The FSRU will have 138,000 cubic meters of LNG storage capacity and a base regasification capacity of 500 million standard cubic feet per day.



Source: Höegh LNG Holdings Ltd.

Figure 8-2 FSUR Image

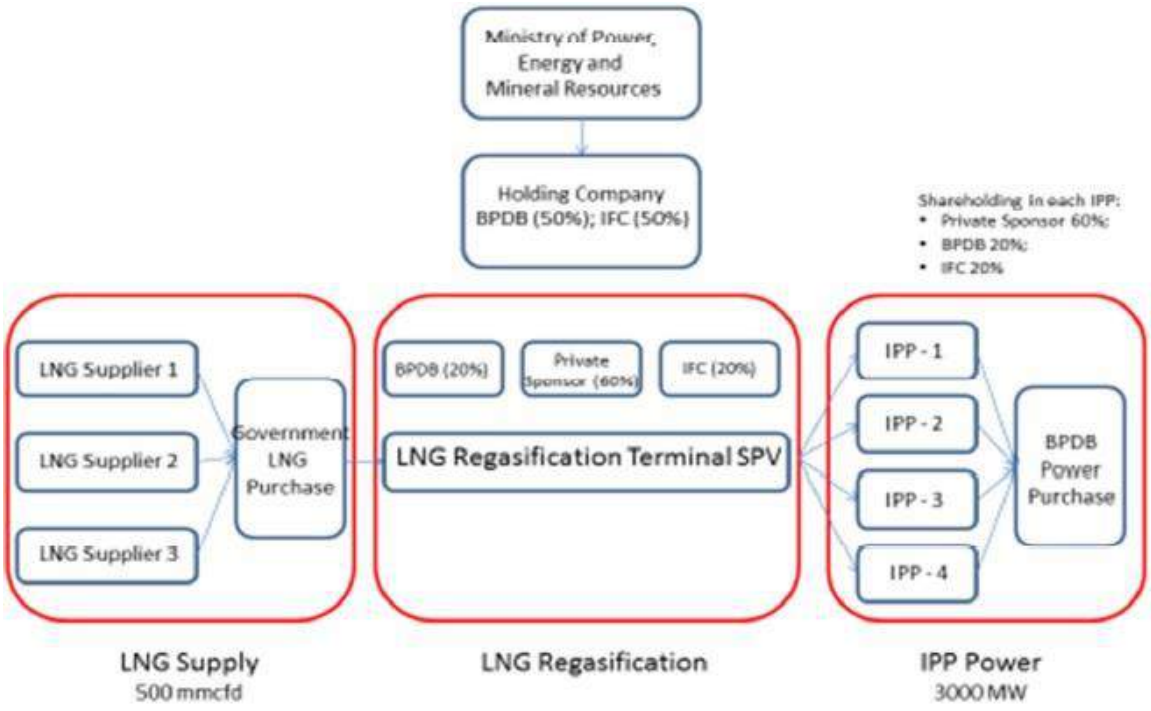
FSRU has some advantages over onshore LNG receiving terminal, in terms of up-front construction cost, construction period, easiness of dismantling, etc. (for further detail of economic cost comparison, refer to the following section). But on the other hand, FSRU operation is largely influenced by weather and sea phenomena condition. This is because onshore LNG receiving terminal is needed to utilize LNG for a long time and supply stably natural gas to the customer. Thus the technical challenges for the basic plan and main specification of LNG receiving terminal will be shown here.

8.4 Status of Land-based LNG terminal Planning

In parallel with the introduction of FSRU, the Government is also processing on-shore (land based) LNG terminal project. Currently two GoB agencies, namely Power Cell and Petrobangla have their own land-based LNG plans.

8.4.1 Power Cell Project

This "Land Based LNG Terminal Project" is expected to import 5MMTPA (approx.710 mmscfd) to supply to newly built or existing 3,000MW gas-fired power plants (IPPs expected). The project will be operated on BOO (build-own-operate) basis, operated by LNG consortium mainly sponsored by private finance, and LNG itself will be procured by the Government (see the below figure).



Source: Power Cell

Figure 8-3 Structure of On-shore LNG Terminal and IPPs

The candidate site of this land-based LNG terminal is Matarbari/Moheshkhali area, which is adjacent to the JCA-supported Matarbari Ultra Super Critical coal power plant. Power Cell is the executing agency of this on-shore LNG terminal project, BPDB is the off-taker of LNG and power, and International Financial Corporation (IFC) is an advisor as part of their power sector private sector investment promotion.

The four contractors have been short-listed including one Japanese firm[24]. The employment process of the feasibility study consultant has been in progress since 2015. Design and construction schedule of the LNG will be determined in the feasibility study.

As described above, this Power Cell driving LNG terminal plan is expected to serve for power generation plants. To meet the growing national gas demand including non-power sector (e.g. Transport), more comprehensive LNG plan (e.g. LNG master plan) would be required.

8.4.2 Petrobangla Project

In January 2016, Petrobangla floated the consultant EoI for the feasibility study consultant of LNG projects. According to the EoI document, Petrobangla, similarly to Power Cell, is planning to develop two land-based LNG terminals, one 1,000 mmscfd in Moheshkhali, and/or the other 1,000 mmscfd in Payra. As of June 2016, no further detail is yet available and the plan seems to be still at an early stage.

8.5 Economic Comparison between FSRU and Land-based LNG Receiving Terminal

This Section is primarily intended to make comparison of the two different LNG Import infrastructure, FSRU and Land LNG terminal, in terms of economics. However, it should be understood that each method has its own features and advantages. Therefore this Section also covers all the design factors to be considered for the introduction and construction of LNG infrastructures.

8.5.1 Overview

At the moment (as of May 2016) negotiation on the introduction of FSRU (Floating Storage and Re-gasifying Unit) is underway between Petrobangla and Excelerate Energy from US. According to press report (Bangladesh Energy and Power News) general description of the FSRU Project is as follows:

Location	:	Moheshkhali
Storage Capacity	:	138,000 M3
Re-Gasification Capacity	:	500 mmcfd
Start of Commercial Operation	:	2018
Contract Term	:	15 years, on BOOT base
Service Charge	:	USD 0.49 per mcf

The facility will include FSRU (Floating Storage and Re-gasifying Unit) and Single Point Mooring Buoy system anchored to the sea bottom. Gas produced from LNG is delivered through a conduit of the Buoy system and submarine pipeline and tied into the onshore pipeline system. LNG loading to FSRU will be carried out by Ship to Ship transfer. In order to supply 500mmcfd of gas, more than 60 shipments will be required in a year. Capacity of the shuttle tanker will be the same or smaller than that of FSRU. Construction of FSRU is almost the same as that of LNG tanker. Retired LNG tankers can be remodeled as FSRU to save construction cost. Operation of FSRU in general is vulnerable to weather condition and emergency evacuations plan must be in place if it is operating in the cyclone prone area.

Land LNG Terminal requires larger space near shore, capable of accommodating more than 10 tanks. This is to minimize investment to the infrastructure and also to secure freedom to construct additional

[24] According to Power Cell, these four companies are: Mitsui & Co. Ltd., Japan, Royal Dutch Shell (Netherland), China Huanqui Contracting & Engineering Corp. (HQC) (China) and PetroNet LNG Limited (India).

tanks to meet the incremental demand. Initial tank numbers are assumed to be two to match with the performance of FSRU under negotiation, and to be expanded with the increase of demand.

Tank size has been designed larger to meet the increasing size of LNG tankers. Recent trend of tank size constructed in Asia (Korea) is 180,000 kl and larger to accommodate Q-Flex size. Berth size is designed for Q-Max (265,000 kl) size.

8.5.2 Land-based LNG terminal specifications and construction cost

Land LNG Terminal Specification and Construction Cost Estimate to be used for cost comparison with FSRU is as follows:

(1) Specification for land –based LNG terminal

Objectives of Land LNG Terminal may differ from case to case and sometimes designed for specific power plant only. But in Asia in general, LNG is constructed by taking emergency factor into consideration and therefore some allowance in the storage capacity is included.
In general, annual tank rotation is 12 times as an operational Index. However, Bangladesh is gas producing country and significant amount of gas is supplied domestically, and therefore storage allowance can be trimmed off in case of Bangladesh. In the economic comparison, 20 times of rotation is used. This 20 times is considered low enough in comparison with the case of FSRU with 60 times and more to supply 500 mmcfd of gas

Following are assumed terminal specification.

Terminal Size	:	90 ha
Tank Size	:	180,000 kl
Initial tank Numbers and gas supply	:	3 (500 mmcfd)
Final tank Numbers and gas supply	:	14 (3,000 mmcfd max.)
Jetty	:	Initially 1
Berth Number and capacity	:	1(Q-Max-127,000ton/265,000M3)
Berth will be expanded to suit.		

Note that Re-Export capability and loading arms may be added to allow LNG trading in future, Break water may be required to allow stable off loading.

Tank Utilization	:	18/Year/tank
Capacity	:	1.8 Million ton/yr/tank

(2) Initial land LNG –based terminal construction cost

Assuming that Initially 2 tanks are constructed to commence commercial operation and supply 500 mmcfd of gas. Initial EPC cost inclusive of 3 tanks, re-gasification, Jetty, Loading Arms, operation rooms are USD 550 Million. 90ha of Land acquisition cost capable of constructing 14 tanks in total is assumed USD 200 million, and project development cost of USD 10 million. Initial Project Cost is assumed to be 760 million. Numbers of tanks will be increased with the increase of gas demand. Final construction cost after completion of 14 tanks will be USD 2,260, and gas supply capacity will be 3,000 mmcfd as maximum.

8.5.3 Operation cost comparison

FSRU appears to be constructed as a private enterprise project. To make fair comparison, operation charge of land LNG terminal, inclusive of tugboat operation is circulated based on the economic factors of 10% of IRR, 20% of Corporate Tax, and 20 years of Depreciation.
Economic data of FSRU is given in the News Press "Bangladesh Energy and Power News". According to the press, Operation Charge of tugboat (Port Operation Cost) is excluded and need to be covered by Petrobangla.

Table 8-3 Operation Cost Comparison between FSUR and Land-based LNG Terminal

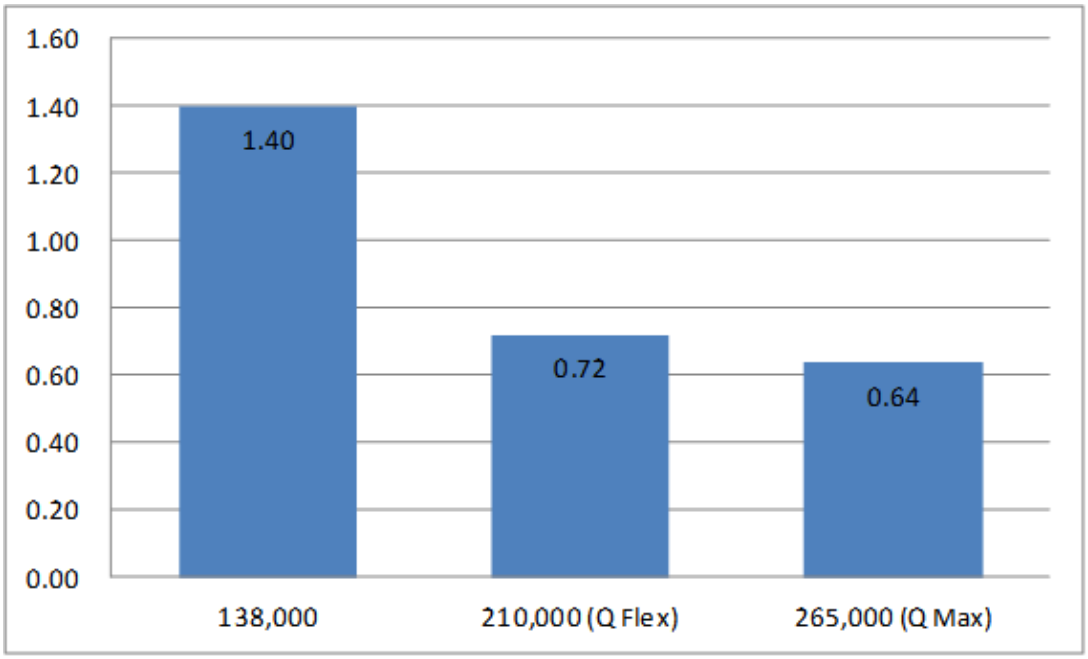
		FSRU (See Note 1)	Land LNG (See Note2)	
			Initial 3 Tanks	Expanded to 14 Tanks
Tank Capacity	M3	138,000	3X180,000	14x180,000
Annual LNG Delivery	Times/Year	59	40	186
Re-Gasification Capacity	MMscfd	500	500	3,000
Construction Cost	MM USD		760	2,260
Operation Charge	USD/Mcf	0.49	0.64 (See Note3)	0.33 (See Note 3)
Note:				
1: Data from Bangladesh Energy and Power News				
2: Land Acquisition Cost for Terminal assumed USD 200 million				
3: Tax Rate 20% and IRR 10% assumed, Including Port Operation Cost				

Source: JICA Survey Team

8.5.4 Freight cost comparison

Freight cost of LNG differs to the size of LNG tankers. To reduce the unit freight cost, size of the tanker has become larger. In this report LNG freight cost from Middle East (Ras Laffan) to Chittagong is assumed based on the data from Middle East to Korea/Japan.

Storage capacity of FSRU is 138,000m3. To supply LNG to FSRU, the same and/or smaller sized shuttle tankers will be used. For Land LNG Terminal, freight of Q-Flex is used for this economics comparison. Following is a comparison of unit freight cost:

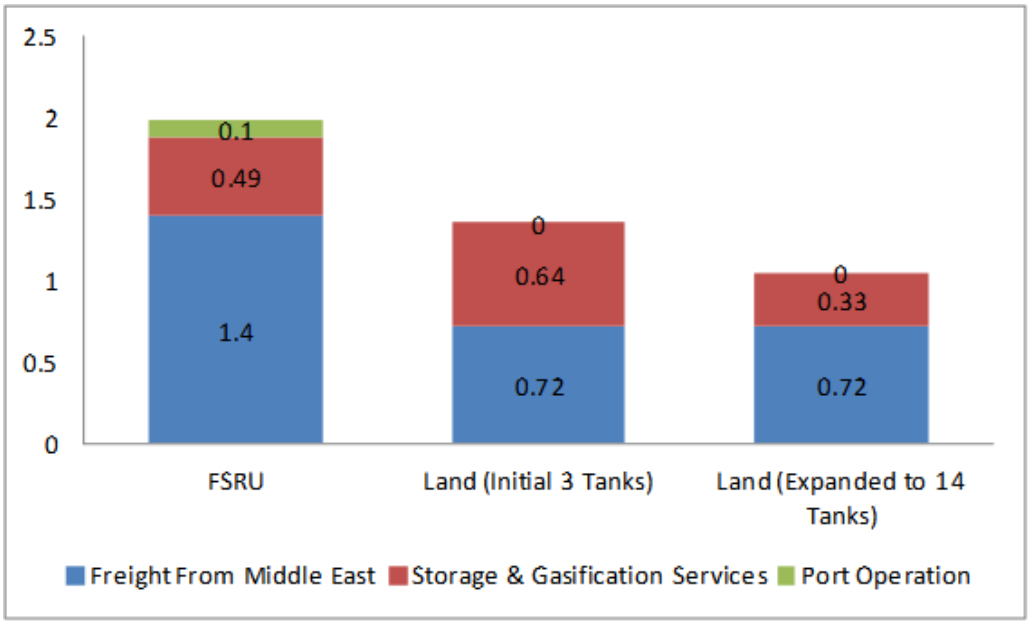


Source: Base data from Freight Study by KOGAS in 2011
Note that NM (Nautical Mile) is adjusted to the Port of Chittagong (from NM 6156 to NM 3833)

Figure 8-4 Transport Cost (USD/MMTBU) by Tanker Size

8.5.5 Operation cost comparison

Assuming that LNG is shipped out from port of Middle East at the same FOB price, cost structure of the gas at the terminal outlet in Moheshkhali is as follows:



Source: JICA Survey Team

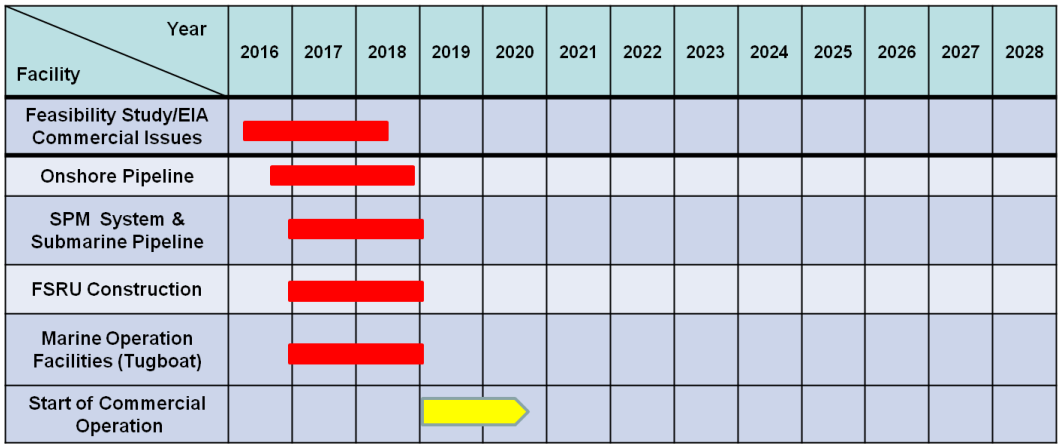
Figure 8-5 Operation Cost Comparison (USD/MMBTU) between FSRU and Land LNG Terminal

In view of the comparison of overall cost from the port of origin to gas delivery point, Land LNG terminal has a potential to minimize the cost associated with LNG introduction.

FSRU uses small shuttle tanker to deliver LNG and therefore cost of the transportation is higher. Operation Charge (Storage/re-gasification and port operation) of Land LNG terminal is higher at the initial stage of the operation due to a heavier investment cost for land acquisition and associated infrastructure construction. However, Operation Charge will be lower with the increase of handling volume. Note that Port Operation Charge is included in the Land LNG terminal operation, but not in FRSU case.

8.5.6 Construction time schedule

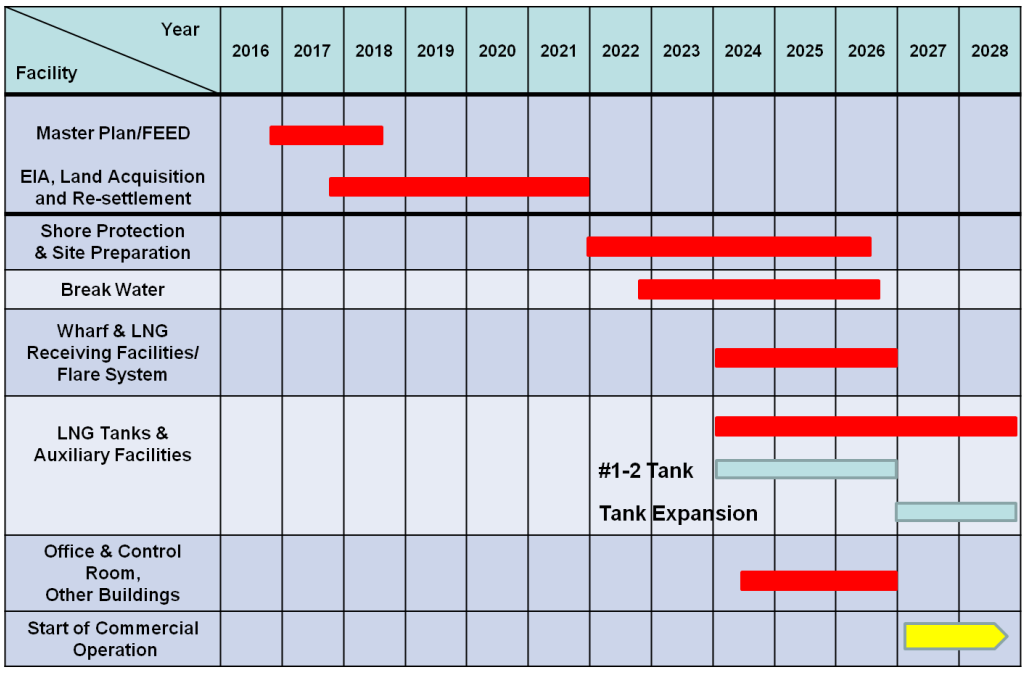
Majority of construction work of FSRU is carried out at a shipyard and amount of on-site construction work is very small. Project schedule from EIA (Environmental Impact Assessment) to the commencement of operation is short and takes less than 3 years.



Source: JICA Survey Team

Figure 8-6 Time Schedule for FSRU Construction

Project schedule for land LNG terminal is longer than that of FSRU. Significant time and effort to be injected to EIA including agreement with the local people and re-settlement plan associated with land acquisition. Large scale land preparation work and infrastructure construction such as breakwater if necessary, will be carried out. Construction of tank foundation to avoid uneven settlement is also time consuming work. Overall project schedule from EIA to commencement of operation will be 8-10 years.

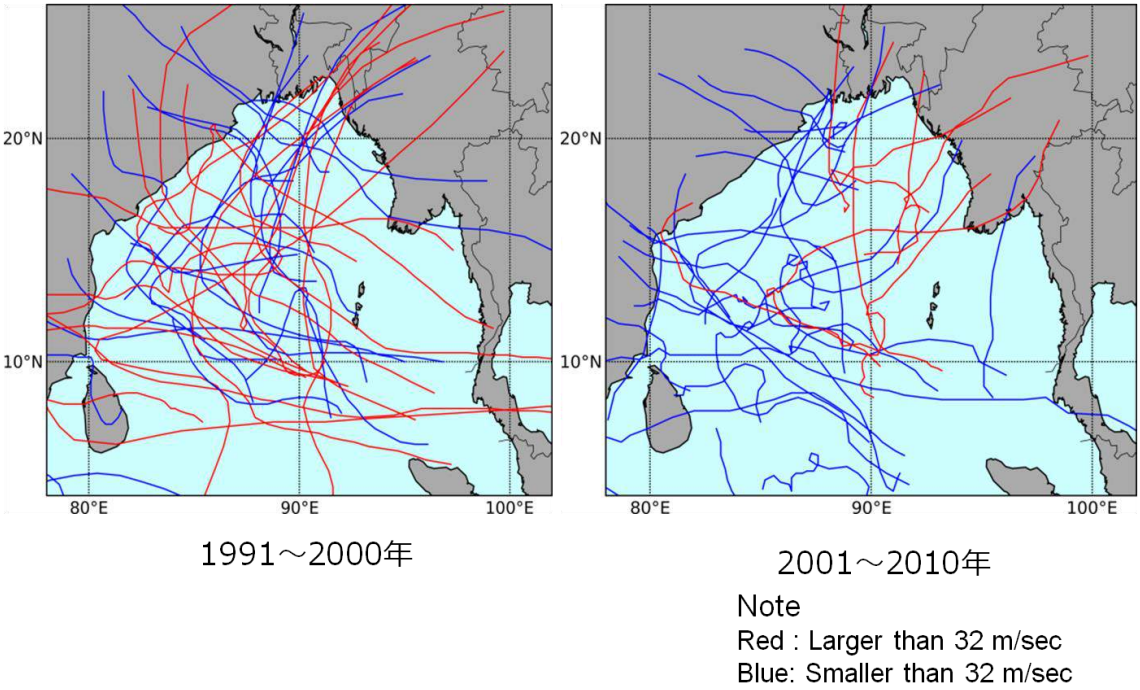


Source: JICA Survey Team

Figure 8-7 Time Schedule for Land-based LNG Terminal Construction

8.5.7 Cyclone risks for FSRU

Operation of FSRU is vulnerable to weather condition. Bay of Bengal is known as Cyclone. Frequency of Cyclone landing at Moheshkhali area is not many in comparison with other areas, but influences every year. Scale of Cyclone is reported to be increasingly larger than before. Operational risk of FSRU should be investigated.



Source: Nippon Koei Research Institute

Figure 8-8 Cyclone Outbreak in Bay of Bengal

8.5.8 LNG Master Plan

Prior to introducing LNG, several issues such as construction of LNG infrastructures, operation of gas distribution systems, impact to existing infrastructures and strategy for LNG procurement should be investigated further and need to be strategically prepared as a Master Plan.

Nature of gas is changing from domestic to LNG. It is understood that the change of process parameter requires thorough investigation based on the procedures so called “Management of Change”, i.e., how the change of gas composition, the dryer circumstance, the change of pressure balance impact to the existing facilities to be investigated.

Through the Master Plan, capacity building and human resource development also should be considered.

8.6 LNG Trade Contract

8.6.1 Background of LNG pricing

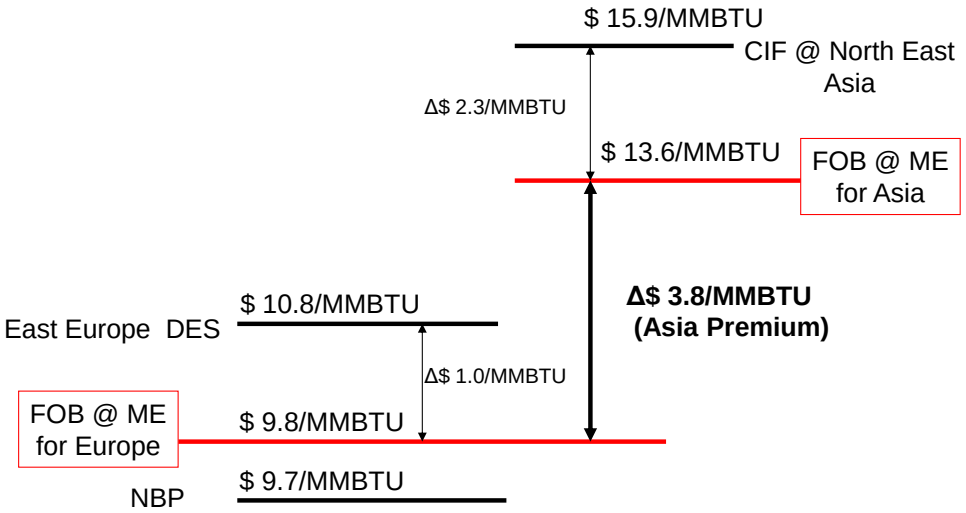
In the 1960s, natural gas in general has been used locally in the city gas distribution outreach area. Gas demand has increased due primarily to an advancement of gas turbine technology for power generation and also increasing demand for chemical uses. To meet the increasing demand, LNG and long distance pipeline was developed to deliver the gas from remote areas.

In Asia, the first LNG was delivered in Japan in 1969 from LNG project in Alaska. Since then, demand for LNG has increased significantly. New LNG projects in Malaysia, Burney and Indonesia, etc. has also been developed and supply gas energy to Japan.

LNG purchase and sale Contract between LNG supplier and buyer has been made based on bilateral Take or Pay Contract. It was designed to share the project risk between the parties, i.e., Price risk borne by Supplier and Quantity risk borne by Buyer. The price was pegged at Low Sulfur Crude Oil, a major clean fuel for power generation in 70's.

Liberalization of Electric Power and Gas Sectors took place in USA and UK/Europe in the 90's. LNG supply contracts have also been affected by this move. In addition to a long term Take or Pay Contract, Spot Market was also created. Suppliers are required to supply LNG to a competitive market directly.

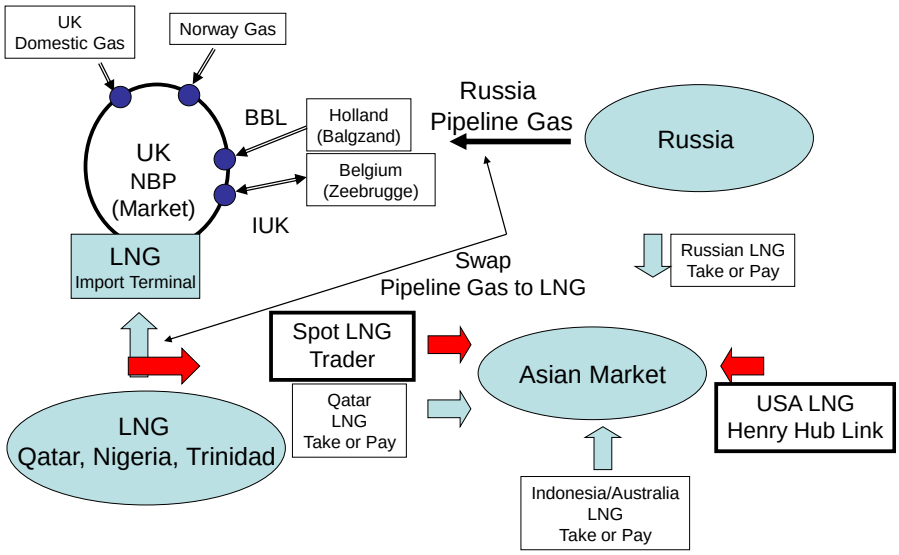
In Asia, long term Take or Pay Contract has long been used predominantly. This has created "Asia Premium", price differential between liberated market in UK and non-liberated region of Asia. Asian end-users have suffered from higher LNG price than market value.



Source: Argus LNG Daily

Figure 8-9 Asia Premium April 2012-Mar 2013

Asia has been lagged behind from US and Europe, however, Asian utility companies has also started to be aware of the risk of long term contract. New LNG traders, such as Gazprom Exports and Vitol, have started to supply destination free cargos on a spot basis, through swapping operation or purchasing from spot market. LNG market in Asia is showing more fluidity and market linked LNG cargos are also available in Asia.



Source: Argus LNG Daily

Figure 8-10 Fluidization of LNG Market

8.6.2 LNG market

Competitive gas market was created in UK. The market price is called National Balancing Point or NBP, and provides benchmark for gas pricing among pipeline gases and LNGs. The resulting gas price is totally independent from oil price, achieving "de-coupling" from crude oil.

In Asia, Singapore LNG is aiming to create LNG market through LNG trading using spare capacity of its own LNG storage tanks. At this stage, their affordable tank capacity is not necessarily large enough to create LNG Market and expansion of the capacity is awaited. PTT of Thailand owns and operates LNG terminal in Maphtapuht, Rayon, Thailand. PTT is buying part of LNG through auction to reduce market risk in long term contract. PTT is planning to re-export LNG for other demanding market in Asia. These terminals in Singapore and Thailand are expected to supply LNG produced in Middle East at market price in Asia.

Significant deposits of shale gas and coal bed methane are discovered in US. Production of these gases has brought the price lower than ever before. Under the circumstances, several gas export projects have started in Gulf area, Oregon, and pacific coast of Canada. LNG pricing formula is different from the conventional crude oil linked pricing system, but based on Henry Hub market pricing. Gas Price Formula for LNG from US to Asia (CIF) is shown as follows:

Table 8-4 CIF at Asia for LNG from US

Cost B/D	USD/MMBTU
Market Price	Henry Hub Priced
Pipeline Tariff	0.6
Liquefaction	3.0
Freight/Insurance	3.0
CIF	Henry Hub Price +6.6

Source: KOGAS and others

CIF Asia will be Henry Hub price plus USD 6.6/MMBTU. Assuming that Henry hub Price is USD 4 /MMBTU, CIF Asia will be USD 10.6/MMBTU. Note that freight cost is based on Panama Size Vessel. There are still rooms to reduce the price if larger vessel is used from Gulf, via Cape to Bangladesh.

8.6.3 New LNG procurement strategy

Japan and Korea import 60 % of world LNG supply in total. Liberalization of the utility industries in these countries will impact context of LNG purchase and sale contract, because long term take or pay can be a risk under liberalized market. Accordingly, Spot or short term contract will play an important role in the contracting strategy and old take or pay contract needs to be more flexible accompanied by appropriate option contracts.

Key LNG Procurement Strategy for Terminal Operators in Asia will be as follows.

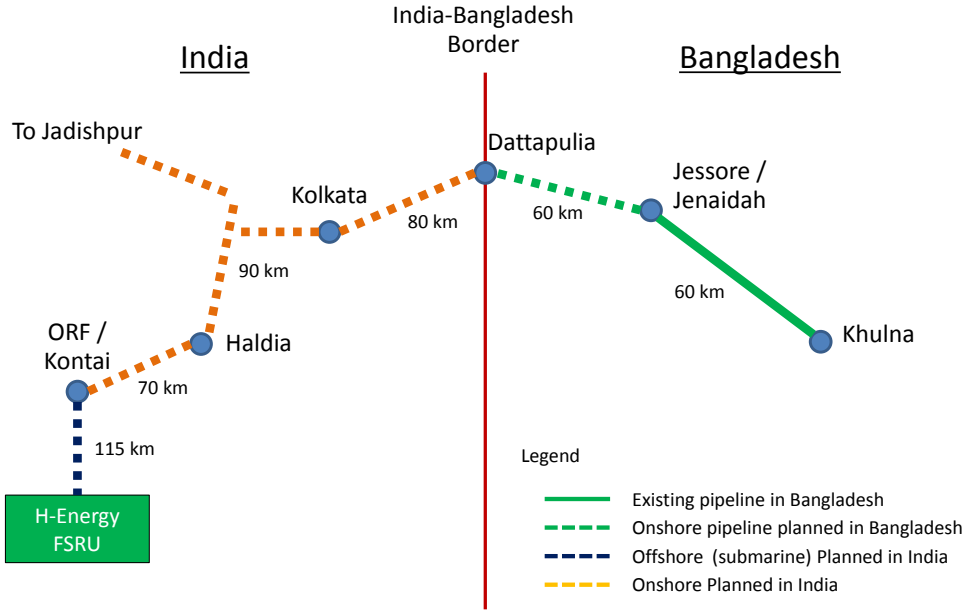
(1) Combination of Long Term Contract and Short (Spot) term Contract
(2) Short Term Contract:
  1) Introduce Auction System
  2) Use futures for risk management
(3) Long Term Contract
  1) Option Contract with quantity increase and decrease Claus
  2) Destination free

The above points should be incorporated into a future LNG MOU as well.

8.7 Cross-border LNG Trade

8.7.1 Project overall

The project is to import LNG 125 mmscfd (up to 250 mmscfd) and to develop cross-border gas transmission pipeline from a FSRU in the state of West Bengal, India to a to-be-built gas combined cycle power plant in Khulna (400MW *2). As the schematic below shows, total length of the on-shore pipeline from Kontai, India to Khulna, Bangladesh is approximately 360km and submarine pipeline portionis115km. RMS is to be built in Dattapulia, and the pipeline will be further extended and tied into existing system at Jessor, 60 km away from Dattapulia, Imported gas will be transported by using existing 60 km pipeline to Khulna.



Source: NWPGCL

Figure 8-11 Cross-border LNG Schematic Diagram

8.7.2 Executing agency

Indian private company H-Energy is expected to be responsible for all the facilities in India side (e.g. LNG procurement, pipeline development). In Bangladesh side, NWPGCL will be a project owner, while GTCL will be commissioned from NWPGCL, under the authority of Power Division.

8.7.3 Progress status

MOU and term sheet were concluded between H-Energy and NWPGCL. Gas Supply Agreement is not (?) yet concluded.

8.7.4 Schedule

Pipeline operation will start in 2018, and the Khulna 400MW＊2 will start operation in 2019.

8.7.5 Construction cost

Cost of 60 km pipeline between Dattapulia and Jessor is estimated approximately 60 million USD. ADB will provide financial support, including FS for the pipeline and the Khulna 400MW*2 power plant.

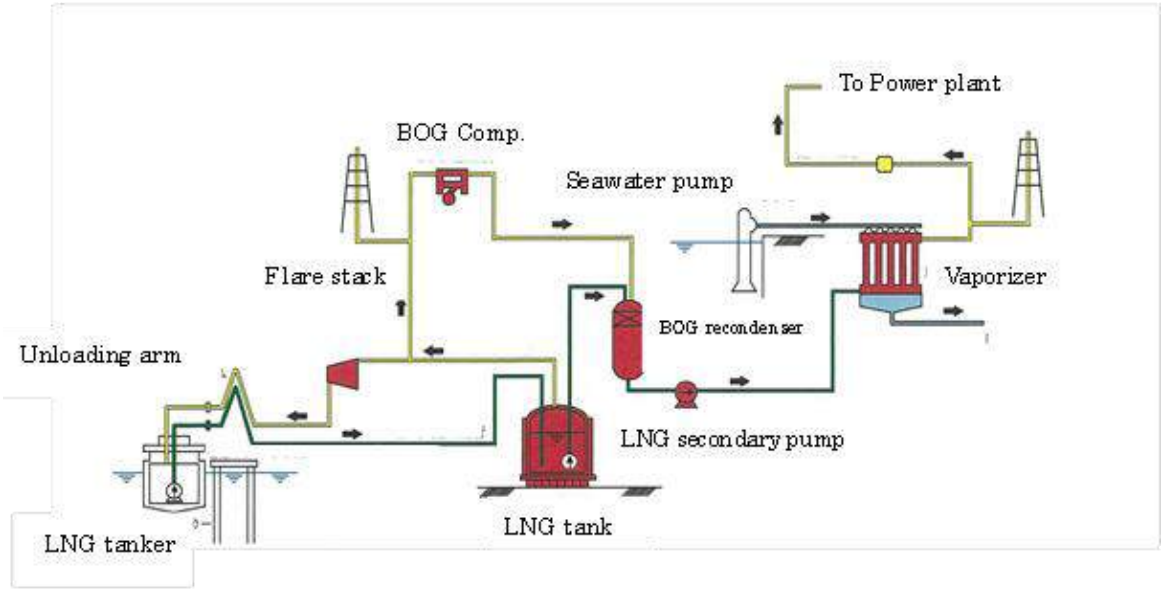
8.8 Land-based LNG Receiving Terminal Planning

8.8.1 General planning

At the first, gas send-out capacity and its related main equipment should be specified.
Key points to specify them are summarized.

(1) Annual LNG operation capacity (fixed by LNG tanker capacity and annual number of docking to LNG jetty)
(2) LNG Tank storage capacity (number of tank revolutions is considered.)
(3) Selection of vaporizer by sea water temperature and quality
(4) Gas send-out pressure (This will specify the LNG secondary pump.)
(5) Necessity of BOG re-liquefaction system
(6) Necessity of heat value adjustment by LPG or air
(7) Necessity of odorization system
(8) Spare unit arrangement of main equipment
(9) Future expansion plan (road map to expansion)

Typical schematic flow diagram of LNG receiving terminal will be shown in the below Figure.



Source: IHI Technical Report Vol.50, No.2 (2010)

Figure 8-12 Flow Diagram of LNG Receiving Terminal

8.8.2 Current planning status

At the second, gas production capacity will be studied and then main equipment specification will be clarified. Now the capacity of LNG receiving terminal is assumed as same as that of FSRU (500mmcfd, 3mm LNG ton per annum) because the same gas amount can be delivered to the customer even if FSRU is removed by the contract. Main equipment specifications and plot plan will be shown in the Tables and Figure below respectively.

Table 8-5 Design Criteria for Terminal Layout and Main Facility

Layout plan	Necessary land space for the final stage (1,500MMCFD) should be secured. Main facility will be expanded in accordance with the demand growth after the first stage completion (500MMCFD).
LNG storage tank specification and code & standard for tank	Bangladesh is an earthquake country, so full containment double dome roof type tank will be recommendable. Code & standard for tank design should be API for inner tank and EN for outer tank, which is applied world widely. Maximum storage capacity per unit can be 180,000 m3. The distance between tanks should be 0.5 times of tank diameter.
Number of LNG storage tank	20 times of 180,000m3 tank capacity will be needed annually. By this, necessary number of LNG storage tank can be set up.
NG send out condition from the terminal and tie-in condition with pipeline	NG send out pressure will be 1,100 psig (76barg). Tie-in point is on the way of new pipeline from Moheshkhali to Anawara.
Assumption of availability of the harbor	It is assumed as 95%. The planned availability of FSRU is 96.2% by Excelerate Energy.
Number of Jetty for terminal expansion	If standard sized LNG vessel (140,000m3) will be mooring 86 times a year, annual LNG receiving amount will come to 5.5 MTPA. Thus one jetty at the first stage and two jetties at the final stage will be needed.
Vaporizer specification	Peak hourly send out ratio during a day can be assumed as 9.5%. By this, capacity of vaporizer can be set up. ORV type vaporizer can be selected.
Other facility	1. BOG treatment facility will be designed. 2. Odorant injection facility will be designed for safety. 3. Metering facility will be designed. 4. Heating value adjustment will be not designed due to the almost equality of LNG and domestic NG. 5. Dual electric power system will be designed in substation. 6. Automatic control system in CCR will be designed. 7. As a preventive disaster system, firefighting and monitoring system will be designed. 8. Cooling water, IA, Nitrogen, and portable water supply system will be designed.
Layout plan	Necessary land space for the final stage (1,500MMCFD) should be secured. Main facility will be expanded in accordance with the demand growth after the first stage completion (500MMCFD).
LNG storage tank specification and code & standard for tank	Bangladesh is an earthquake country, so full containment double dome roof type tank will be recommendable. Code & standard for tank design should be API for inner tank and EN for outer tank, which is applied world widely. Maximum storage capacity per unit can be 180,000 m3. The distance between tanks should be 0.7 times of tank diameter.
Number of LNG storage tank	20 times of 180,000m3 tank capacity will be needed annually. By this, necessary number of LNG storage tank can be set up.
NG send out condition from the terminal and tie-in condition with pipeline	NG send out pressure will be 1,100 psig (76barg). Tie-in point is on the way of new pipeline from Moheshkhali to Anawara.

Assumption of availability of the harbor	It is assumed as 95%. The planned availability of FSRU is 96.2% by Excelerate Energy.
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Source: JICA Survey Team

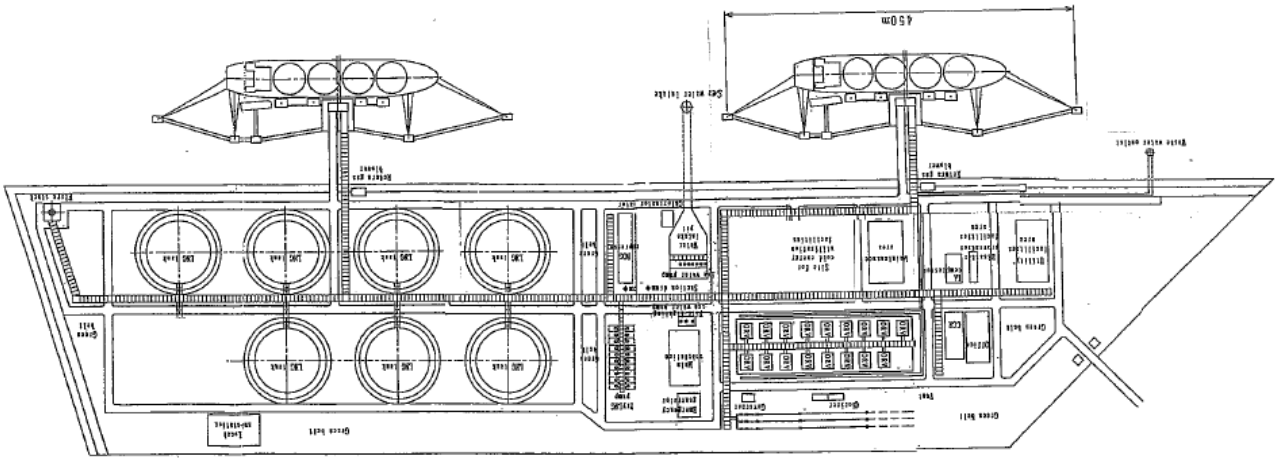
Table 8-6 Main Facility Specifications

	First stage (500MMCFD,3.5MTPA)	Final stage (1,500MMCFD, 10.4MTPA)
LNG storage tank	180,000 m3 X 3 units	180,000 m3 X 7 units
LNG pump	Primary pump; 300 t/h X 6 units + 3 spare units: total 9 units Secondary pump; 150 t/h X 6 units + 2 spare units: total 8 units	Primary pump; 300 t/h X 14 units + 7 spare units: total 21 units Secondary pump; 150 t/h X 18 units + 2 spare units: total 20 units
Jetty	1 jetty	2 jetties
Vaporizer	180 t/h X 5 units + 2 spare units: total 7 units ORV type is recommendable.	180 t/h X 15 units + 2 spare units: total 17 units ORV type is recommendable.
BOG treatment system	BOG compressor: 15 t/h X 4 units + 1 spare units: total 5 units BOG recondensor: 30 t/h X 2 units + 1 spare units: total 3 units Flare stack: 50 t/h X 1 unit (in long term blackout, BOG will be burnt to open air at flare stack.)	No expansion plan
Sea water intake pump	13,000 t/h X 3 units + 2 spare units: total 5 units	13,000 t/h X 9 units + 2 spare units: total 11 units

Source: JICA Survey Team

The logical and economical layout and area study of LNG receiving terminal is a very crucial matter at the basic and detail design stage.It should be done in accordance with the fixed systematic flow diagram. In this sense, the indicative layout plan as shown below is generated on the basis of send-out gas volume and it clarifies the design methodology of unloading facility, storage tank facility, vaporizer facility, and utility facility,etc.

Another attention has to be paid for the economic and functional main piping and cable route design which will connect each facility zone. Moreover future equipment space and piping layout should be studied fully for the future expansion in the terminal.



Source: JICA Survey Team

Figure 8-13 Typical Plot Plan of LNG Receiving Terminal (50ha, 10MTPA)

8.8.3 Impact of the LNG vaporized gas to the existing gas distribution network

Natural Gas produced at the terminal will be transferred to new pipeline (30 inch, 91km, from Moheshkhali to Anawara CGS) through metering station nearby and then delivered to Chittagong division.
In Chittagong division, LNG vaporized gas and domestic gas will be mixed each other but it will not cause a big damage for the end user by the following study.
First, when each heating value is focused on, LNG heating value (HHV) in RasGas, Qatar is around 1,055 BTU/ cft (source: JICA survey) and domestic gas heating value (HHV) is in average 1,042 BTU/cft (source: Petrobangla), which is almost equal. However, if LNG is imported from other countries on a spot basis, the special attention will be needed.
Second, LNG vaporized gas will be sent-out to the transmission line and then 290 MMCFD of it will be consumed in the power plant and fertilizer plant near to Chittagong division and remaining 210 MMCFD will be spread nation widely. However this 210 MMCFD is relatively small when compared to the total gas send-out amount of 2,740 MMCFD supplied from all domestic gas fields.

Table 8-7 Sector Wise Gas Demand and Supply

Unit: MMCFD

Sectors	Customer Category	Demand	Supply
Bulk	Power	1454	1070
	Fertilizer	317	200
	Power	70	68
Non-Bulk	Industry	452	448
	Captive	489	467
	CNG	128	125
	Domestic	332	330
	Commercial and others	33	32
	Total	**3275**	**2740**

Source: Petrobangla

8.8.4 Specification of LNG tanker and harbor conditions

(1) Specification of LNG tanker

LNG taker will be designed larger in capacity year by year but、Q-max class tanker is huge and is limited by the project, so Q-flex class tanker will be applied in Bangladeshi terminal.

Table 8-8 LNG Tanker Size

LNG Tanker		Class (DWT[25])	Length L (m)	Breadth B (m)	Loaded Draft D (m)
LNG Tanker	Q-max	130,000	350	55	13.7
	Q-Flex	110,000	315	50	12.5
	Conventional	80,000	300	50	12.0
Reference: Collier		80,000	220	36	13.0

Source: JICA Survey Team

(2) Performance requirements for waterways and basins

Performance requirements for waterways and basins are defined as follows in Technical Standard and Commentaries for Port and Harbor Facilities in Japan. (http://www.ocdi.or.jp/technical-st.html)

1) Performance criteria of waterways

- Breath of channel : In the channel where ships may meet each other, not less than the breadth over the ship's total length will be needed.
- Water depth of the channel : 1.1 times as much as ship's loaded draft will be needed.
- When the channel has an elbow-shaped bend, the angle of intersection of the centerline at the bend of the channel is around less than 30 degree and the radius of curvature is more than about 4 times as long as the length between perpendiculars of the ships.

2) Performance criteria of basins

- Width of basins : in case of turning around by tugboat, a circle space should have a diameter twice longer than the ship length

[25] DWT: Dead Weight Ton

- Water depth of basins：enough water depth more than the loaded draft of the ship (maximum loaded draft plus affordable water depth) should be secured under the standard space by the port authority
- Calmness of basins：calmness which can make more than 97.5% unloading possible through the year should be secured.

Table 8-9 Reference Values of Threshold Wave Height for Cargo Handling Works Not Affected by Swell, or Long Period Waves

Ship type	Threshold Wave height for cargo handling works ($H_{1/3}$)
Small craft	0.3m
Medium/large ship	0.5m
Very large ship	0.7-1.5m

Source: JICA Survey Team

(3) Harbor condition

Specification of LNG Harbor (Waterways & Turning Basin)
Based on Technical Standard and Commentaries for Port and Harbor Facilities in Japan, LNG Harbor will be specified.

Table 8-10 Specification of LNG Harbor for Receiving Q-Flex Class LNG Tanker

Vessel		Class (DWT)	Waterways(Channel)			Turning Basin	
			Width 1L (m)	Length 5L(m)	Depth 1.1d(m)	Diameter 2L (m)	Depth 1.1d (m)
LNG Tanker	Q-Flex	110,000	315	-	14.0	630	14.0
Reference: Collier		80,000	250	1200	15.0	600	15.0

Source: JICA Survey Team

(4) Port entrance and leaving condition of LNG tanker, Unloading condition at LNG jetty

With reference to Technical Standard and Commentaries for Port and Harbor Facilities in Japan and Japanese port entrance and leaving condition of LNG tanker and unloading condition at LNG jetty, maximum wave height (H1/3) for pier docking and undocking in the terminal can be defined as 1.5 meter.
In case of LNG tanker, due to the small specific gravity of LNG, above water surface area is large, so ship operation and unloading work is likely to be influenced by the wind power. In the technical Standard and Commentaries for Port and Harbor Facilities in Japan", there is no limitation of pier docking and undocking under the windy condition but the maximum allowable wind speed is set up to 8 to 15m/sec in almost Japanese LNG receiving terminal. Thus it will be also set up to 15m/sec here in Bangladesh. Calmness should be more than 95 %

Table 8-11 Calmness Condition in the Channel and Basins

		Threshold Wave Height $H_{1/3}$ (m)	Threshold Wind Speed (m/sec)
LNG Tanker	Entrance of Channel	1.5	15
	Berth	1.5	15
Reference: Collier	Entrance of Channel	1.5	-
	Berth	1.0	-

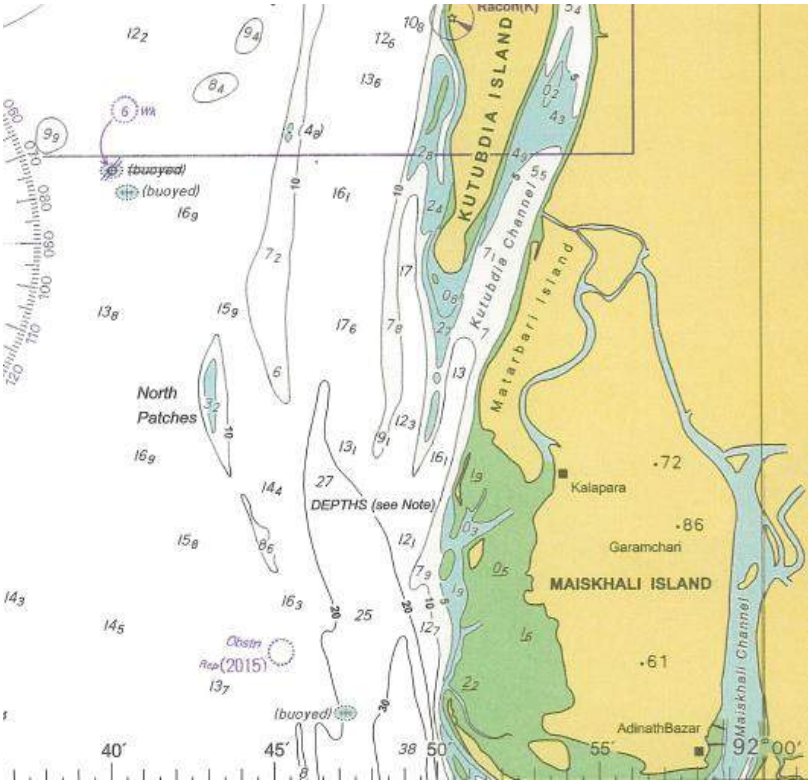
Source: JICA Survey Team

(5) Study of geographical and marine phenomenon condition near to the candidate site of LNG receiving terminal

1) Sea water depth

The chart of the candidate site of LNG receiving terminal will be shown in below Figure. The candidate site is located in the north of Bay of Bengal. Partially some reefs and shoals can be found but they are not barriers for the entrance of LNG tanker.

Marshy areas are spread along with the coast where the range of the tide will influence largely. The criteria of LNG receiving terminal construction are to avoid the marshy area, to set up LNG berth at offshore, and to dredge and cut the channel. When dredging and cut is applied for the channel, long term maintenance of dredge area should be studied.

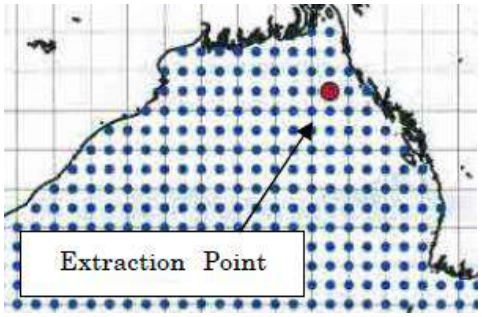


Source: JICA Survey Team

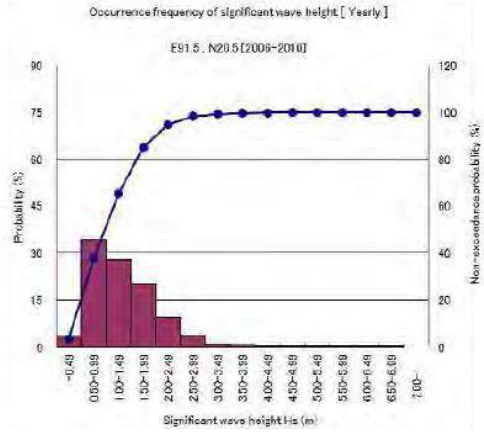
Figure 8-14 Chart of Candidate Site

2) Deep water waves data

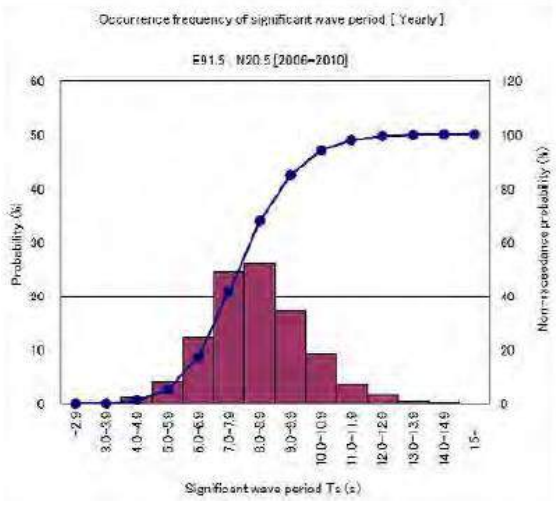
Deep water waves data at the planning site of coal fired power station in Chittagong is forecasted by the expected deep water waves data for the next 50 years based on the data at the extraction point in the north Bengal bay.
The expected frequency of deep water waves through the year from 2006 to 2010 will be shown. The expected frequency of over 1.5 meter wave height is around 65%、wave direction is most likely to be SSW.



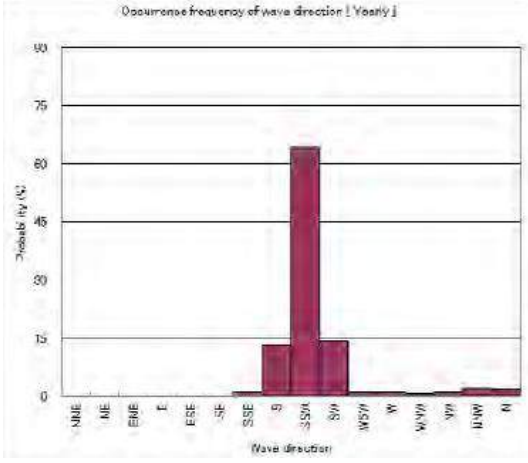
- Period : 2006.1.1～2010.12.31
- Extraction Point : Long. 91°30' E, Long. 20°30' N
- Time Interval : 1 hour
- Data Elements : Significant wave height、period and direction



Predominant Wave Height
- 0.50m～0.99m ;34%
- 1.00m～1.49m ;28%
- 1.50m～1.99m ;20%



Predominant Wave Period
- 8.0s~8.9s ;64%
- 7.0s~7.9s ;25%
- 9.0s~9.9s ;17%



Predominant Wave Direction
- SSW ;64%
- SW ;14%
- S ;13%

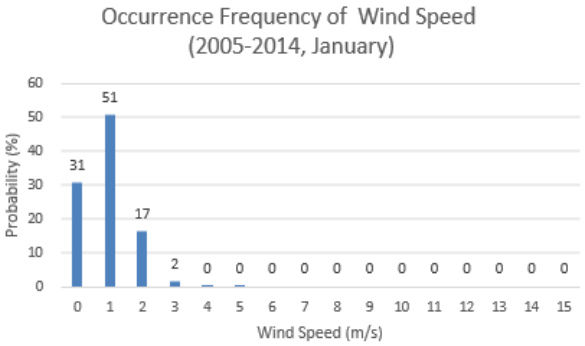
Source: "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)

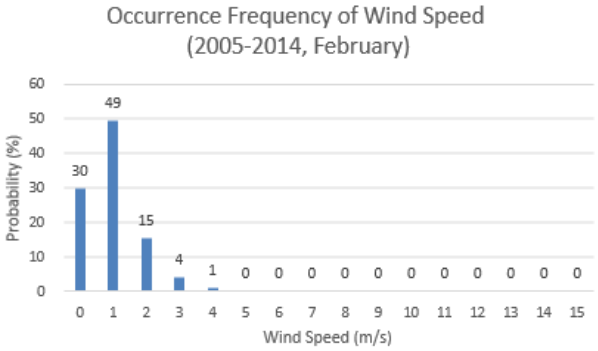
Figure 8-15 Deep Water Waves Data

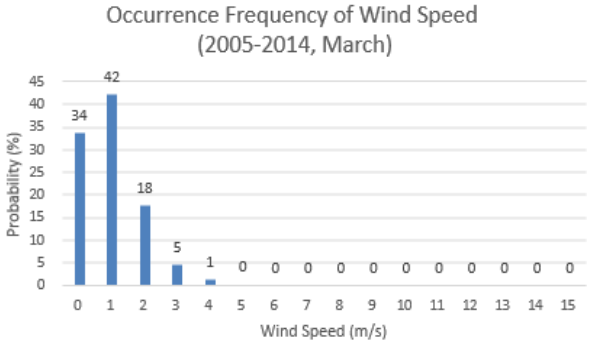
3) Wind data

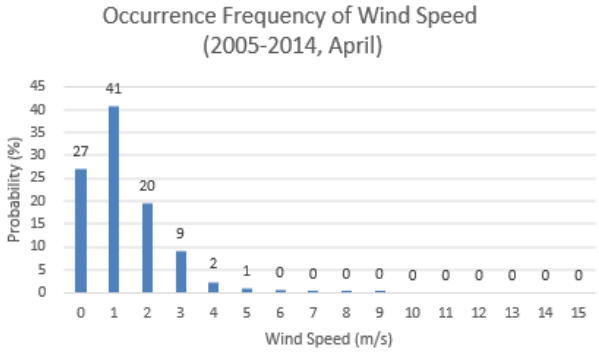
Based on "THREE HOURLY WIND SPEED AND DIRECTION" at Kutubdia which is close to the candidate site, the occurrence frequency of wind speed and direction is summarized.
Wind speed of more than 30knots was found only one time at 40knots at 15:00 PM on 17 Apr. 2009. The occurrence frequency of less than 30knots (15.4m/sec) was 99.99%. Therefore maximum allowable wind speed of 15m/sec or less for docking/ undocking and unloading work is found to be appropriate.
In terms of wind direction, North winds from November to February and South winds from April to October are most likely to occur. In winter season, "Calm" (wind speed
0.5m/sec or less) condition will be kept for a long time.

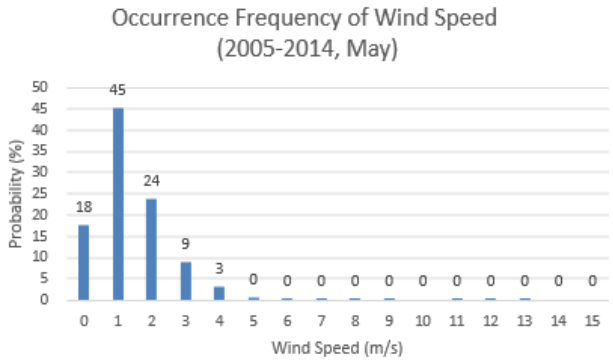
<u>Occurrence Frequency of Wind Speed</u>

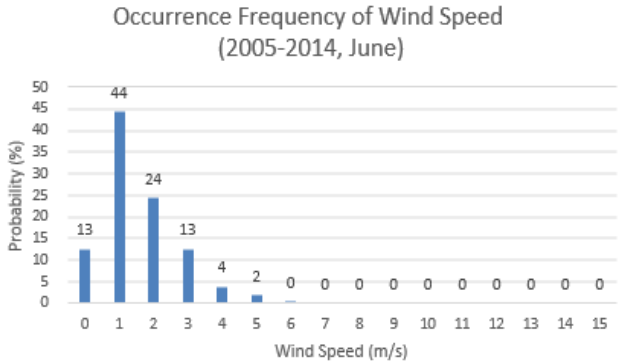


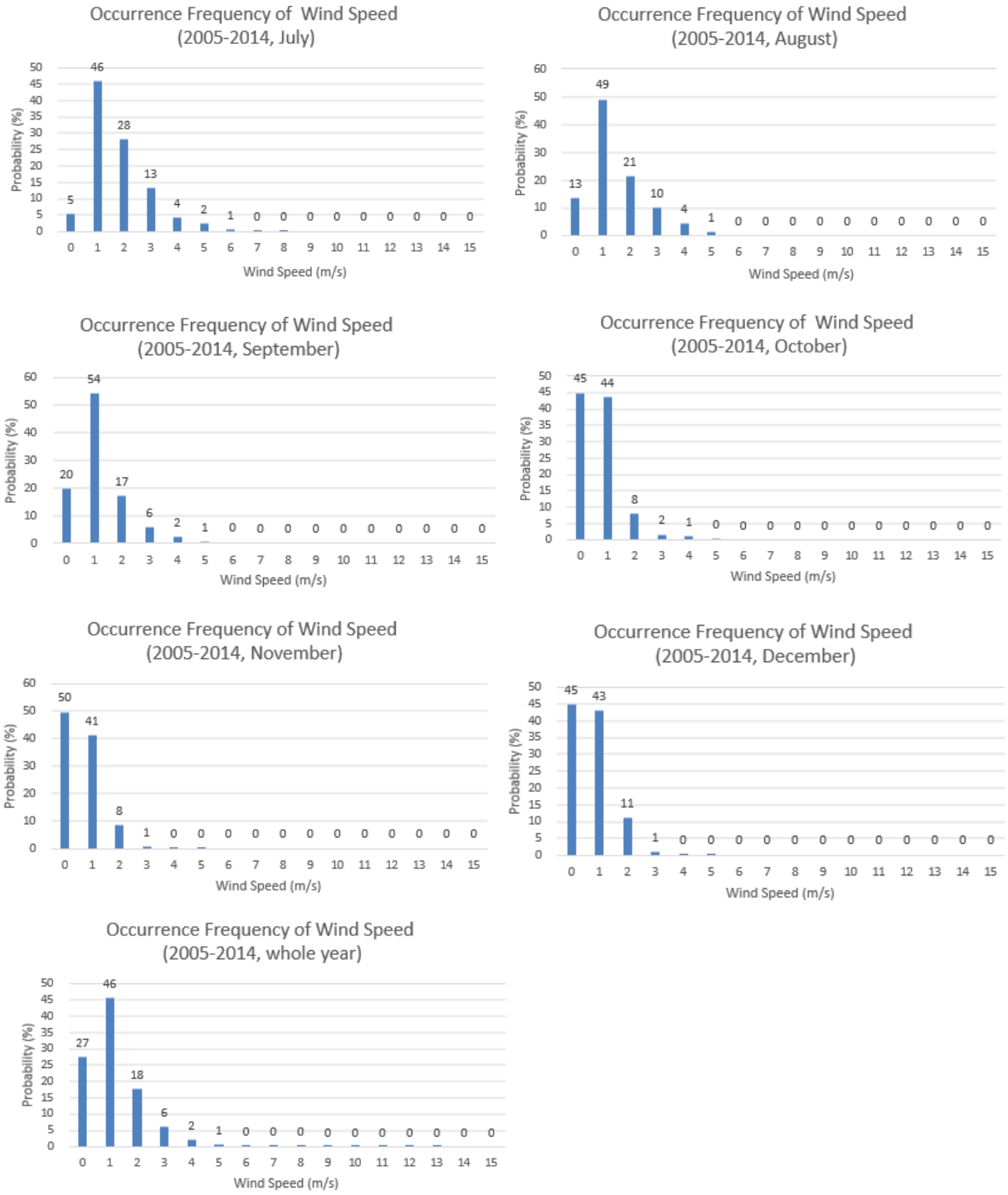








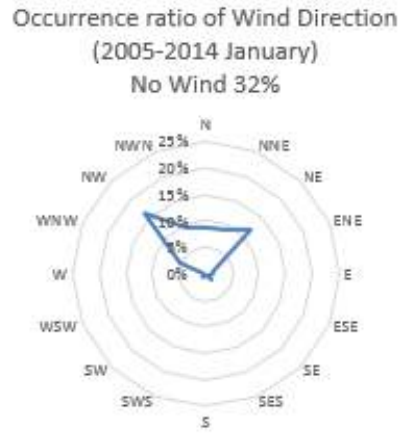


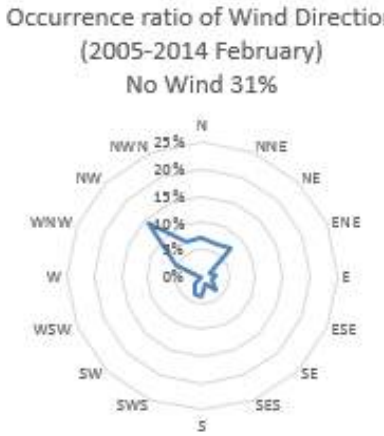


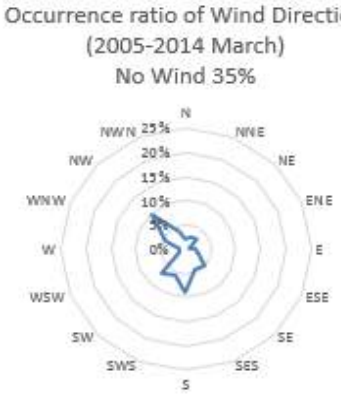
Source: JICA "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report" (March 2015, JICA/TEPSCO/TEPCO)

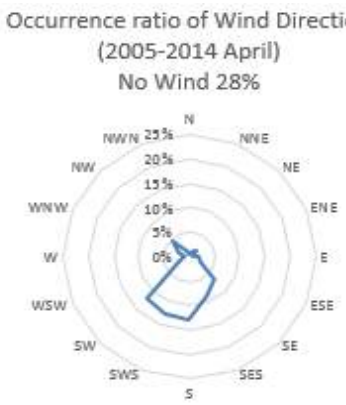
Figure 8-16 Occurrence of Wind Speed

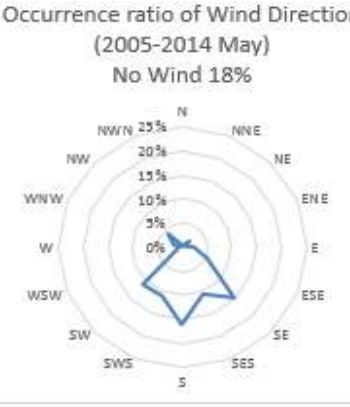
Occurrence Ratio of Wind Direction

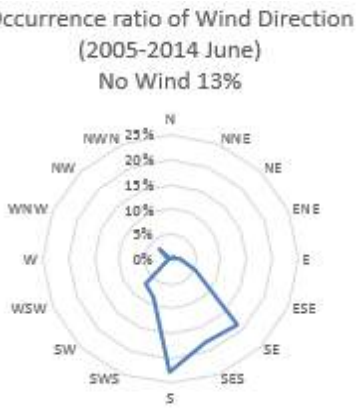


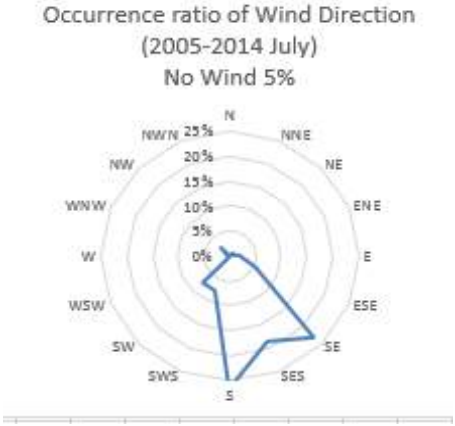


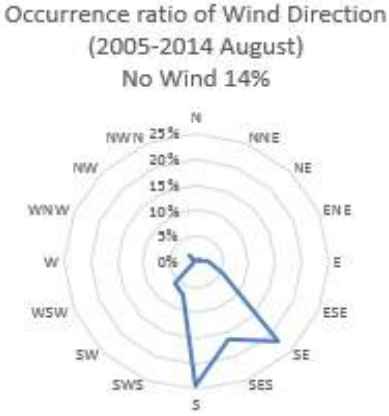














Source: JICA "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)

Figure 8-17 Occurrence of Wind Direction

〔Remark〕
In terms of wind conditions, 1 hour measurement data could not be obtained, so instead of it, "THREE HOURLY WIND SPEED AND DIRECTION" data at Kutubdia was utilized and the occurrence frequency was studied. 1 hour measurement data at near the site will be needed for the detail study.

(6) Site selection of LNG receiving terminal

1) Site selection

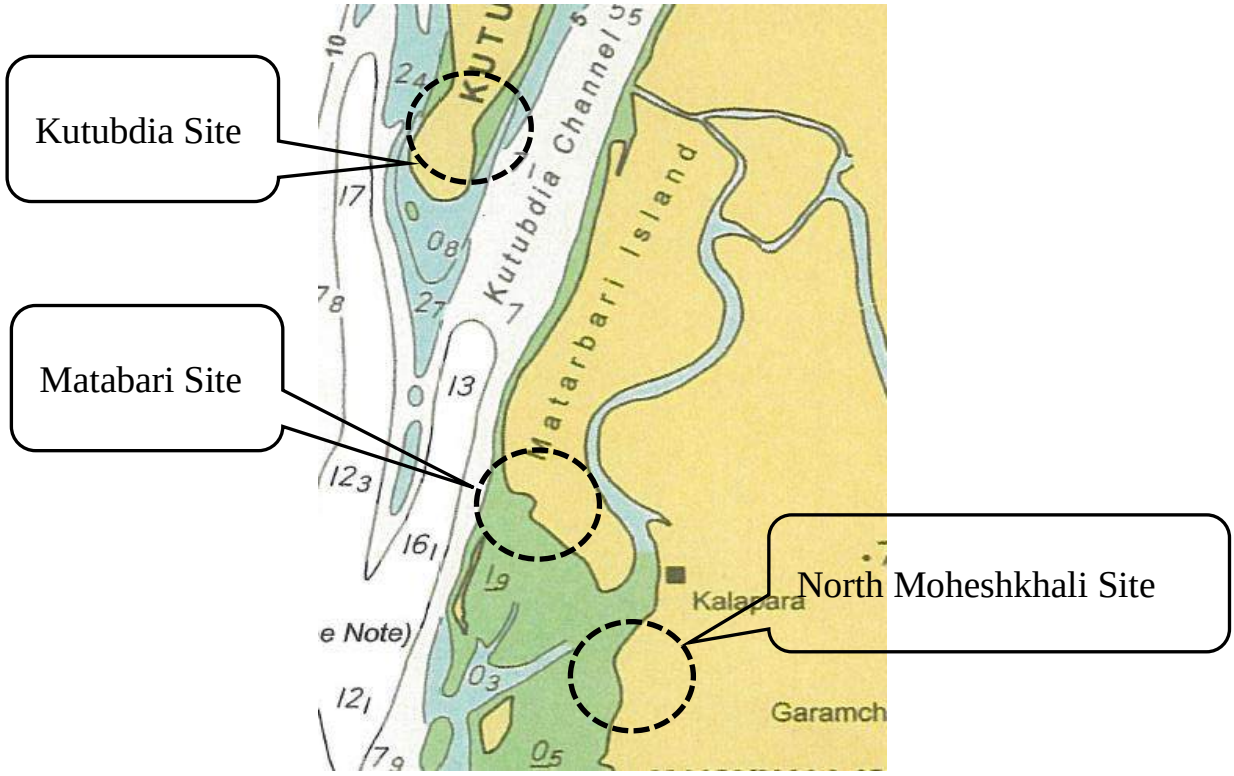
Three candidate sites of “Matarbari”, “North Moheshkhali”, and “Kutubdia” were selected in accordance with the above (1) to (5) criteria.

Furthermore the calmness was studied and compared in each candidate site. Above all, for Matarbari site, detail case study with three different ideas of LNG jetty design was done.

Table 8-12 Candidates of LNG Receiving Terminal LNG and Harbor/jetty Design Conditions

Case	Candidate site and condition		Remark
Case1-1	Matarbari Site	Jointly owned port	Jointly own port by coal power station and LNG receiving terminal
Case1-2		Individual port (without breakwater)	Construct LNG jetty in front of the ocean without breakwater
Case1-3		Individual port (with breakwater)	Construct LNG jetty and breakwater in front of the ocean
Case2	North Maheshkhali Site		Dredge shallow beach and construct channel and LNG jetty
Case3	Kutubdia Site		Dredge Kutubdia Channel and construct LNG jetty

Source: JICA PMSP2015 Survey Team



Source: JICA Survey Team

Figure 8-18 Candidate Sites of Land-based LNG Receiving Terminal

2) Evaluation by calmness (unloading availability)

Table 8-13 Case1-1 Jointly Owned Port Plan in Matarbari (Excavated Type Plan)

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	Entrance of channel	1.5m	94.7%＜95% By the Owner's judgement
	LNG berth	1.5m	more than 99.9% ＞ 95% Good
(Ref.)Coal port	Entrance of channel	1.5m	99.4% ＞ 96% Good
	Coal berth	1.0m	99.9% ＞ 96% Good

Source: JICA Survey Team

Note: In the feasibility study of collier, calmness was evaluated at the entrance of channel but for LNG tanker, calmness will be evaluated at the entrance of channel after turning around and root change.

Table 8-14 Case1-2 Matarbari Plan (Conventional Type Plan：Without Breakwater)

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	LNG berth	1.5m	94.7%＜95% By the Owner's Judgement
(Ref.)Coal port	Entrance of channel	1.5m	94.7% ＜ 96% Not Sufficient
	Coal berth	1.0m	93.5% ＜ 96% Not Sufficient

Source: JICA Survey Team

Table 8-15 Case1-3 Matarbari Port Plan (Conventional Type Plan：Breakwater Construction)

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	LNG Berth	1.5m	more than 96.5% ＞ 95% Good
(Ref.)Coal port	Entrance of channel	1.5m	99.2% ＞ 96% Good
	Coal berth	1.0m	96.5% ＞ 96% Good

Source: JICA Survey Team

Table 8-16 Case2 North Maheshkhali Plan

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	Entrance of channel	1.5m	96.8% ＞ 95% Good
	LNG berth	1.5m	more than 96.2% ＞ 95% Good
(Ref.)Coal port	Entrance of channel	1.5m	96.8% ＞ 96% Good
	Coal Berth	1.0m	96.2% ＞ 96% Good

Source: JICA Survey Team

Table 8-17 Case3 Kutubdia Channel Plan

	Area	Threshold Wave Height	Rate of Effective Working Days
LNGport	LNG Berth	1.5m	more than 94.7%＜95% By the Owner's judgement

Source: JICA Survey Team

Remarks:
a) In this study calmness analysis was not done at the candidate port. To select the candidate site, detail calmness analysis should be implemented and studied.
b) Max allowable wind speed and wave height for unloading and criteria for docking and undocking at LNG port should be fixed by the Owner in consideration to the feasibility and operation of LNG receiving terminal.
c) Evacuation method, port for evacuation, and basins in case of bad weather should be considered.

3) Evaluation result of candidate site

Table 8-18 Candidate Site Evaluation Result

Case	Case1-1	Case1-2	Case1-3	Case2	Case3
calmness	◎	○	◎	◎	○
Comparison of Cost	Cost effective	Cost effective *Filling Soil Balance	Fairly expensive (Breakwater construction)	Expensive (Continuous dredging)	Expensive (Continuous dredging)
Natural Environment	-	-	-	Mangrove forest	-

Source: JICA Survey Team

Remarks
a) For the evaluation of breakwater construction cost, continuous dredging cost, and environmental cost, reference is made to the" Study of Coal Fired Project in Chittagong"b) It is uncertain how difficult it is to secure embankment material for land creation of LNG receiving terminal yard but case1-1, case2, and case 3 will be an effective plan in order to secure a certain amount of soil volume by dredging and cut for port preparation.

8.8.5 Ground level

"The pre-FS of coal fired power station in Chittagong" shows the detail study of a flood tide caused by the ebb and flow and cyclone. With the same criteria, land creation can be planned in LNG receiving terminal.

Ground level of LNG receiving terminal facility yard can be fixed as +10.0m M.S.L with reference to the flood tide which may ocuure once in 50 years by cyclone. On the other hand, ground level of the port can be fixed as +5.0m M.S.L.

(1) Design tidal level

H.W.L. = +2.20m M.S.L M.S.L. = ±0.0m L.W.L. = -2.20m M.S.L.

(2) Storm surge height

Table 8-19 Storm Surge Height

Storm Surge Height	Average	25-year Return Period	50-year Return Period
Base on Maximum Data	4.2m	8.0m	9.0m
Base on Minimum Data	3.3m	6.2m	7.0m

Source: JICA Survey Team

(3) Design ground level

1) LNG Facilities Yard E.L. = +10.0m M.S.L.
2) Port Revetment E.L. = +5.0m M.S.L

8.8.6 Subsurface exploration

With "the pre-FS report of coal fired power station in Chittagong", the comprehensive subsurface exploration was implemented in 2012 and 2014. The result in 2014 will be shown in the following.

Subsurface at local site is composed by;

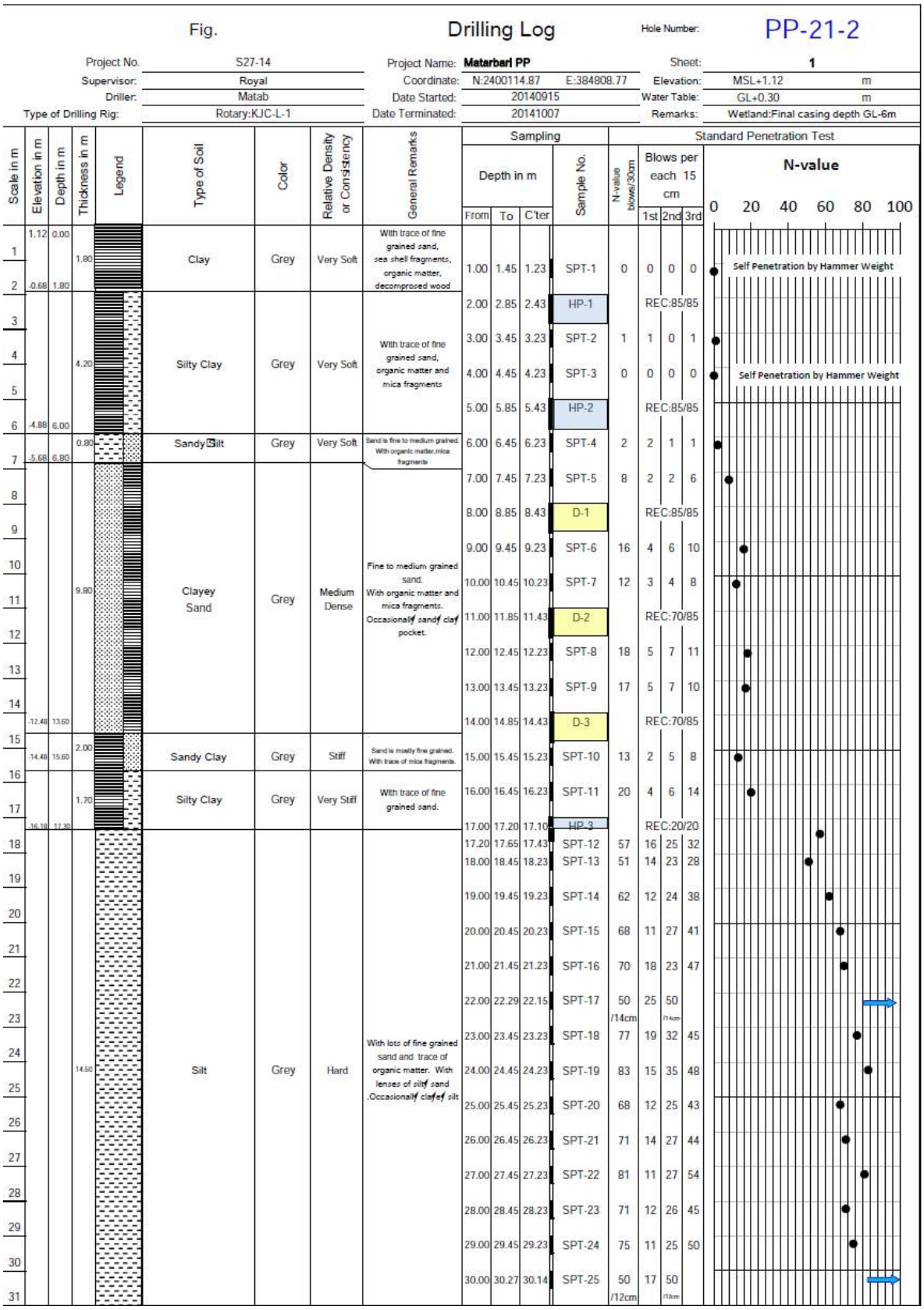
1. sand layer of 2 m thickness in the surface, then
2. alluvial sandy soil and alluvial clay of N value of 10 to 20 which thickness is 20 m, then
3. diluvial sandy and clay of N value of 30 to 40

Bearing pile for the main structure like LNG Storage Tank should be inserted to this diluvial sandy (DS).

Table 8-20 Subsurface Data (part.1)

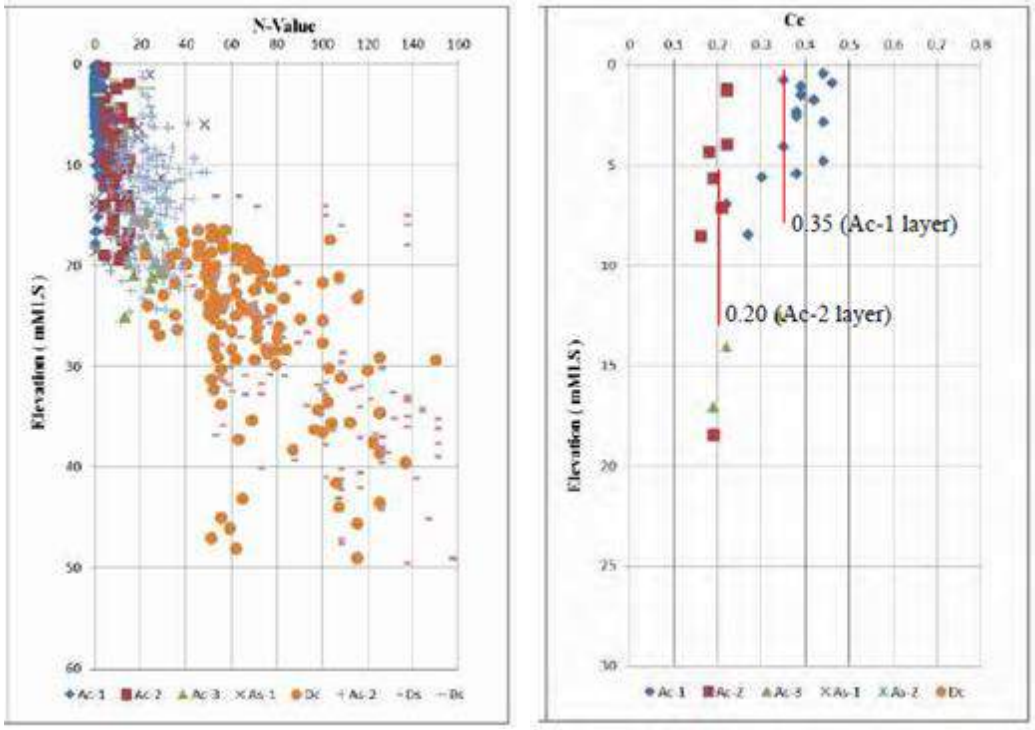
Layer	Material	Relative Density or Consistency	Thickness of Layer (m)	SPT(N) Values
Bs	Sandy Soil	Loose to Medium Dense	0.6 to 2.0	4 to 24
Ac-1	Clayey Soil	Very Soft to Soft	0.8 to 12.7	0 to 4
Ac-2	Clayey Soil	Medium Stiff to Stiff	0.9 to 8.7	4 to 15
Ac-3	Clayey Soil	Stiff to Hard	1.1 to 9.0	15-30
As-1	Sandy Soil	Very Loose to Loose	1.1 to 6.0	0 to 10
As-2	Sandy Soil	Medium dense to Dense	0.7 to 21.9	10 to 50
Dc	Clayey Soil	Hard	1.4 to 17.3	≧30
Ds	Sandy Soil	Very Dense	0.5 to 13.2	≧50

Source: "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)



Source: "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO), Appendix-C-17-01 Drilling Logs p.94

Figure 8-19 Drilling Log



Source: Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)

Figure 8-20 Subsurface Data (Part2, 3)

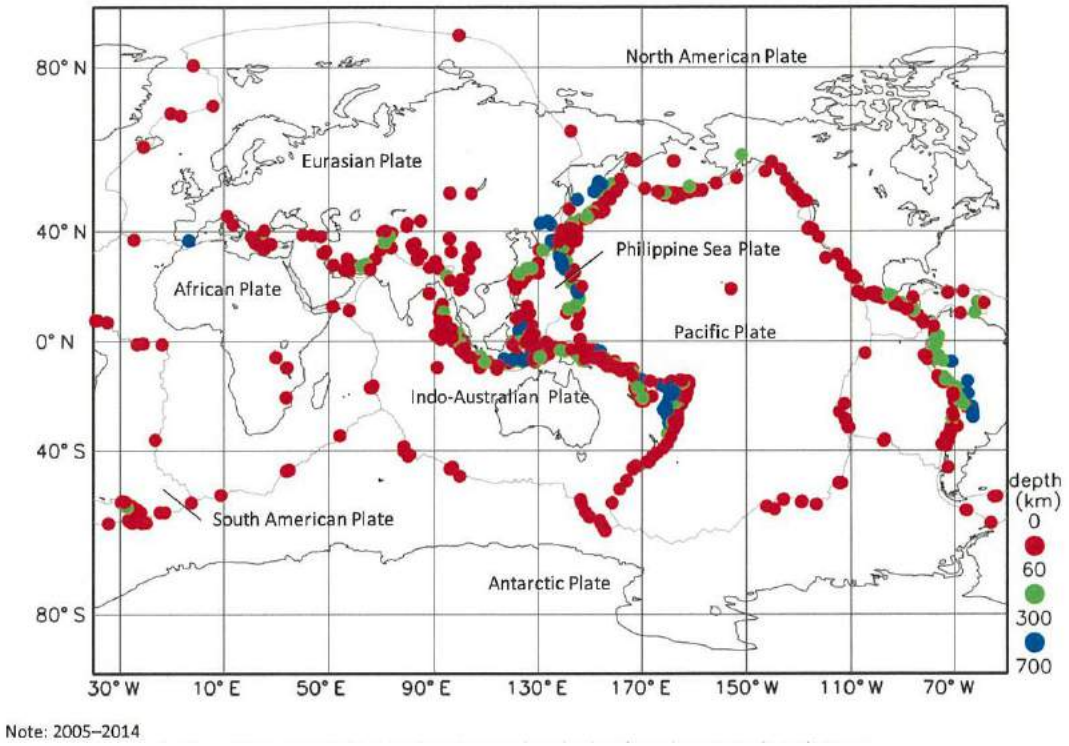
The surface layer, alluvial sandy and alluvial clay are relatively weak. And the foundation of LNG facility yard should be raised by 10 m as a countermeasure against the flood tide. Therefore the comprehensive soil stabilization will be needed.
If spoil or excavated soil is used as an embankment material, the reinforcing ground of banking may be needed by the property of earth and sand.

Alluvial clay: PVD (Prefabricated Vertical Drain Method), DMM (Deep Mixing Method) Alluvial sandy: SCP (Sand Compaction Pile Method) Embankment material: DMM, etc.

8.8.7 Earthquake

(1) Distribution of earthquake centre

Worldwide hypo central distribution and plate location will be shown in the below Figure.
The boundary between Indian plate and Eurasian plate is faced in Bengal Bay and here mega scaled earthquake has been frequently occurred in the past.



Source: White Paper on Disaster Management" (Cabinet Office, Government of Japan)

Figure 8-21 Worldwide Hypocenter Distribution (for Magnitude 6 and Higher Earthquakes) and Plate Boundaries

(2) Seismic design

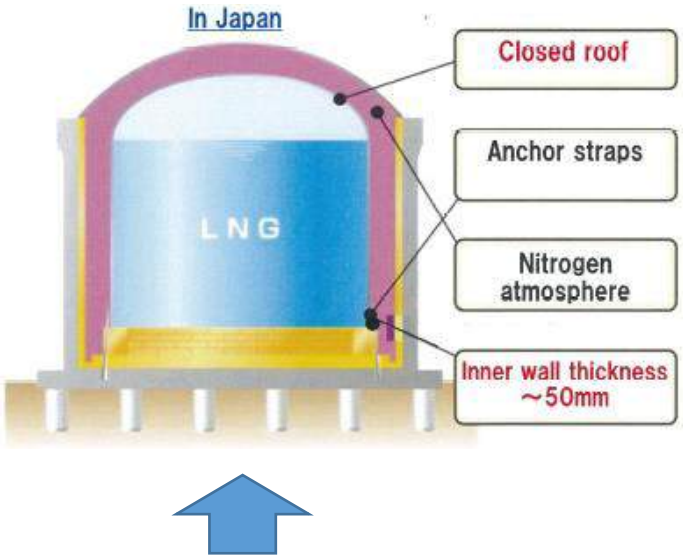
1) Seismic design standard

Bangladesh is a seismically active nation, so「BANGLADESH NATIONAL BUILDING CODE 2006」was established and applied as an earthquake resistant design code.
LNG tank and other facility in the terminal are supposed to be designed in accordance with this standard

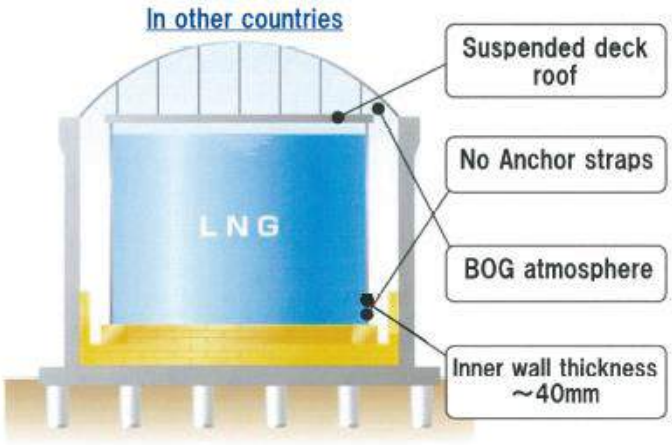
2) Earthquake- resistant LNG storage tank

Normally design seismic coefficient of LNG Storage Tank is designed as SSE 0.2g and OGE 0.1g in Japan and other countries.
In no seismically active nations like Thailand and Singapore, the suspended deck type LNG Storage Tank can be applied but in Bangladesh dome roof type (full containment type) LNG Storage Tank will be recommended, which has been already applied in Taiwan and Japan.

Dome roof type PC LNG Storage Tank



Suspended deck type PC LNG Storage Tank



Source: JICA Survey Team

Figure 8-22 Structure of Earthquake- resistant LNG Storage Tank



Source: Osaka Gas Senboku terminal

Figure 8-23 Overview of Above Ground Dome Roof Type PC LNG Storage Tank

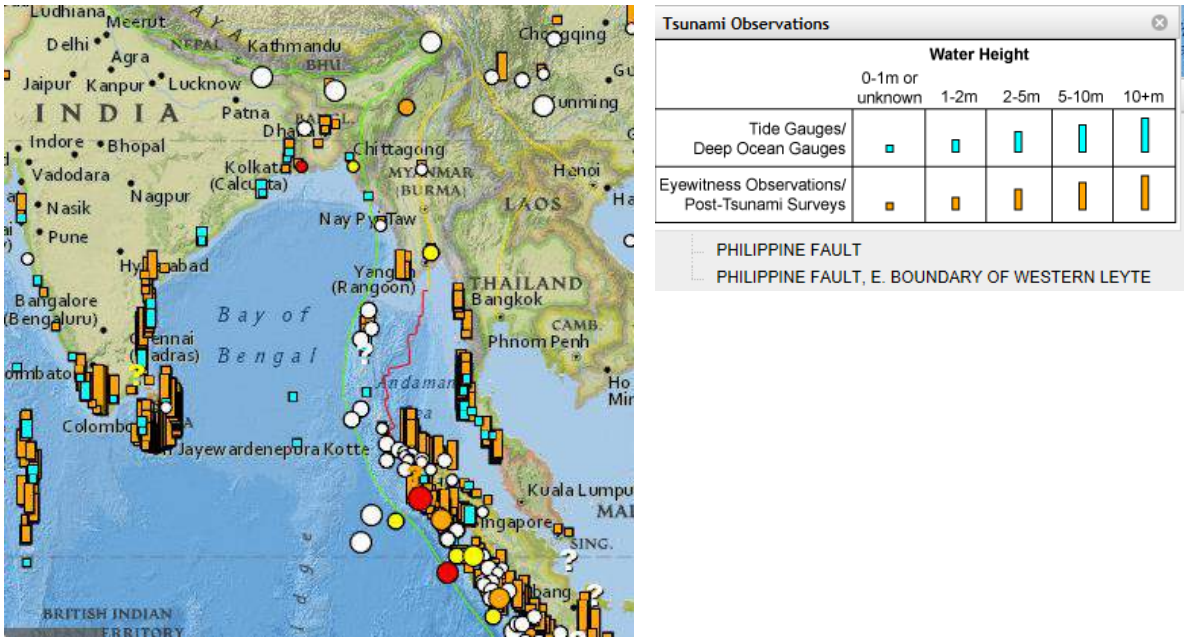
1) In Japan anti-earthquake design procedure for LNG storage tank has been established.
2) Japanese LNG storage tank manufacturer is familiar with major international design code and standard such as API and EN.
3) Bangladesh is identified as a seismically active nation, so the dome roof type LNG storage tank is better fitted in the seismic design than the suspended deck type LNG storage tank. Dome roof type LNG storage tank has many construction experiences among the seismically active nations such as Japan and Taiwan.
4) Dome roof type LNG storage tank is superior to suspended desk type LNG storage tank in anti-sloshing performance. In the dome roof type LNG storage tank, N2 gas is filled in the gap between inner and outer tank wall, so the dome roof type LNG storage tank is more safety because LNG leakage is more detective than the suspended deck type LNG storage tank.
5) The maximum allowable capacity of the dome roof type LNG storage tank based on API and EN code and standard is seemed to be 180, 000 m3 per unit in Bangladesh.
6) In Japan 180,000m^3 or 200,000m^3 or 23,000m^3 LNG storage tanks have been already constructed and steadily operated.

Remarks
The material described an active fault in Bangladesh has not been disclosed yet but an active fault may be present near to the candidate site of LNG receiving terminal.
LNG Storage Tank should be designed to be far from the active fault as much as possible because the damage will be so large in case of the large scale disaster.
When feasibility study or FEED of LNG receiving terminal will be implemented, a geological survey at site should be done and the obtained data should be reflected to site selection, plot plan, and earthquake-resistant design of main equipment in the terminal.

8.8.8 Countermeasures to Tsunami

Bangladesh is very close to the border area between the plates, so Tsunami attack by large scale earthquake should be seriously considered. Tsunami hazard map in the Indian Ocean and Bay of Bengal will be shown in the below Figure.

The candidate site of LNG receiving terminal is located in the north peak of Bay of Bengal where the expected Tsunami height is 1 to 3 meter. This Tsunami height is less than that made by a cyclone, so Tsunami height may not be considered in the design of LNG receiving terminal..



Source: NOAA: National Centers for Environmental Information Natural Hazards Viewer-Tsunami Observation

Figure 8-24 Tsunami Hazard Map in the Indian Ocean and Bay of Bengal

At the feasibility or FEED stage, the countermeasure should be studied again for the large scale earthquake occurred in the boundary area between the plates in Bay of Bengal.

8.8.9 CAPEX & OPEX of on shore LNG receiving terminal

With the average cost index in the existing on shore LNG receiving terminal, CAPEX at the 1st stage (500MMCFD of NG send-out capacity, 3.5MTPA of LNG loading capacity) and the final stage (1,500MMCFD of NG send out capacity, 10.4 MTPA of LNG loading capacity) will be shown respectively in Table 8-21. Each specification of the 1st stage and final stage can be referred in the below Table.

Table 8-21 CAPEX Estimation

(Unit: US MM$)

	1st stage (500MMCFD, 3.5 MTPA)	Final stage (1,500MMCFD, 10.4 MTPA)
Land acquisition	200	200
Jetty and loading facility	100	200
Regasification facility	130	320
LNG storage tank	300	700
Others	30	80
Total	760	1,500

Source: JICA Survey Team

On the other hand, OPEX will be assumed to be varied from US$0.3/MMCF at 1st stage to US$0.6/MMCF at final stage when applied Japanese and Korean terminal operation record.

8.9 Challenges and Issues of LNG Terminal Implementation

8.9.1 Preparation for Finance

For the construction and operation of the LNG Terminal, financial preparation is significantly important to cover the capital/operational expense to be borne by the public.
In this regard, the Energy Security Fund was created last year to ensure availability of future expensive energy for funding the import of LNG, the building of LNG terminal, import of liquefied petroleum gas (LPG), construction of LPG terminal and other projects related to energy security. According to the article by Financial Express dated 22 August, 2016, “Energy set to be dearer with expensive LNG, LPG imports”, the fund was created in accordance with the BERC order over the hike of natural gas tariffs in September last year, when it increased the average prices of natural gas by 26.29 per cent. Since the distribution companies were profiting from the sale of natural gas before the price hike, the commission created the fund with the asset value of natural gas, as fixed at Tk 25 per cubic metre by the government. Some Tk 28 billion will be accumulated into this fund every year, the BERC official estimates.
As of August 2016, BERC is under finalization of guidelines for using the Energy Security Fund.
This kind of fund preparation can be further strengthen for securing the budget for LNG terminal,though well consideration of effect on economy by gas price hike should be taken in parallel.

8.9.2 Establishment of LNG value chain

(1) To ensure a stable LNG supply and reduce LNG stock period in tank by the diversification of LNG supply source and securement of LNG transportation route, the Buyer, in the LNG sale and purchase agreement, should negotiate to mitigate “Take or Pay condition” the change of destination and to induce the lower price by the cooperation with other Buyer. LNG transportation contract should be also competitive.
(2) The reliable LNG unloading, storage, vaporization, and send-out should be operated in a safe, stable, and low cost manner.
(3) LNG supply method should be diversified such as send-out gas, LNG re-loading, LNG bunkering as ship fuel, LNG truck loading to the satellite station. At the same time, the stable LNG demand should be found in power plant, industrial/commercial/residential sector, and the third party operating the terminal.

8.9.3 Operation of LNG receiving terminal

LNG receiving terminal will apparently play an important role as one of energy infrastructure year by year. The terminal should be operated smoothly at start up period and then should be operated steadily to pursue the high availability and reliability.
To achieve it, various attention is needed from the point of operating organization, facility planning, maintenance, training, anti-disaster facility, and environmental protection, etc.

(1) Operating organization

Operation of the terminal needs operating team, maintenance team and engineering team as a whole. Each team needs a skillful engineer in the gas processing field as a team leader. The beginner should study through the Vendor's seminar or others and should be given the opportunity to study in the similar LNG receiving terminal abroad, which will be very effective manner to enhance the understanding. When the commercial operation has started, operating team should take a leadership to address the operating issues.
Next, main responsibility of each team will be clarified.

- Operating team is normally organized by 4 teams and will do a time shift work in 24 hours through the year. It will also designate operating facility regarding to the requested send-out gas amount and also support LNG unloading operation in the terminal side when LNG vessel will reach to the terminal.
- Maintenance team works in a day time to grasp the operating condition of all facility though the daily check by database and establish the unique maintenance criteria designated for the terminal.
- Engineering team studies the reason of mal function in the commercial operation and will address the improvement of the facility when considering the optimum repairing plan and budget.

(2) Operation management

Operator will monitor and control all of the facility in the terminal from CCR. Especially the optimum LNG storage tank operation and special attention should be paid to the protection of tank stratification phenomenon. .
The amount of send-out gas and utility consumption should be managed for the stable operation and safety in the terminal.
Operator will also patrol the local site periodically and try to find the mal function point such as gas leakage, abnormal noise and vibration, etc.

(3) Maintenance of the facility

Maintenance team will prepare the monthly and yearly maintenance plan and the mid to long term maintenance plan with the budget by the enough discussion with operating team.
To cope with the unexpected equipment failure and system error, the utilization of "on-line call system" or remote maintenance contract with Vendor may be effective. Further as a self-maintenance measure, the optimum management of the inventory and the update information exchange with maintenance service provider will be also crucial.

(4) Education and training

Through the internal discussion (QC circle activity) to initiate the operation manual and the optimum countermeasure at if case, the operation skill at normal and emergency situation will be developed. Operator should join with the purpose to the technical tour in other terminal and seminar and/or training program by Vendor, which will develop the operation skill of the team.

OTS (Operating training simulator) has been developed in a recent year, which enables to generate various mal function cases in the monitor and evaluate operator's skill to recover from such mal function cases logically.

8.9.4 Effective terminal management

With the growing gas demand in Bangladesh in the future, the enforcement of gas demand supply management system will be more needed nation widely. Namely if LNG receiving terminal is constructed in many places to compensate the supply shortage of domestic gas, the integrated gas dispatch center will be needed to order the allocated gas send-out amount to each LNG receiving terminal. Practically the SCADA system owned by TGCL should be highly upgraded to meet this requirement.

From the view point of stable NG supply, to cope with the serious mal function at major facility and natural disaster, back up operation manner among the plural terminals should be studied and trained. Moreover in preparation for terrorist attack and riot, the terminal security plan should be seriously considered and emergency training should be carried out as a routine work.

Chapter 9 Coal Supply

9.1 National Coal Development Policy

9.1.1 Present situation of the coal policy

Currently, the progress is not seen in Coal Policy, and the future prospect is not clear, either. On the other hand, the extension plan of production in Barapukuria coal mine is advancing.

As a specific example of the new coal mine development, there are Dighipara、Khalaspir and Phulbari.The application of the exploration license of Dighipara goes out from Perobanngla and the applications of new coal mine development of Khalaspir and Phulbari also go out, but they are under suspension because the government does not accept them.

9.1.2 PSMP2010 review

Table 9-1 shows the comparison between predicted production until 2041 by domestic coal mine and predicted value in PSMP2010.

In addition, the figures in Table 9-1 are shown by a graph in Figure 9-1. The reasons that lowered amount of predicted production of PSMP2016 in comparison with that of PSMP2010 are following the fact that the Coal Policy at the time of PSMP2010 elaboration was very positiveand the PSMP Study Team with Bangladesh counter parts made a rather ambitiousproduction prediction in PSMP 2010, but based on the current situation of not positive Coal policy and on the fact that all applications for the coal development are shelved, prediction of production in PSMP2016 is rather conservative.

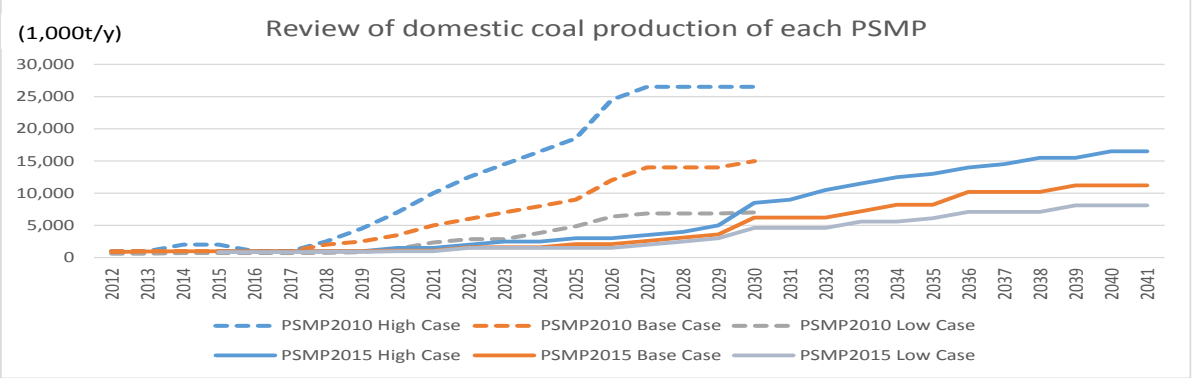
Table 9-1 Comparison of Forecasted Domestic Coal Production between PSMP2010 and This Investigation

Year	Domestic Coal Production in PSMP2010 (1,000t) (Note: From 2005 to 2008 shows actual production)			Domestic Coal Production in PSMP2016 (1,000t) (Note: From 2012 to 2013 shows actual production)		
	High Case	Base Case	Low Case	High Case	Base Case	Low Case
2012	1,000	1,000	600		855	
2013	1,000	1,000	600		947	
2014	2,000	1,000	700		1,000	
2015	2,000	1,000	700	1,000	1,000	850
2016	1,000	1,000	700	1,000	1,000	850
2017	1,000	1,000	700	1,000	1,000	850
2018	2,500	2,000	750	1,000	1,000	900
2019	4,500	2,500	850	1,000	1,000	900
2020	7,000	3,500	1,350	1,500	1,100	1,000
2021	10,000	5,000	2,350	1,500	1,100	1,000
2022	12,500	6,000	2,850	2,000	1,600	1,500
2023	14,500	7,000	2,850	2,500	1,600	1,500
2024	16,500	8,000	3,850	2,500	1,600	1,500
2025	18,500	9,000	4,850	3,000	2,100	1,500
2026	24,500	12,000	6,350	3,000	2,100	1,500
2027	26,500	14,000	6,850	3,500	2,600	2,000
2028	26,500	14,000	6,850	4,000	3,100	2,500

Year	Domestic Coal Production in PSMP2010 (1,000t) (Note: From 2005 to 2008 shows actual production)			Domestic Coal Production in PSMP2016 (1,000t) (Note: From 2012 to 2013 shows actual production)		
	High Case	Base Case	Low Case	High Case	Base Case	Low Case
2029	26,500	14,000	6,850	5,000	3,600	3,000
2030	26,500	15,000	7,000	8,500	6,200	4,600
2031				9,000	6,200	4,600
2032				10,500	6,200	4,600
2033				11,500	7,200	5,600
2034				12,500	8,200	5,600
2035				13,000	8,200	6,100
2036				14,000	10,200	7,100
2037				14,500	10,200	7,100
2038				15,500	10,200	7,100
2039				15,500	11,200	8,100
2040				16,500	11,200	8,100
2041				16,500	11,200	8,100

Remarks: YEAR shows the fiscal year in the table. The fiscal year Bangladesh is from July to June. For example, 2012 show from July, 2012 to June, 2013 in 2012

Source: JICA Survey Team



Source: JICA Survey Team

Figure 9-1 Comparison with PS2010

9.1.3 Significance of the coal development

There are two reasons that Bangladesh will push forward domestic coal development in the future.

(1) Steady supply of the increasing import charcoal

The coal demand of Bangladesh mentioned later in 9.4.1 is expected to become 60million tons in 2041. On the other hand, the demand of thermal coal in the Southern and Eastern Asia will rapidly increases. As a result, it is unknown whether Bangladesh can import overseas coal of stable quality at reasonable price. It is therefore predicted that it becomes the course of nature to make efforts to supply domestic coal instead to the possible extent.

(2) Coking coal and thermal coal

There is coking coal in some coal field in Bangladesh. The price of coking coal costs approximately 2 times in comparison with thermal coal and the demand is very huge in the world including India. Generally, foreign coutries producing coal, such as Australia are selling coking coal and middling as

thermal coal after washing coal. In the case of Bangladesh, coking coal will be exported and middling will be supplied to a domestic coal fired power station. The investment effect of the coal mine development is very big.

9.2 Current Situations and Issues of Supply and Demand of Domestic Coal

9.2.1 Coal reserve of each coal field and estimated minable coal reserve

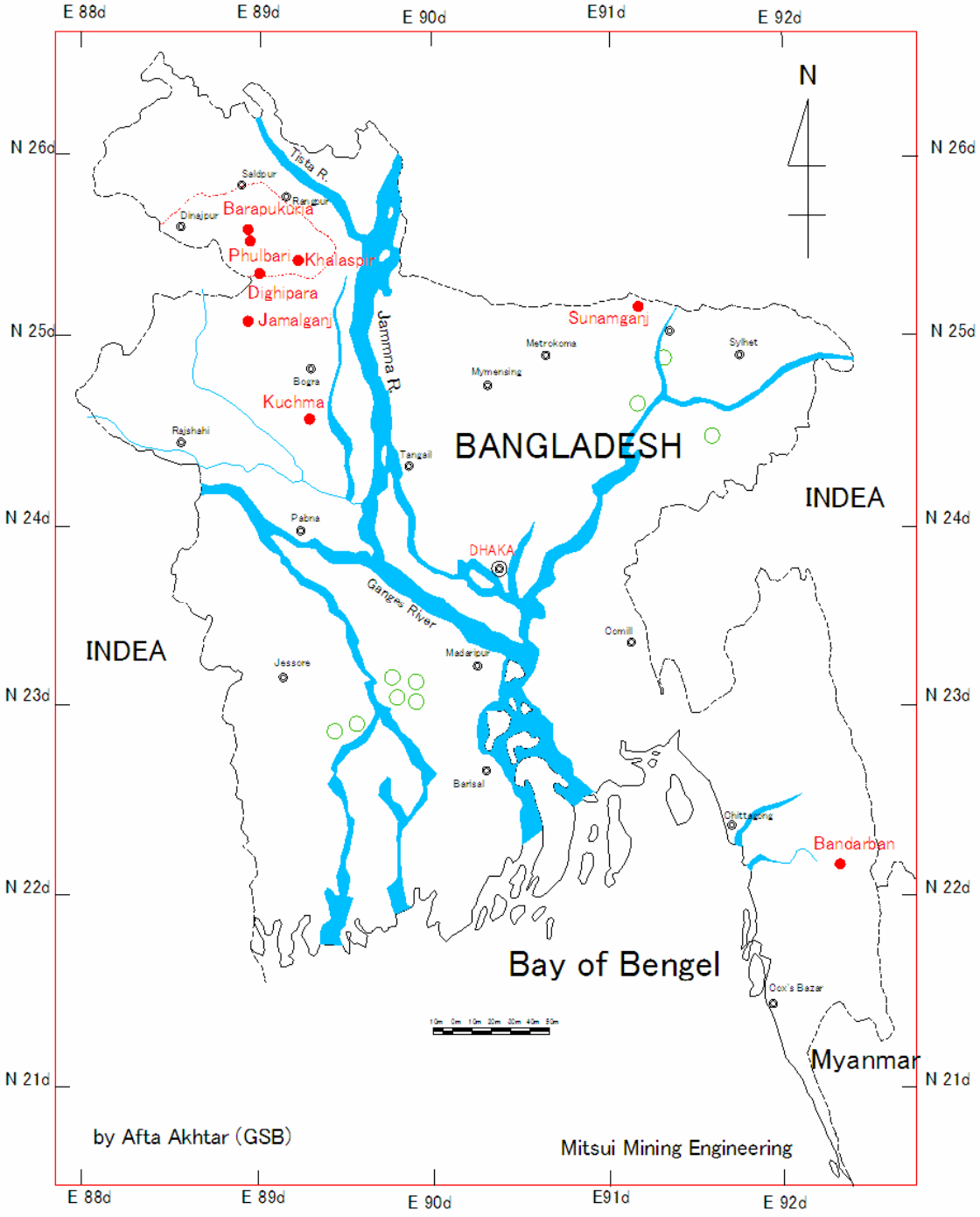
It is well known that the bituminous coal, which is called “Godwin coal” of the Permian Period as well as sub-bituminous coal to lignite of the Tertiary Era occur in Bangladesh. According to the present development data, there are five coal fields in Bangladesh, all of which located in between the Jamuna river and the Padma river in the northwestern part of Bangladesh. The measured and probable coal reserves in total are estimated to be 3.3 billion tons. According to the Draft Coal Policy (June 2007), the measured coal reserve that can be mined for the time being is estimated to be 1,168 million tons, except in Jamalgonj where coal seams are located relatively deep underground. Though there is no additional information in the study of PSMP2016, as developments continue, probable coal reserves are likely to increase. Figure 9-2 indicates the location of coal fields.

Coal in Bangladesh is generally characterized as having low ash content and low sulfur content that are in favor of the environment. It is bituminous coal with properties similar to the coal being used by power stations in Japan. Another grade of coal, which is classified into coking coal for iron production whose commodity value is very high in the market, is also available.

Meanwhile, the problem lies in its mining method. For underground coal mines, the thick coal seams (30 to 40m) pose a problem for the mining method and mining rate. For open-cast coal mines, the mining method which includes dewatering technology to prevent inundation and protect the environment has become an issue, because coal deposits accumulate in the relatively deep underground (170 to 450m) and such a coal mine tends to have an aquifer, called "UDT (Upper Dupi Tila)," over the coal seams. The upper coal seam in particular is dotted with a rice field, the places of residence of inhabitants, and the move of inhabitants, social environmental consideration become the important issue.

Table 9-2 shows the details of six coal fields that were explored and the progress in their development. The Barapukuria Coal Mine is the only operating coal mine in Bangladesh and is undergoing completely mechanized underground mining, the details of which will be described later. An open-cast coal mine development in Phulbari came to a deadlock due to the oppositions by the local people, which will give directions to the coal mine development in Bangladesh. In other words, coal mine development in Bangladesh will depend on whether the Government of Bangladesh can successfully win, as a national policy, consent from people for an open-cast mining method, which is superior to underground mining in terms of stable coal production.

Table 9-3 shows estimated minable coal reserve depending on open-cast and underground mining method. As for the quantity of actual minable coal, 438 million tons in No .1 to No.4, it is calculated based on present mining method.



Source：GSB

Figure 9-2 Locations of Coal Fields in Bangladesh[26]

[26] Red points indicate coal fields.

Table 9-2 Coalfield Development Status in Bangladesh

No.	Coal field name	Develop-ment year	Exploring company (Number of borings)	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured coal reserve (100 million tons)	Measured＋probable coal reserves (100 million tons)	Remarks
1	Barapukuria (Dinajpur)	1985 -87	GSB (31)	118 -506	6	51	3.03 (Minable coal reserve by U/G: 64 million tons)	3.9	・Petrobangla and China National Machinery Import and Export Corporation (CMC) in China concluded an development agreement in 1994. BCMCL was founded in 1998. Capacity designed: One million ton /year. ・Enhancement of production is under planning. ・A small-scale open-cast mining project is feasible. For open cut mining technology introduction, Tata of the Indian company suggested open-air mining, but the government does not give a conclusion. Consent? ・A 250MW coal-fired thermal power station is in operation, and a study is on the table to build a new 125MW power station.
2	Phulbari, (Dinajipur)	1997	BHP (108)	150 -240	2	15-70	5.72	5.72	・Asia Energy has completed a feasibility study. When the company was going to engage in a large-scale open-cast coal mine development, the development project was suspended in August 2006 due to oppositions by local people. ・It is a problem that the Phulbari open-cut mining plan submitted by Asian energy did not touch about groundwater behavior and a landfill plan after mining. The biggest problem is drinking water and irrigation water measures of inhabitants. ・Although Global Coal Management has succeeded to the development interest, progress made so far is unknown.
3	Khalaspir, (Rangpur)	1989 -90	GSB (14)	257 -483	8	42.3	1.43	6.85	・The measured coal reserve is 143 million tons. ・F/S was completed by Chinese consultant of U/G mining in Shandon. But, the government was not satisfied with the F/S report. The report included ten exploration drillings and good 3D seismic exploration. ・The annual coal production plan ranges from two million to four million tons.
4	Dighipara, (Dinajipur)	1994 -95	GSB (5)	328 -407	5	62	1.5	6.0	・GSB made five borings in a 1.25 km2 area and found five coal seams. The initial probable coal reserve is 600 million tons. ・A Korean syndicate has approached Petrobangla for development and investment. ・BAPEX carried out an investigation into 2D seismic exploration in Dighipara. The report is under preparation at present.

No.	Coal field name	Develop-ment year	Exploring company (Number of borings)	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured coal reserve (100 million tons)	Measured＋probable coal reserves (100 million tons)	Remarks
5	Jamalgonj, (Bogra)	1962	GSB (10)	640-1,158	7	64	10.53	10.53	・Largest coal field in Bangladesh ・Targeting coal seam gas of CBM (coal bed methane) in deep underground ・There are three proposals to develop in Jamalgonj, which are Coal Bed Methane(CBM) for recover gas from coal seam, Underground Gasification(UCG) by Green Energy in Australia, U/G mining by Chinese company. But the government didnot give any conclude to these proposals.
6	Kuchma, (Bogra)	1959	SVOC	2,380 -2,876	5	51.8			・Targeting coal seam gas of CBM (coal bed methane) in very deep coal seam

Source: GSB and edited by JICA Survey Team

Table 9-3 Minable Coal Reserve depending on Mining Method

	Coal field name	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured reserves (million tons)	Mining method	Minable coal reserve (million t)
1	Barapukuria (Dinajpur)	118 -506	6	51	303	U/G (15%)	45.5
2	Phulbari, (Dinajipur)	150 -240	2	15-70	572	O/C (60%)	343.2
3	Khalaspir, (Rangpur)	257 -483	8	42.3	143	U/G (15%)	21.5
4	Dighipara, (Dinajipur)	328 -407	5	62	150	U/G (15%)	22.5
5	Jamalgonj, (Bogra)	640-1,158	7	64	1,053	U/G (10%)	105.3
6	Kuchma, (Bogra)	2,380 -2,876	5	51.8			
Total					3,300		438

Source: Edited by JICA Survey Team

9.2.2 Current situation and issue of Barapukuria coal mine

(1) Overview

The Barapukuria Coal Mine was developed jointly by Petrobangla and XMC-CMC in China by an agreement of M&P (the Management, Production and Maintenance) concluded in 1994. According to the M&P Contract, CMC has transferred mechanized longwall mining method and achieved a certain degree of stable production of coal. The first contract achieved a production of 3.65 million tons against targeted 4.75 million tons during 71 months from September, 2005. Furthermore, after an international bid aiming at a production of 5.5 million tons, XMC-CMC entered again into the second contract with MPM&P (Management, Production, Maintenance & provisioning Services). This was contracted on a premise to go back in August, 2011. In this contract, the LTCC (Longwall Top Coal Caving) facilities of thick seam mining technology were introduced in December, 2012. It started operation from May, 2013. The face conveyer carries mined coal of 3m operating height and the rear conveyor installed rear of self advancing support carries collapse coal of about 2 m hight . Technical fixation and increased production in thick seam are expected.

All the underground facilities are from China. The vertical shaft is 300m long, and the skip capacity for coal hoisting is set to 3,300t/d. Coal productionis stable in recent years. Coal is supplied for neighboring Barapukuria Thermal Power Stations (125kw x 2). Remaining coal is primarily supplied for brick constructions and other purchasers in the general industry. At present, the coal mine has an annual production capacity of approximately one million tons, and a study to reinforce the production capacity is underway in order to cope with possible capacity increase of the power station. The mine is also planning to expand its annual production up to 1.5 million tons in the future.

(2) Production results

The amount of production and sales of the Barapukuria coal mine are shown in Table 9-4. PDB in the table means the sales volume for the Barapukuria power station and the coal mine has always the coal stock of two months at the mine for the Barapukuria power station. LTCC face operated in 2013 and the production became stable and rising. Production decreased due to water burst and delay of withdrawal & installation of a face in 2014/2015. However, it is thought that it is near to achieve 1 million tons of production, a target of original existing facilities. On the other hand, the sales price of the coal for the power station is US$130/t (from May, 2015) and Tk 13,680[27]/t for the local buyer (from January, 2014, including VAT). This price level, comparing with a mine mouth price of Australian coal of similar coal quality, is considerably higher than that of Australia which is around US $ 50-60 as ofMarch, 2015.
However, the coal price for a local buyer was lowered to Tk 8,000/t(US$102.5) on May 19, 2016 because an overseas coal price became cheaper.

[27] When ONE US$ is to be 78Tk (March 2014), Tk 9,200 is US$ 118.

Table 9-4 Coal Production and Sales Records at Barapukuria Coal Mine

Year	Production (t)	Sale (t)	
		PDB	Others buyers
Till June, 2004	91,038		70,132
2004-2005	87,143		74,768
2005-2006	303,016	209,235	45,020
2006-2007	388,376	460,231	5,707
2007-2008	677,098	491,354	10,393
2008-2009	827,845	532,488	258,081
2009-2010	704,568	501,132	319,255
2010-2011	666,635	463,923	107,795
2011-2012	835,000	499,972	332,526
2012-2013	854,804	643,978	288,266
2013-2014	947,125	524,143	338,618
2014-2015	6,75,776	5,222,129	313,405
Total	7,058,423	4,326,458	2,163,965

Souce：Annual Reportof 2-14-2015, Barapukuria Coal Mining Co. Ltd

Table 9-5 Change of the coal sales price to PDB (Barapucuria power station)

Sl No.	Date on which prices fixed	Price of coal/t (US$)
1	29 May 2001	61.50
2	July 2008	71.50
3	July 2010	85.50
4	01 Feburuary 2012	105.00
5	01 May 2015	130.00

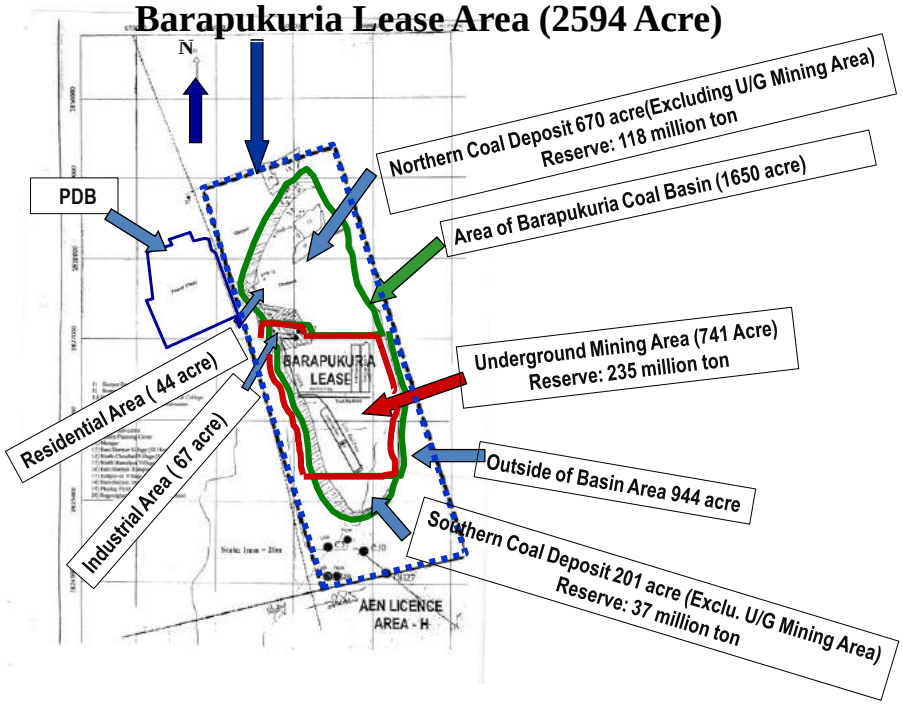
Souce：Annual Reportof 2-14-2015, Barapukuria Coal Mining Co. Ltd

(3) Expansion plan of the mine

An expansion planof the mineis composed of Southern part (reserves 37 million tons) and Northern part (reserves 118 million tons). The area surrounded in a red line shows an existing mine and the area surrounded in a green line shows expansion plan in Figure 9-3. Figure 9-4 shows the details of Northern part and Southern part. Attention is to be paid to the Northern part development where it is proposed to examine open cast mining method.

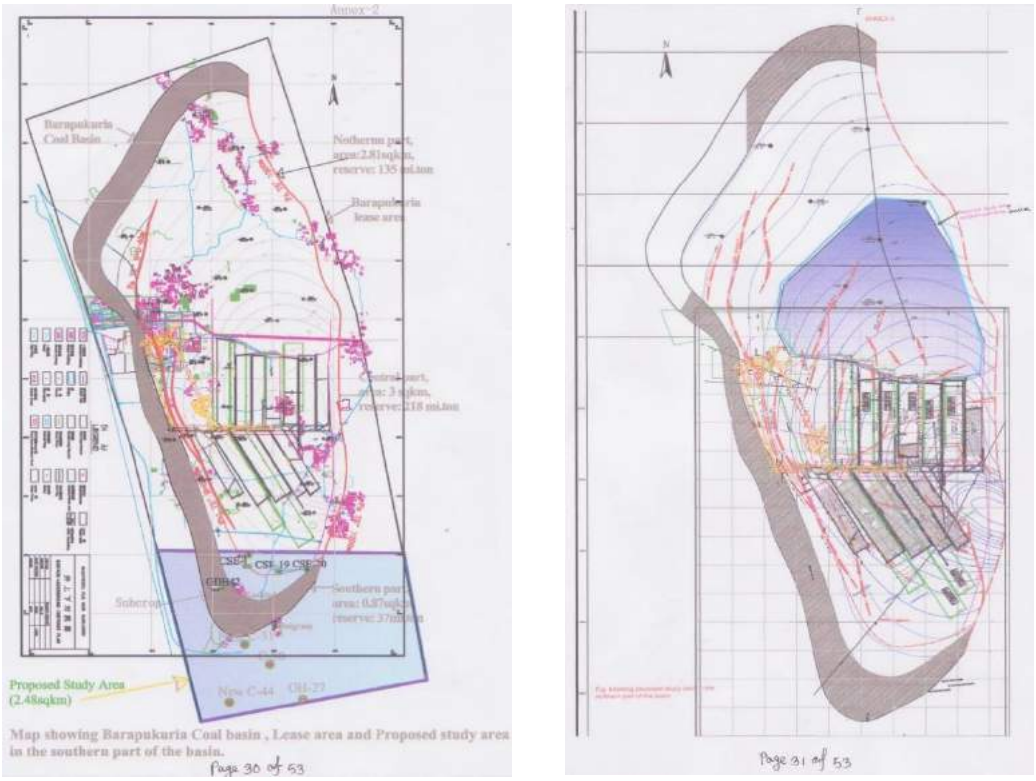
The plan will be along with suggestions of PSPM2010 that opencast mining method in Bangladesh by a small pilot plan should be carried out and technical issues and social environmental problems should be examined at first through the pilot plan. The hydrological survey by six trial borings is already finished and a report is completed. The judgment of the Bangladesh government is awaited now.

Barapukuria coal mine is the first underground coal mine in Bangladesh. The accumulated experience in the past 10 years such as coal mining technology, coal mine administration, and environmental measures is very valuable. The Barapukuria coal mine has the leadership role as a model coal mine, and their practical accomplishment will become references of new investment, necessary technical standards and the production cost for the future Bangladesh new coal mines.



Source: Barapukuria Coal Mining Co. Ltd

Figure 9-3 Expansion Plan of Barapukuria



Source: Barapukuria Coal Mining Co. Ltd

Figure 9-4 Expansion Plan of South Area (at left) and North Area (at right)

(4) Issues

(a) The stabilization of production in the deeper place than 2nd Slice[28] by LTCC.

LTCC face operated from May, 2013, and Face 1210, Face 1206 were finished. The mining height was 3m in original at 1st Slice and the mining height of these LTCC faces was total 5m by mechanical mining height (3m) plus caving height (2m) and the caving height is planned to increase more. It is under examinination now but the person in charge did not seem to have a particularly big problem.

(b) Increased production

The present transporting capacity of a shaft skip to carry out the mined coal to the surface is small with 8 tons. It will be possible to increase it to around 1.2 million tons per year by extension of the operating time of skip and the reinforcement of an underground coal reserve pocket. When more than 1.5 million tons per year production is foreseen, new investment will be required to upgrade capacity of the skip or to make a new skip shaft.

(c) An aspect of technology transfer to Bangladesh engineer and worker

Technology transfer at Barapukuria Coal Mine is very important to predict the future development and production at underground coal mines in Bangladesh.

- Regarding the methods of the technology transfer, there is “On the Job Training” and “Classroom within MPm&P Contract” between China and BCMCL. Safety control items are exceptionally very important in technology transfer program.

- The production technology and safety technology are particularly important in various kinds of technical acquisition. The safety technology is the most important among them. In Japan, the coal mine corporate strategy of “Safety First, The Production Second” has been demanded from old days.

9.2.3 An aspect of undeveloped coal field

Obvious progress was not found as mentionedin REMARKS of the Table 9-2 for the present situation of each coal field.

9.2.4 Forecast of domestic coal production

Table 9-6 shows forecast of domestic coal production until 2014 including future coal mine development program.

[28] When thick seam is mined by longwall mining method in underground, thick coal seam is divided into some thicknesses of coal seam because all seams can’t be mined at a time. 2nd slice is called coal seam mined secondly.

Table 9-6 Performance and Forecast of Domestic Coal Production

Year	Total coal production (High Case) (1,000t/y)	Total coal production (Base Case) (1,000t/y)	Total coal production (Low Case) (1,000t/y)	Production of Domestic Coal Mine (1,000t/y)														
				Existing Coal Mine & New O/C					New Coal Mine (U/G & O/C)									
				Barapukuria U/G & new O/C					Kalaspir(U/G)			Dighipara(U/G)			Phulbari(O/C)		
				Under Ground mining (U/G)			Open Cast mining(O/C)		U/G			U/G			O/C		
				(HC)	(BC)	(LC)	(HC)	(BC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)
2005-6		303			303												
2006-7		388			388												
2007-8		677			677												
2008-9		828			828												
2009-10		705			705												
2010-11		667			667												
2011-12		835			835												
2012-13		855			855												
2013-14		947			947												
2014-15		676			676												
2015-16	1,000	1,000	850	1,000	1,000	850											
2016-17	1,000	1,000	850	1,000	1,000	850											
2017-18	1,000	1,000	900	1,000	1,000	900											
2018-19	1,000	1,000	900	1,000	1,000	900											
2019-20	1,000	1,000	900	1,000	1,000	900											
2020-21	1,500	1,100	1,000	1,500	1,100	1,000											
2021-22	1,500	1,100	1,000	1,500	1,100	1,000											
2022-23	2,000	1,600	1,000	1,500	1,100	1,000	500	500									
2023-24	2,500	1,600	1,000	1,500	1,100	1,000	1,000	500									
2024-25	2,500	1,600	1,000	1,500	1,100	1,000	1,000	500									
2025-26	3,000	2,100	1,000	1,500	1,100	1,000	1,500	1,000									
2026-27	3,000	2,100	1,000	1,500	1,100	1,000	1,500	1,000									
2027-28	3,500	2,600	1,500	1,500	1,100	1,000	1,500	1,000	500	500	500						
2028-29	4,000	3,100	2,000	1,500	1,100	1,000	1,500	1,000	1,000	1,000	1,000						
2029-30	5,000	3,600	2,500	1,500	1,100	1,000	1,500	1,000	1,500	1,000	1,000	500	500	500			
2030-31	8,000	5,700	3,600	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	1,000	1,000	1,000	500	500	500
2031-32	9,000	6,200	4,100	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	1,500	1,000	1,000	1,000	1,000	1,000
2032-33	10,500	6,200	4,100	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	2,000	1,000	1,000	2,000	1,000	1,000
2033-34	11,500	7,200	4,600	1,500	1,200	1,100	4,000	2,000	2,000	1,000	1,500	2,000	1,000	1,000	2,000	2,000	1,000
2034-35	12,500	8,200	4,600	1,500	1,200	1,100	4,000	2,000	2,000	2,000	1,500	2,000	1,000	1,000	3,000	2,000	1,000
2035-36	13,000	8,200	5,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,000	1,000	1,500	3,000	2,000	1,000
2036-37	14,000	10,200	5,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,000	2,000	1,500	4,000	3,000	1,000
2037-38	14,500	10,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	4,000	3,000	2,000
2038-39	15,500	10,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	5,000	3,000	2,000
2039-40	15,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	5,000	4,000	2,000
2040-41	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000
2041-42	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000









Remarks: The arrow in the Table shows a run-up term including authorization for the coal mine development, construction.

Source：JICA Survey Team

9.3 The Present Aspect and Issues of the Import coal

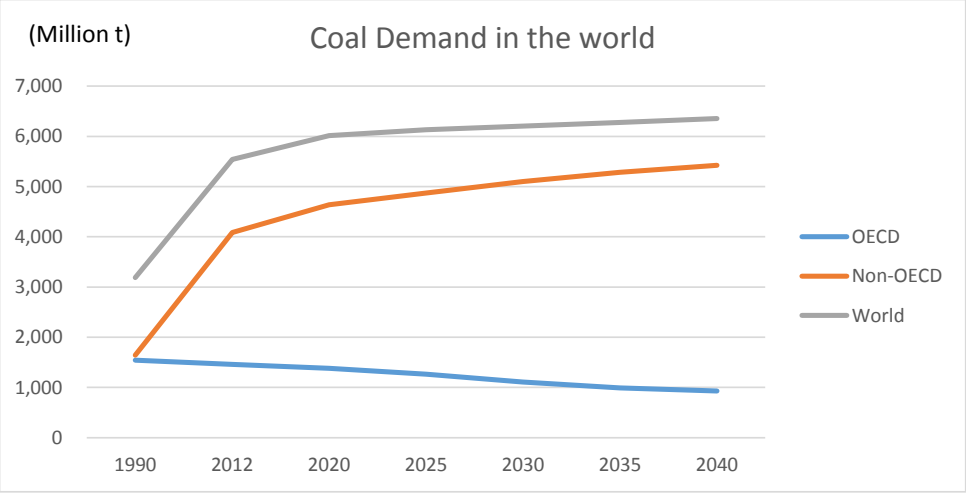
9.3.1 General view

Figure 9-5 shows the quantity of world coal demand until 2040 in New Policies Scenario[29] of World Energy Outlook of IEA. Coal demand for Non-OECD countries increases rapidly from the Figure. The quantity of demand for Non-OECD countries is expected to increase five-fold of the demand of current OECD countries. China and India occupy this main increase as shown in Figure 9-6.

On the other hand, trend of coal import by Southeast countries as shown in Figure 9-6 is important for Bangladesh. Figure 9-7 shows the coal import trend of Southeast countries excluding China and India to begin with Malaysia, Thailand and Philippines which areimportant coal consumer countries. It is in particular a trend of these past five years to pay attention. Table 9-7 shows the import quantity of each country.

It is obvious from the Table that the coal import of each country suddenly increases. In addition, the result of our investigation found that Bangladesh, actually, imports coal of approximately 4 times bigger than the volume shown in the Table. With this statistical discrepancy, the figures in Figure 9-7 and Table 9-7 should be interpretated with prudence.

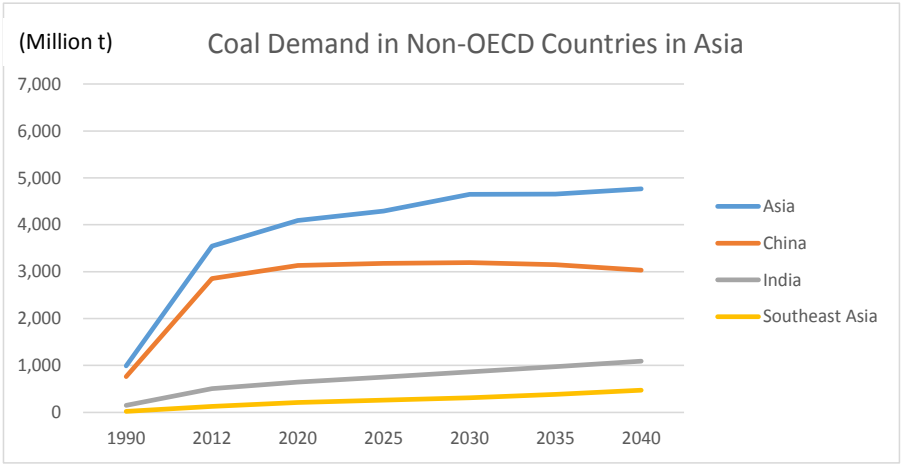
It will be difficult to predict exactly how much coal Bangladesh can import sustainably and economically depending on coal quality, price, concession, but it seems that Bangladesh will have a tough time to procure coal given the prospected coal demand in Southeast in the near future. Therefore, if Bangladesh lowers the specification of the coal quality compared with that of circulating coal now, 20-30 million tons of coal will be imported in a stable manner at a stage in 2030 from India, Indonesia, Australia or some of African countries. However, sincethe quantity of import coal demand for Bangladesh in 2040 is expected to be around 60 million tons as shown in Table 9-12, solutions must be found for many issuessuch as unstable coal quantityand quality as well as coal price.



Source: Coal market outlook by World Energy Outlook 2014

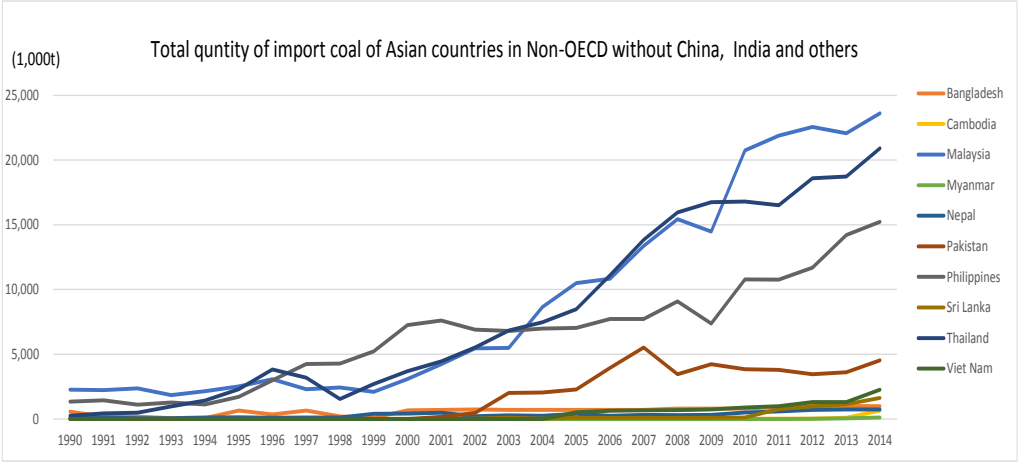
Figure 9-5 Forecast of Coal Demand in the World

[29] The World Energy Outlook 2014 (WEO-2014) presents projections for three scenarios. The Current Policies Scenario is based on those government policies and implementing measures that had been formally adopted as of mid-2014. The New Policies Scenario, which is WEO's central scenario, takes into account the policies and implementing measures affecting energy markets. The 450 Scenario is projection considering control global warming until 450ppm.
As for the prediction of EIA (Energy Information Administration, United States Department of Energy), it may be said that New Policies Scenario watches a predictive number modestly because Current Policies Scenario of IEA is near.



Source: Coal market outlook by World Energy Outlook 2014

Figure 9-6 Forecast of Coal Demand in Non-OECD Countries in Asia



Source: Coal Information, IEA

Figure 9-7 Quantity of Import Coal of Southeast Asian Countries in Non-OECD without China, India and Others

Table 9-7 Quantity of Import Coal of Asian Countries in Non-OECD without China, India and Others for the Past 5 Years

(1,000t)

	2009	2010	2011	2012	2013	2014
Malaysia	14,477	20,737	21,881	22,558	22,064	23,611
Thailand	16,740	16,802	16,510	18,586	18,726	20,909
Philippines	7,367	10,772	10,755	11,681	14,199	15,224
Pakistan	4,227	3,838	3,782	3,446	3,598	4,524
Viet Nam	724	884	978	1,295	1,308	2,260
Sri Lanka	100	108	760	962	1,131	1,617
Bangladesh	800	800	924	1,000	1,000	988
Nepal	307	489	583	698	724	724
Cambodia	16	17	19	21	96	642
Myanmar	0	0	0	8	47	113
Totl of Asia in Non-OECD without China, India and others	44,758	54,447	56,192	60,255	62,893	70,612

Source: Coal Information, IEA

9.3.2 Import coal price

Present coal price has a tendency to fall due to global oversupply. Figure 9-8 shows the change of FOB coal price of 6,700kcal/kg at Newcastle Port from 2002 through 2015 in terms of coal price (¢) per 1,000kcal/kg. The coal price gradually declines from 2011 and is still declining now. There is a prediction that the price will in turn start to increase around 2020, but the percentage of such rise is not identified.

The prediction of coal price until 2040 is not easy under present situation, but Figure 9-9 shows a prediction of coal price starting from October, 2015 using the approximation of straight line, except when the price shows substantial change in a rather brutal manner.

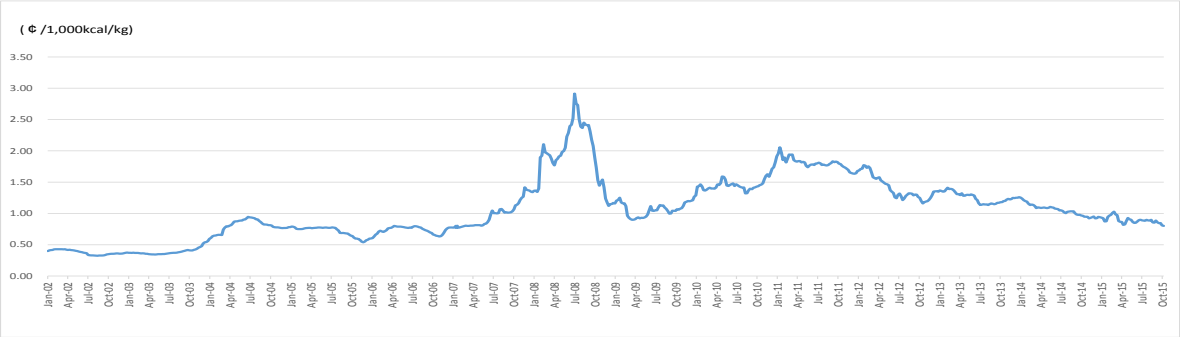
In addition, there is some difference in coal price (¢) per 1,000kcal/kg by the calorific value of the coal. Table 9-8 shows the mean weight of the coal price of each calorific value when 6,500kcal/kg is assumed as 1.000 in Indonesian Coal Index (ICI)[30] which Argus announces for the past 2 years.

Using this differenciation by calorific value, coal price prediction until 2040 of 6,300kcal/kg and 4,700kcl/kg is made in Table 9-9. This prediction is based on an assumption that 6,300kcal/kg will be approximately equal to 6,500kcal/kg and is adopted Weight 1.000 and 4,700kcl/kg will be equal to 5,000kcal/kg and is adopted Weight 0.919.

Table 9-10 shows predicted coal price of 6,300kcal/kg composed of CIF price and an unloading expense in Chittagong, on a premise to import from Australia. Equally, Table 9-11 shows predicted coal price of 4,700kcl/kg.

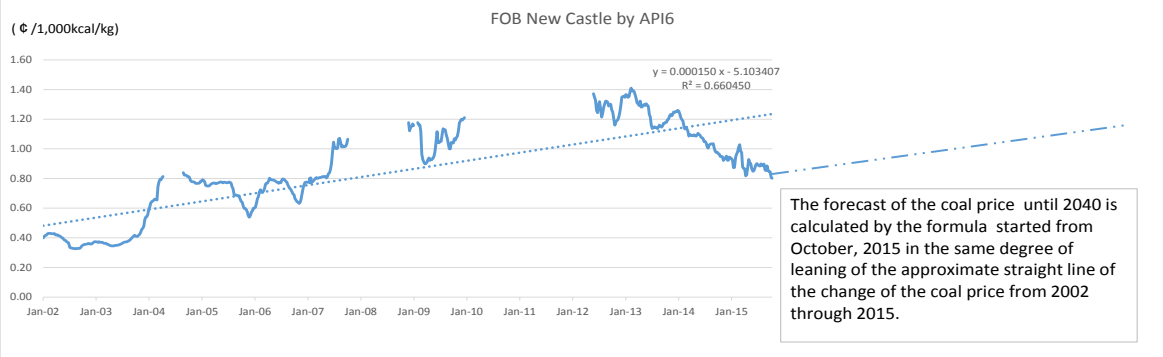
As a result, coal cost becomes generally about half compared with the forecast of coal cost in PSMP2010.

[30] Indonesian Coal Index / ICI (Coal) The ICI (Indonesian Coal Index) reflects the spot price of five key grades of Indonesian coal — 6,500 (ICI 1), 5,800 (ICI 2), 5,000 (ICI 3), 4,200 (ICI 4) and 3,400 (ICI 5) kcal/kg GAR. It is published weekly and is the average of the Argus fob Indonesia price as reported in the Argus Coal Daily International report and the PT Coalindo Energy weekly panel system. The full database of time series data is available from 2006.



Source: API6, by Argus

Figure 9-8 Coal Price of 1,000kcal/kg Movement at Newcastle Port in Australia



Source: API6, by Argus

Figure 9-9 Forecast of Coal Price of 1,000kcal/kg

Table 9-8 Weight of Coal Price by Calorific Value by ICI, Indonesia

6,500 Kcal/kg	5,800 Kcal/kg	5,000 Kcal/kg	4,200 Kcal/kg	3,400 Kca/kg
1.000	0.977	0.919	0.769	0.638

Source: Indonesian Coal Index

Table 9-9 Forecast of Coal Price of 1,000kcal/kg to High Grade Coal and Low Grade Coal

Year	¢/1,000kcal/kg for High grade coal	¢/1,000kcal/kg for Low grade coal	Coal Price(US$)	
			6,300kcal/kg	4,700kcal/kg
2015	0.80	0.74	50.5	34.6
2020	1.07	0.99	67.7	46.4
2030	1.35	1.24	85.0	58.3
2040	1.62	1.49	102.2	70.1
2050	1.90	1.74	119.5	81.9
2060	2.17	1.99	136.8	93.8

Source: JICA Survey Team

Table 9-10 Total Cost including FOB, Freight, Insurance and Handling Cost from Australia

Year	FOB Price of 6,300kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	50.5	15.0	16.0	81.5	0	65.5
2020	67.7	17.8	17.8	103.3	0	85.5
2025	85.0	20.5	19.7	125.1	0	105.5
2030	102.2	23.2	21.5	147.0	0	125.5
2035	119.5	26.0	23.4	168.9	0	145.5
2040	136.8	28.7	25.2	190.7	0	165.5

Source: JICA Survey Team

Table 9-11 Total Cost including FOB, Freight, Insurance and Handling Cost from Indonesia

Year	FOB Price of 4,700kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost (US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	34.61	9.1	16.0	59.7	0	43.7
2020	46.43	10.7	17.8	75.0	0	57.2
2025	58.26	12.4	19.7	90.3	0	70.7
2030	70.09	14.1	21.5	105.7	0	84.1
2035	81.92	15.7	23.4	121.0	0	97.6
2040	93.76	17.4	25.2	136.4	0	111.1

Source: JICA Survey Team

9.4 Prediction of Coal Demand & Supply

9.4.1 Prediction of coal demand & supply

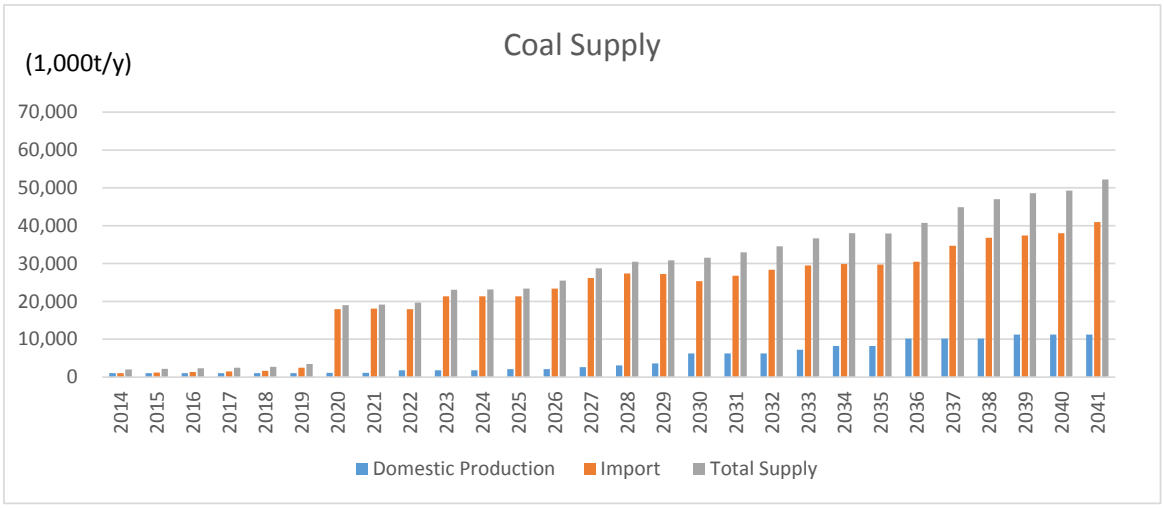
Table 9-12 shows domestic supply and demand of the coal until 2041. Figure 9-10 shows the coal supply and demand by a graph. Since coal demande of for power generation is predominant, demand quantity was predicted based on a new coal-fired power station construction plan.

Table 9-12 Prediction of Coal Demand & Supply

(1,000t)

		2015	2020	2025	2030	2035	2040	2041
Supply	Domestic	1,000	1,100	2,100	6,200	8,200	11,200	11,200
	Import	1,163	17,905	21,304	25,311	29,739	38,041	40,977
	Total	2,163	19,005	23,404	31,511	37,939	49,241	52,177
Demand	Power	430	16,339	19,460	26,082	30,860	40,486	43,067
	Non-power	1,733	2,666	3,944	5,429	7,079	8,755	9,110
	Total	2,163	19,005	23,404	31,511	37,939	49,241	52,177

Source: JICA Survey Team



Source: JICA Survey Team

Figure 9-10 Coal Supply

9.4.2 The issue of coal supply

(1) Implementation of imported coal infrastructure in the F/S.

- The F/S for the CTT (Coal Transshipment Terminal) planned in the Matarbari area has already been completed (Source: Preparatory Survey for the Construction and Operation of Imported Coal Transshipment Terminal Project in Matarbari Area in People's Republic of Bangladesh (as a PPP infrastructure project)).

- In this plan, phased development for CTT was recommended to provide sufficient flexibility, i.e., to expand the CTT when the power generation program development and realistic commission operation date (COD) become certain.

- The first phase of the CTT will commence operation in 2025 (planned amount of coal: 10.4 million t/year); the object of the second phase will include those power stations that commence operation by 2029 (amount of coal: 25.6 million t/year) and use the CTT.

- For the future, with an increase in the development of new coal-thermal power plants there is a need to implement the F/S for the infrastructure and plan for efficient coal transportation.

- The actual value of the loading and unloading situation in the Bay of Bengal is important.

(2) Construction Based on the F/S

- For CTT (Coal Transshipment Terminal), efficient coal supply operation while ensuring long-term stability is desired. When planning in Bangladesh, it is important to take into account the natural characteristics such as the broad expanses of sand, cyclones and high rainfall, and the protection of precious animals and plants.

- When importing coal over a long period of time, facility planning that can respond to changes in the type of coal is desirable as, depending on the coal mine reserves, future coal mines and countries may change.

- The promotion of mechanization and securing of stable supply for offshore loading and unloading by floating crane; the implementation of early construction of the CTT.

9.4.3 Coal demand of industry

The quantity of coal demand for domestic industry in Table 9-12 is predicted based on a growth rate of Table 9-9 for the past 5 years. It is difficult to grasp the real coal consumption. Table 9-13 is data from an annual report of the Bangladesh Statistics Bureau, but the real import amount is considered to be enormous. The figure of statistics seems to reflect the import from the sea route mainly. The import by the land route from India seems not included in this table.

The main industry of coal consumption in Bangladesh is brick factory and there are small rolling mil factories (foundry) in addition. As for the coal consumption of brick factories, the quantity of brick production of 34/unit x 3500unit=119,000 units by operation for six months requires 700t of coal. Generally, typical production quantity of the brick per one factory is 1lakh (100 thousand units). Therefore, 1,000 brick factories consume 700,000tons of coal per year.

Table 9-13 Data of Quantity of Import Coal by Bangladesh Bureau of Statistics

Year	Cord No.	Item	Import amount (t)	Import price (BDT)	@ BDT/t
2019/2011	2701	Coal & Briquette	59,778	476,813,100	7,976
	2704	Coke and Semicoke of coal	4,464	104,318,000	23,316
2011/2012	2701	Coal & Briquette	56,636	411,608,100	7,268
	2704	Coke and Semicoke of coal	3,903	103,100,000	26,416
2012/2013	2701	Coal & Briquette	82,228	495,411,576	6,025
	2704	Coke and Semicoke of coal	3,359	90,888,657	27,058
2013/2014	2701	Coal & Briquette	NA	NA	NA
	2704	Coke and Semicoke of coal	2,645	65,094,975	24,616

Source: Bangladesh Bureau of Statistics (BBS)

9.4.4 The quality of import coal for industry

JICA Survey Team carried out a field work asking questions to a coal seller nearby Fatulla Station of the river mouth of Madaripur of Dhaka City. He was selling Indonesian, Indian and Chinese coal, among which Indonesian coal was major coal at the time of investigation.
The sales covered three kinds of calorific value, 5,000, 6,500 and 7,500kcal/kg and annual sold volume was 20,000t - 30,000t. The coal was shipped by a boat from Chittagong. Table 9-14 shows analysed contents of the coal which the coal seller sold. The quality such as the calorific value is good, but sulfur content is high. The coal imported by land by the northeast Indian side of the Bangladeh has also high sulfur content and the Bangladesh goverment is prohibiting import of high sulfur coal, but controlis not easy.

Table 9-14 Coal Quality for a Brick Factory

Item	Unit	Base	Coal sample	
			Indonesia A	Indonesia B
Total moisture	wt%	AR	11.0	4.8
GCV (HHV)	kcal/kg	AR	6,360	7,100
	MJ/kg		26.7	29.7
NCV (LHV)	kcal/kg	AR	6,140	6,880
	MJ/kg		25.7	28.8
[Proximity analysis]				
Moisture	wt%	AD	5.7	3.4
Ash			6.9	8.8
Volatile Matter			44.0	43.8
Fixed Carbon			43.4	44.0
Total Sulphur	wt%	Dry	2.71	0.86

Source: JICA Survey Team

9.5 Environmental and Social Aspects of Coal Development

9.5.1 Environmental Impact Assessment

Basic rules of Environmental Impact Assessment are given by Environment Conservation Act 1995. The clause 12 of the Act "No industrial unit or project shall be established or undertaken without obtaining, in the manner prescribed by rules, an Environmental Clearance Certificate from the Director General". Environment Conservation Rules 1997 (subsequent amendments in 2002 and 2003) stipulate the procedures and required documents by categories (see Table 9-15).

Table 9-15 EIA Categories and Required Clearance and Documents

Category	Required clearance	Required documents
Red	Location clearance, Environmental Clearance	Feasibility Study report (FS report), IEE or EIA, Resettlement Action Plan (RAP), No Objection Certificate of the local authority (NOC), Emergency and pollution minimization Plan
Orange B	Location clearance, Environmental Clearance	FS report, IEE, NOC, Emergency and pollution minimization Plan, RAP
Orange A	Location clearance, Environmental Clearance	General Information, Raw materials and the manufactured product, NOC, Process flow, Layout, Effluent discharge arrangement, RAP
Green	Environmental Clearance	General Information, Raw materials and the manufactured product, NOC

Source: Environment Conservation Rules 1997

MOE has prepared various guidelines of EIA such as Guidelines for Industries in 1997, EIA Guidelines for Coal Mining, Guidelines for Gender Responsive Environmental Management. All the coal and gas development projects have to apply Environmental Clearance to DOE of Dhaka, Chittagong, Khulna, or Rajshahi Division. It is not clear that which categories should be applied to various kinds of Gas and coal projects (see Table 9-16).

Table 9-16 EIA Guidelines for Gas and Coal Sector

Activities	Category	Guidelines to be referred
Coal exploration	?	EIA Guideline for Coal Mining
Coal mining	Red	EIA Guideline for Coal Mining
Coal storage	?	EIA Guidelines for Industries in 1997
Coal Power Plant	Red	EIA Guidelines for Industries in 1997

9.5.2 Experienced environmental and social impact of coal development

Currently there is only one coal mine in operation. Information is gathered from Barapukuria Coal Mining Co. Ltd (BCMCL) and literatures.

(1) Environmental and social impact of Barapukuria Coal Mine

EIA report and Environmental monitoring reports were prepared for the Barapukuria Coal Mine project. But both of them are not disclosed by BCMCL. BCMCL does not submit the monitoring reports to DOE periodically. There are many reports and articles which suggest various Environmental and Social impact caused by the project. Based on the hearing, articles and reports, 320 households were resettled and 622 acers of land were acquired at the construction stage. After the subsidence happened, fish farming has started, wildlife has commenced to use the pond as their habitat. But 2,500 people were additionally resettled by the subsidence, and 15 villages were affected by lowered underground water (see Table 9-17). Compensation measures have been taken but some affected people are thinking that compensation is not enough (see Table 9-18). It seems that Environmental and Social impacts are not fully controlled.

Table 9-17 Reported Environmental and Social impact by Barapukuria Coal Mine

Items	Impact	Source
Tremor	Tremor is experienced by local people.	Hearing from BCMCL
Subsidence	Subsidence area is 627 acres (2.5 km2). Compensation to the affected land, houses and others was finished and issues are solved.	Hearing from BCMCL
	Subsidence started in 2008 and lowered around 1m. 2,500 people in seven villages are affected. Eight to ten “tin sheds” are proposed by BCMCL. Government is planning to establish Coal City for 10,000 families.	Hoshour (2011)
Underground water degradation	Underground water level was lowered and 15 villages lost their access to water.	Hoshour (2011)
Water pollution	2200m3/h treated water is discharged into river. People are using the treated water for irrigation. People are growing fishes at the pond of the subsidence area and wildlife is using the pond.	Hearing from BCMCL
	30ton/hr waste water is drained that is mainly acidic in nature and rest of water is recycling. AMD, classified as hard water, contains harmful heavy metals and metalloids like HCO3-, Na+, Ca+ which have a tendency to leach out over a period of time.	Akter et al. (2015)
	The chemical properties of surrounding water such as concentration of Calcium, Magnesium, Lead, Iron, Copper, Zinc etc are greatly increased by the mixing of coal water and greatly impacts on the farmer’s field soil.	Hasan (2013)

Items	Impact	Source
Soil contamination	By releasing heavy metals which are associated with coal such as aluminium (Al^{3+}), zinc (Zn^{2+}) and manganese (Mn^{2+}), AMD is affecting directly and indirectly on the Environment and Ecosystem.	Mohanta (2015)
	The chemical properties of surrounding soil of coal mine, such as concentration of Ca, Mg, Pb, Fe, Cu, Zn etc is greatly increased by the farmer's field soil.	Rashid (2014)
Land acquisition	622.28 Acres of land were acquired.	Hearing from BCMCL
Resettlement	320 households were resettled during construction stage.	Hearing from BCMCL

Table 9-18 Reported Social Conflict of Barapukuria Coal Mine

Year	Social conflicts	Source
2011	The national committee to protect oil, gas, mineral resources, ports and power on Monday enforced a six-hour road and rail blockade at Phulbari in Dinajpur, demanding implementation of its seven-point demands including compensation for Aman crops near Barapukuria coal mine area.	New Age (March 29, 2011)
2011	Local peoples blocked railways and a highway protesting the government's plan for open pit mining. Thousands of people demanded compensation for loss of aman crops and postponement of the ongoing land survey. Hundreds of people from Chowhaati, Durgapur, Shahgram, Rambhadrapur, Yousufpur and Bagra villages attacked the 'National Committee' members. At least five people were injured during the ten-minute-long clash.	The Daily Star, (May 5, 2011)
2011	Barapukuria coal miners and staffers stopped production at the mine, demanding regularisation of their jobs.	The Daily Star, (Aug. 24, 2011)
2012	At least 20 people, including three policemen, were injured as thousands of villagers protested and clashed with police. The protestors were demanding disbursement of money granted under the authorities' compensation package; the affected people have been agitating since 2009 after at least 627 acres of land subsided at 10 villages.	The Daily Star, (July 9, 2012)

(2) Accident at Barapukuria Coal Mine

Two serious accidents have been reported by Hoshour (2011) so far. One of it is a fatal accident of a British mining expert by a gas leakage happened in 2005. Second one is a roof cave causing one person dead and 19 wounded in 2010.

9.5.3 Environmental and social risk of coal development

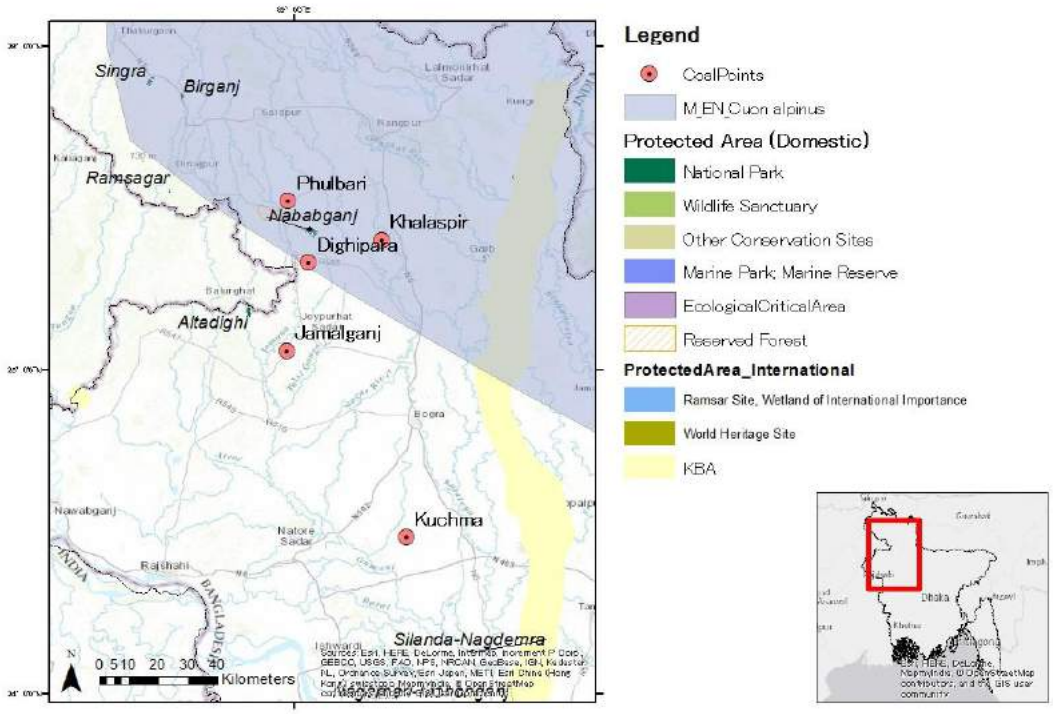
There are several potential coal mine areas in Bangladesh. Among them only one project, Phulbari, has prepared the EIA report which is fully opened on the web. Based on the EIA reports of the Phulbari Coal mine various impacts are expected as shown in Table 9-19. The impacts are larger than Barapukuria because the mining method is open cut.

Table 9-19 Main Environmental and Social Impact Described in the EIA Report of Phulbari Coal Mine

Items	Impact
Soil	Topsoil removal would be 4,300 hectares.
Air	The maximum predicted PM10 (24-hour) concentrations deriving exclusively from Project emissions exceed the residential area standard of the Government only at two locations during year 5 assessment stage.
Surface water	The net result of this land settlement is that some small areas, especially the area immediately to the north of the mine site, could be inundated during a 100-year flood to depths of around 0.2–0.5 m. As it is anticipated that much of this low flow release will be extracted by irrigators, it can be concluded that the mine dewatering flows are unlikely to cause any hydrologic or hydraulic problems in the Little Jamuna River. The Khari Pul creek (which is actually more of a drainage channel, with water flows of 0.3 m3/sec (12 m3/sec during extreme rainfall) carries the untreated wastewater from Barapukuria Coal Mine (just north of the Project area).
Ground water	Dewatering activities will have potential impacts on the local and regional hydrogeological regime, with predicted groundwater drawdown of approximately 25 m at a distance of 4 km from the mine pit, and 15 m at a distance 6 km. This may result in (i) reduction in groundwater availability to the local farming community, Phulbari township, and nearby villages; (ii) reduced baseline flow into watercourses and Ashoorar Beel during the dry season; (iii) land settlement; and (iv) a general reduction in groundwater quality.
Subsidence	Land subsidence in the order of 2 meters (m) at the mine crest, reducing to 0.02 to 0.4 m at a distance of about 5 km from the mine.
Biological Environment	The Project could potentially result in the direct loss of some common habitats. No Sal forests or major Beels will be directly affected by mining activities, but indirect effects may occur as a result of watercourse diversion, discharge of excess mine site-treated “dirty” water, increased sediment load resulting from land clearing and earthworks, mine dewatering activities, and groundwater discharge to watercourses. Other impacts may include weed invasion and elevated noise levels.
Land acquisition	Approximately 5,933 ha of land will be required. Most of them are for the Mine Footprint (85.5%). Other activities are new areas for town and village resettlement sites and the realignment of transport (rail and road) infrastructure.
Sociocultural Environment	Current estimates are that about 9,000 households (some 40,000 people), including some residents at the extreme eastern end of the Phulbari township, will have to be relocated. Population displacement will occur in all four upazilas, with Phulbari being the most affected. In addition, up to 160 households may have to be relocated for the realignment of rail and road corridors.

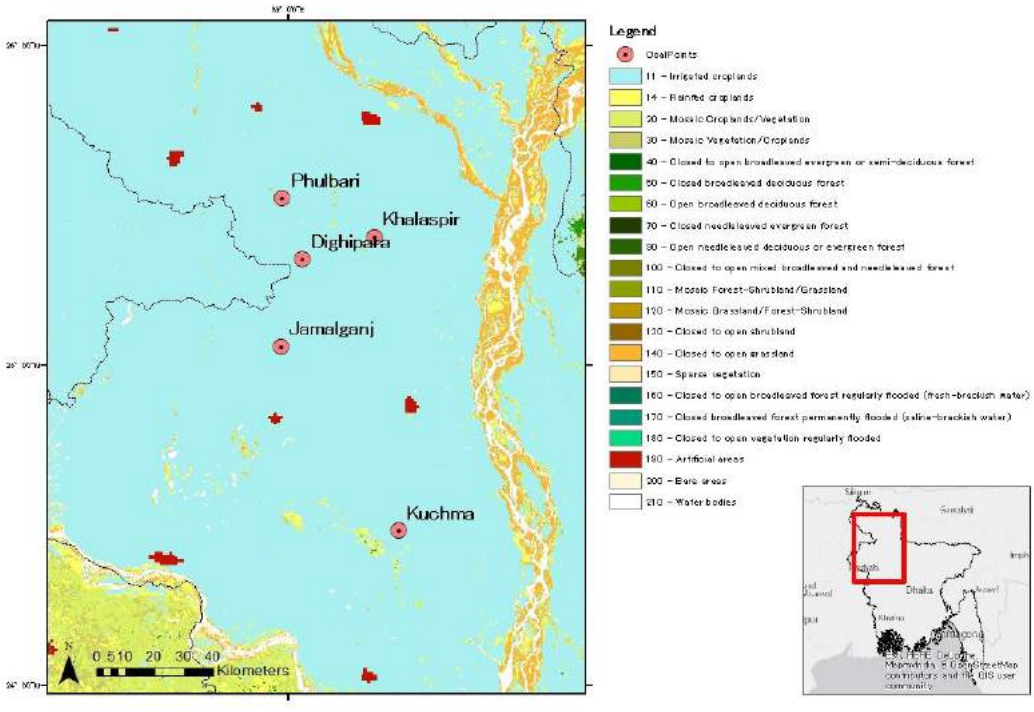
Source: JICA Survey Team

It is not clear that how much environmental impacts will be anticipated for the other four mines. But the impact items would be similar as Phulbari because the locations are ‘Irrigated croplands’ same as Phulbari coal mine (See Figure 9-12). The direct impact on the protected areas will be avoided as the locations are outside of the protected areas. Phulbari, Khalaspir, and Dighipara are in the distribution areas of Dhole (Cuon Alpinus) (See Figure 9-11). Then the impact on bushes and forest area should be minimized and offset mitigation should be considered. Even if underground mining method is selected, some amount of resettlement and land acquisitions will not be avoided. And there is a possibility of people’s protest. Then detail social survey and compensation planning in participatory style is recommended.



Source: JICA Survey Team

Figure 9-11 Possible Coal Mines and Protected Areas



Source: JICA Survey Team

Figure 9-12 Possible Coal Mines and Land Use

Source:

Akter et al. (February 2015) “Degradation of the Surface and Subsurface Water Quality on the Adjacent Area of Barapukuria Coal Mine due to the Improper Effluent Treatment of Mine Waste Water”, International Journal of Emerging Technology and Advanced Engineering Volume 5, Issue 2

Hasan et al. (2013) “Environmental Impact of Coal Mining: A case study on Barapukuria Coal Mining Industry, Dinajpur, Bangladesh” J. Environ. Sci. & Natural Resources, 6(2): 207 - 212, 2013

Kate Hoshour, (March 4, 2011) "Massive protest against Phulbari & Barapukuria coal mines in Bangladesh" International Accountability Project.

Rashid et al. (2014) “Environmental Impact of Coal Mining: A Case Study on the Barapukuria Coal Mining Industry, Dinajpur, Bangladesh” Middle-East Journal of Scientific Research 21 (1): 268-274, 2014

The Daily Star, (May 5, 2011) "Siege protesting open pit mining to continue today"

The Daily Star, (Aug. 24, 2011) "Miners strike halts Barapukuria coal production for 2nd day"

The Daily Star, (July 9, 2012) ”20 injured as Dinajpur land subsidence victims, cops clash,"

Tusher Mohanta et al. (July 2015) “Case study on surrounding area of Barapukuria coal mine impeding soil fertility” International Journal of Scientific & Engineering Research, Volume 6, Issue 7

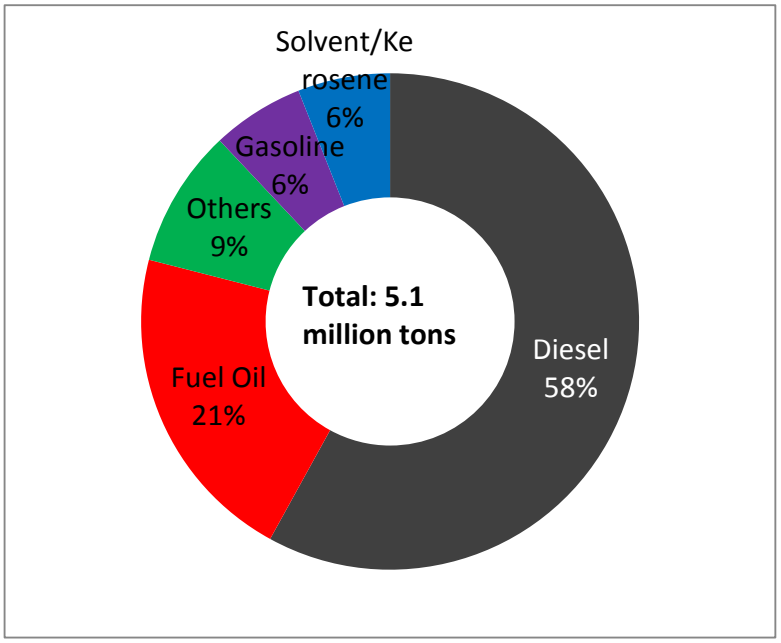
Chapter 10 Oil Products Supply

This Chapter refers to the information collected and analyzed in the JICA-supported survey "Data Collection Survey on Integrated Development for Southern Chittagong Region," (hereafter referred as JICA “Southern Chittagong Survey”) Progress Report (January, 2016), especially on the supply plans. For the demand projection on oil products, this Chapter refers to Chapter 20.

10.1 Forecast of Oil Import

10.1.1 Oil demand

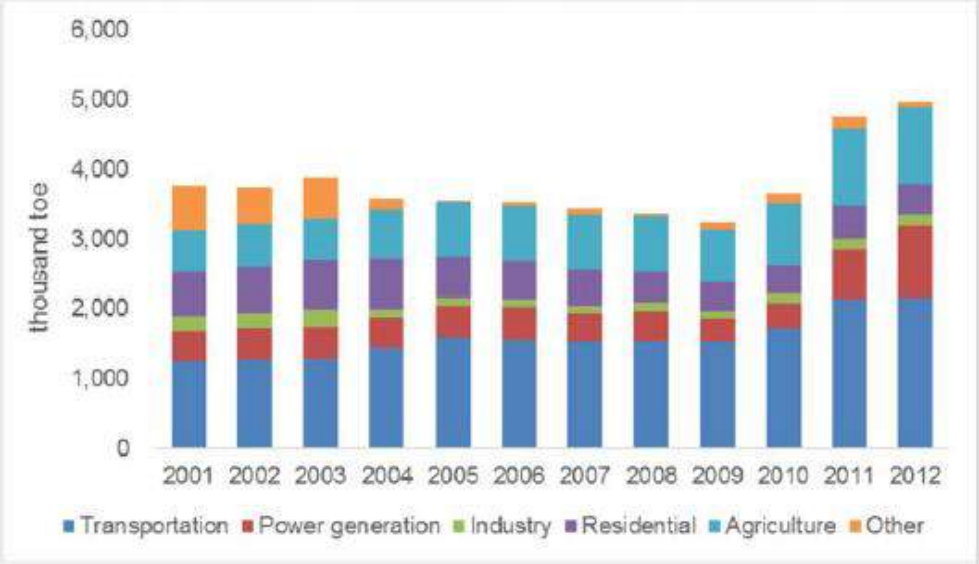
Bangladesh produces a small amount of condensates (about 7,800 barrels per day as of December 2014), from natural gas fields. Condensates are fractionated to petroleum products, such as liquefied petroleum gas (LPG) and motor gasoline and are marketed in the domestic oil market. The domestic condensate supplies only about 5% of the total domestic oil demand in Bangladesh, and the country’s most of the oil demand is met with import from abroad. The country’s annualized oil demand from 2012 to 2013 was 5.1 million tons (about 105,000 barrels per day) according to the obtained data from the Energy Division, Ministry of Power, Energy, and Mineral Resources. More than half of the demand was diesel oil because it is extensively used in various sectors from transportation to power generation, industry, and agricultural sector. The share of fuel oil is relatively high as it is still widely used in the industrial sector. The share of motor gasoline, on the other hand, is low as in Bangladesh motorization process is still at an early stage and the car ownership remains low, as previously described in Chapter 6.



Source: Energy Division, MoPEMR

Figure 10-1 Oil Demand by Products (2012-2013)

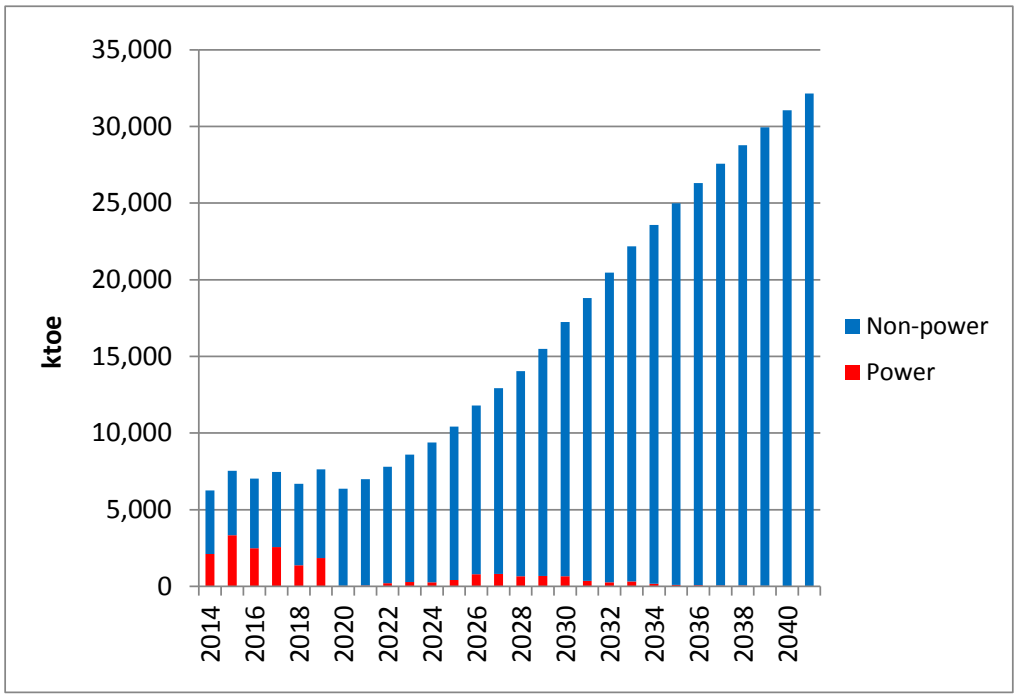
Bangladesh’s oil demand has rapidly grown in the last decade backed by the country’s high economic growth. The country’s oil demand has increased by 1.6 times from 2002 to 2012, and its annual average demand growth rate during the period reached 4.9%. While the demand growth is observed in all sectors, demand in the power generation sector in particular observed the highest growth rate (6.6%).



Source: IEA Energy Balance for non-OECD Countries, 2014 edition

Figure 10-2 Bangladesh's Historical Oil Demand by Sector

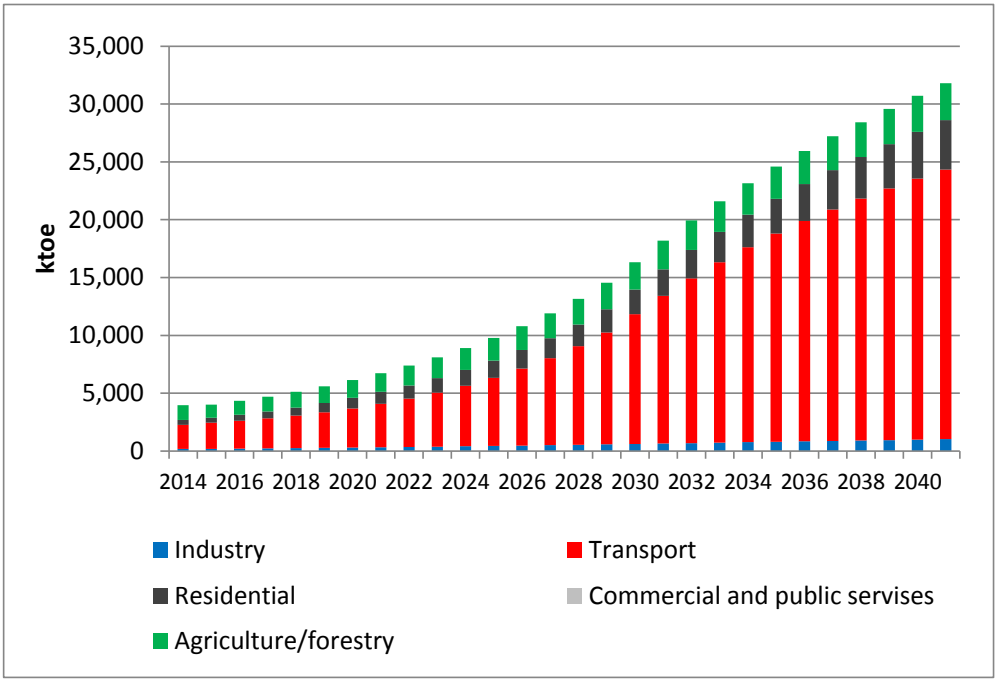
As shown in the below figure, JICA Survey Team forecasts that the country's total oil demand (power sector and non-power sectors) will increase six fold from 2014 to 2041, in average 7.0 % p.a.. Oil demand for power sector will continue to grow until the mid 2020s with the increase of the country's power demand. The demand in power sector, however, will turn into a declining trend because most of the oil products in power sector are consumed by "rental", "quick rental" and captive power generations, and when a large scale power generation becomes online (e.g. an ultra super critical coal power generation) in the mid 2020s, these oil-fired power generations will be retired or kept for stand-by capacity.



Source: JICA Survey Team

Figure 10-3 Oil Demand Projection (Power and Non-Power)

On the other hand, the oil demand from other sectors, most notably in the Transportation sector, is likely to continue its high growth rate and become 10-times more in 2041 than in 2015. This is because the car ownership in Bangladesh is expected to increase as its per-capita income growth, and the country's economic expansion will be associated with high transportation demand of goods and passengers.



Source: JICA Survey Team

Figure 10-4 Oil Demand Projection for Non-Power Sectors, 2014 to 2041

In general, oil demand growth is accelerated when the country's per-capita income approaches to USD 3,000. As 'discussed in Chapter 5, JICA Survey Team projects that Bangladesh's GDP per capita (real) as of 2041 will reach about 3,000 USD.

Though the actual demand growth rate in non-power sector of Bangladesh from 2004 to 2013 was approximately 4%, the PSMP2016 Survey team projects that the future demand growth will be higher than the historical level. Furthermore, Bangladesh used to heavily depend on the domestic natural gas for its transportation sector; however, as the domestic natural gas production declines and the demand in power sector is growing, the demand on natural gas for the Transportation sector is expected to decline, and this reduction will also contribute to oil demand growth in the Transportation sector. Given all these factors, the average growth rate of non-power oil demand is assessed at 7.2% until 2041, and becomes 8-times more than in 2015.

10.1.2 Oil import supply – current status

Because the domestic oil production in Bangladesh is very small, the country depends on import for most of the country's oil needs. The country has one refinery in Chittagong; but its refining capacity is not sufficient to meet the country's total oil demand, and the country imports oil products for the remaining demand. State-owned Eastern Refinery Limited (ERL), the country's only refinery, was built in 1967, and its existing capacity is 1.5 million tons per year. Most of the crude oil processed at ERL is imported from Saudi Arabia and UAE.
Because the country's current oil demand is 5.1 million tons, the remaining 3.6 million tons are met by product imports. Oil products are imported mainly through foreign national oil companies, such as Kuwait Petroleum Corporation or Petronas of Malaysia.

10.1.3 Oil import supply – future projects

As the domestic refining capacity is smaller than the domestic demand, the demand growth automatically increases oil product imports. Bangladesh has several projects to meet the import growth. Domestic refining, to be elaborated in the later section has multiple advantages, such as lower freight cost and lower price volatility against product imports, and is a usually preferred option for an oil importer.

(1) Expansion of Eastern Refinery (ERL)

ERL has a plan to expand its existing capacity from 1.5 million tons to 4.5 million tons. The company plans to finance the expansion project by itself, but it may invite foreign investors by forming a joint venture[31].5 Even after the capacity expansion, however, the domestic refining capacity will be short to the domestic demand. The company, therefore, considers another expansion of the domestic refining capacity, when the expansion of Eastern Refinery is successfully done. The location and the size of the additional capacity expansion have yet been determined[32].

(2) Single Point Mooring (SPM) system project

Shallow draft along the coast of Chittagong has prohibited a direct access of larger-sized tankers, and thus caused a higher shipping cost of crude oil to refinery as lightering operation is required to deliver crude oil. Bangladesh plans to build a single point mooring system offshore Matarbari Island in order to approach this problem. It is reported that China Petroleum Pipeline Bureau (CPP) will undertake the construction of SPM system, and Chinese EXIM bank will provide financial support to the project[33]. Expected construction cost is USD 630 million and expected year of completion is 2018.

SPM system is planned to be built at 60 km offshore from Matarbari Island where the water depth is 27m.The discharged pipeline will be built to the tank terminal that plans to be built in Maheshkhali Island,. The tank terminal will have six crude oil and oil product tanks whose combined capacity will be 2.4 million tons. The discharge pipelines are of two types: one for crude oil and the other for oil product. Discharged crude oil and oil product will be shipped to Eastern Refinery in Chittagong through newly constructed crude oil and oil product pipelines. The capacity of the pipelines is 4.5 million tons per year each. Major components of SPM system are as shown in Table below.

Table 10-1 Major Components of SPM System

Component	Role
Floating Buoy	Floating object that is moored to seabed
Floating Hoses	Hoses to transfer crude oil and oil products from tanker to buoy
Under-buoy Flexible Hoses	Hoses to transter crude oil and oil prodccut from buoy to onshore facility
Anchors	Object to fix the location of the entire SPM sysmte
Pipe-Line End Manifold	Facility to connect flosting hoses to tanker's discharging facility

Source: "Southern Chittagong" Survey Team

[31] JICA "Southern Chittagong" Survey team interview with the Energy Division of MoPEMR, June 7, 2015.
[32] JICA "Southern Chittagong" Survey team interview with the Energy Division of MoPEMR, June 7, 2015.
[33] "Chinese firm gets SPM project Energy division to prepare commercial contract," New Age, 18 January 2015 (http://newagebd.net/87278/chinese-firm-gets-spm-project/#sthash.oIoMyYNT.dpuf)

(3) New refining and petrochemical complex by Kuwait

Kuwait Petroleum Corporation (KPC), the Kuwaiti national oil company, is considering investing a refining and petrochemical complex in Maheshkhali Island in Southern Chittagong. The project emerged in an agenda of the summit meeting when Prime Minister Hasina visited Kuwait in 2000. Although there had not been any progress since then, a delegation of KPC visited Dhaka in May 2015, and they requested to prepare for 1,000 acre (approximately 400 ha) land for the new refining and petrochemical complex in Maheshkhali Island[34]. The planned crude oil distillation capacity is 8.0 million tons and the expected construction cost is USD 6.0 billion. It is reported that the refinery will be built either through a joint venture between KPC and Bangladesh Petroleum Corporation (BPC), or with other international oil companies. KPC considers further expansion beyond 8.0 million tons at a later stage. The size of the refinery, however, could be too large for the domestic oil demand in Bangladesh if the demand would not grow as projected. If that is the case, the surplus capacity would be used for oil product export to neighboring countries.
The detailed configuration of the refining facilities has not been published by KPC as of writing this report. The following table is an expected configuration of the refinery project.

Table 10-2 Expected Configuration of Refinery

Unit	Capacity ('000 tons/y)	Duty
Crude Distillation Unit (CDU)	160	Split crude oil into various hydrocarbon fractions by distillation process
Naphtha Hydrotreating Unit (NHT)	25	Remove sulfur, chlorite, nitrogen, oxygen, metallic compounds in heavy naphtha stream distillated from CDU process to protect CCR catalyst by hydrotreating process.
Kerosene Treating Unit (KTU)	12	Remove sulfur and other inpurities from kerosene stream distillated from CDU process to meet the product specification of Jet A1.
Continuous Catalytic Reforming Unit (CCR)	25	Reform heavy naphtha straight-run from NHT to High Octane Mogas Blending components (reformate) by removing hydrogen with catalysts.
Residue Fluid Catalytic Cracking Unit (RFCC)	35	Convert heavier stream taken from CDU process to lighter stream such as naphtha and diesel oil components with catalysts.
LPG Treating Unit (LTU)	7	Remove sulfur from LPG stream taken from CDU and CCR process to meet the product specifications.
RFCC Naphtha Treating Unit (NTU)	6	Remove sulfur and other inpurities from naphtha stream taken from RFCC process to meet the product specification of motor gasoline.
Propylene Recovery Unit (PRU)	4	Recover propylene from LPG stream to produce high purity propylene.

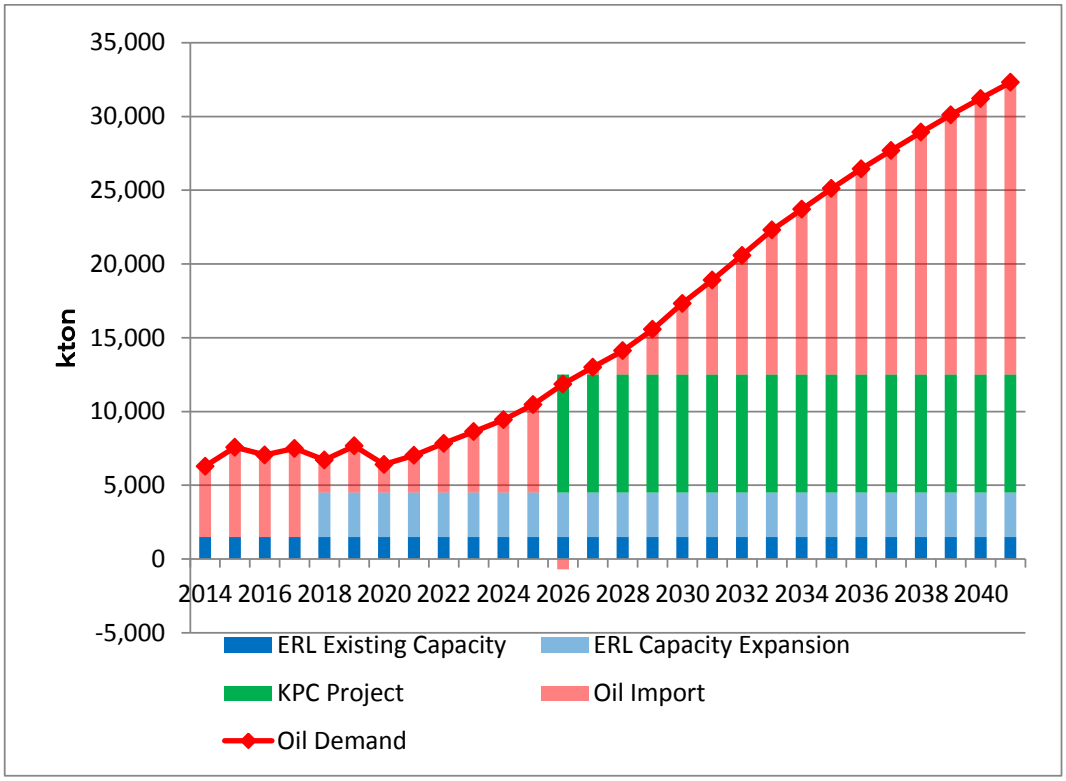
Source: "Southern Chittagong" Survey Team

The project is still at a preliminary stage and the detailed project schedule has not been determined.

[34] "Kuwait to get Maheshkhali land for oil refinery," Financial Express, 25 May 2015 (http://www.thefinancialexpressbd.com/2015/05/25/93953)

10.1.4 Oil supply and demand balance

Oil demand supply balance in Bangladesh is estimated as shown in the below figure. Because the completion year of KPC refinery project has not been determined, its start-up year is tentatively set at 2025 in the following figure[35]. As mentioned above, even with the expansion of Eastern Refinery (ERL), KPC's new refining project or any new refinery expansion by the government, the oil import will continue to increase, as far as the oil demand will sharply grow.



Source: JICA "Southern Chittagong" Survey Team and PSMP2016 Survey Team (project information), and JICA PSMP2016 Survey Team (demand projection)

Figure 10-5 Total Oil Demand & Supply Projection from 2014 to 2041

10.2 Oil Refinery v.s. Oil Import

For a country that has a shortage of refining capacity against the domestic oil demand like Bangladesh, it is important to consider how the country will secure oil product supply, especially whether the country will build a refinery to meet the domestic demand or continue to depend on product import. Building a refinery will obviously bring multiple benefits to the country. Having a refinery will provide more options to secure oil products. If the country has a refinery, the country can import various kinds of crude oil from abroad and thus can diversify its oil supply sources as long as it can be processed at the refinery. Having a refinery also brings a freight cost-saving effect. Crude oil tanker is usually larger than oil product tanker because the size of cargo traded at crude oil market is usually larger than that at oil product market. Freight cost for a large tanker is obviously cheaper than that for a smaller tanker used for product imports. Importing oil in the form of crude oil can also ease negative

[35] Initially, the project completion was plannedto be in 2018. However, the progress of the refinery project is still at an early stage where FEED has not yet started, land acquisition and financing arrangement have not been completed, it is likely to take about 10 years to complete a green-field refinery project. In a similar refiner project in other emerging countries such as Vietnam, it has taken more than 10 years from the initial announcement of the project t commercial operation.

impact of price volatility. Crude oil prices are notoriously volatile, but its price volatility is relatively lower than that of oil product prices. Furthermore, enforcing and monitoring quality specifications of oil product will be easier, if the country can refine its products by itself and does not need to monitor oil product imports from various refineries aboard.

Refinery construction option, on the other hand, certainly has disadvantages against oil product import option. The largest disadvantage is, of course, its need to secure large upfront investment money. Building a greenfield refinery with upgrading capacities often needs several billion dollars and this often becomes the largest obstacle to build a refinery for all countries. Even after the country can build a refinery, it still has a risk of underutilization and low refining margin. Refining industry, particularly in Asia market, has chronically harsh business environment due to excess capacity in the region. Investors in a new refinery have to bear in mind this business risk.

Table 10-3 Pros and Cons of Constructing a Refinery compared with Product Import

Pros	Cons
- More oil product procurement option (diversification of oil product procurement) - Lower freight cost - Lower price volatility - Oil product control	- Large upfront capital expenditures - Risk of low utilization depending on domestic and export demand - Risk of low refining margin for a long period of time

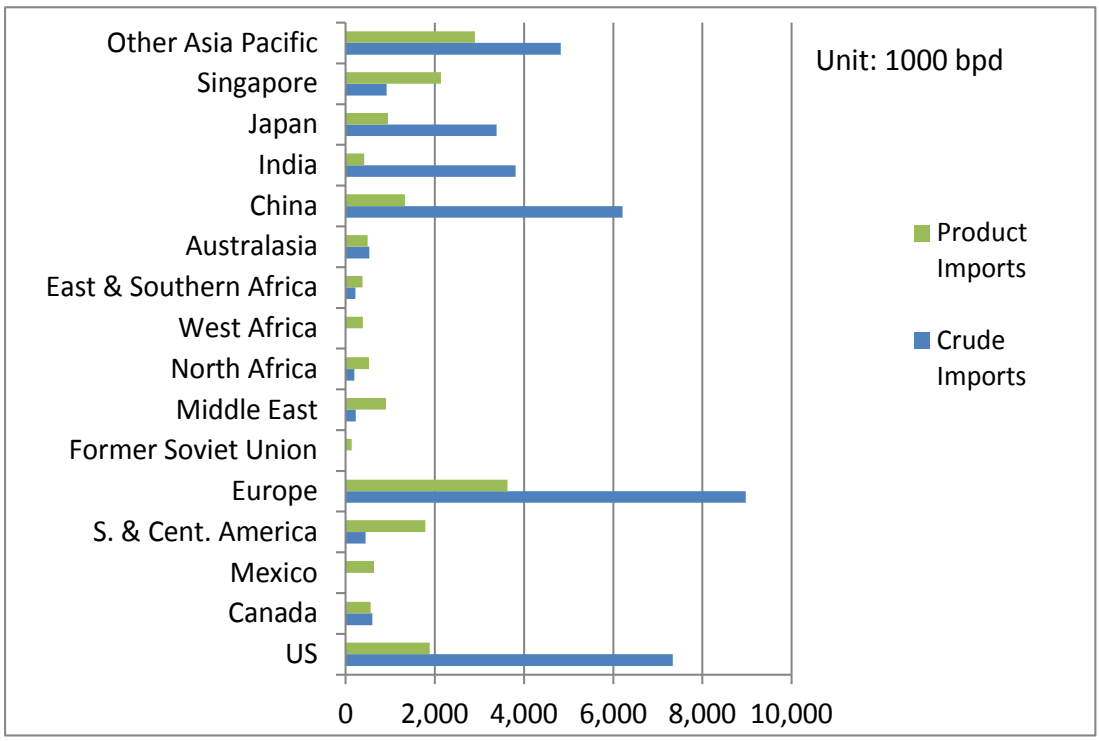
Source: JICA "Data Collection Survey on Integrated Development for Southern Chittagong Region"Survey Team

In the case of refinery and petrochemical project in the southern Chittagong, the project is initiated by KPC and the challenge of large upfront capital investment may be addressed by KPC or other potential investors which KPC may invite. Securing a sufficient fund or finding a reliable operator will maximize the benefits of refinery building and operation.

10.3 Refinery Development – World Trend and Implication to Bangladesh

As described in the above, BPC is planning to construct a new refinery in Moheshkhali area to secure the supply of oil products in Bangladesh. However, Refining industry is matured and considered one of the most competitive industries and merger and re-structuring among refineries are often observed. As discussed in the following section, in Asia, refining margin is lowering, which makes the payout period very long and a huge up-front investment cost difficult to rationalize. Therefore, in Bangladesh, it is quite critical to understand the marketing and operational environment at the planning stage.

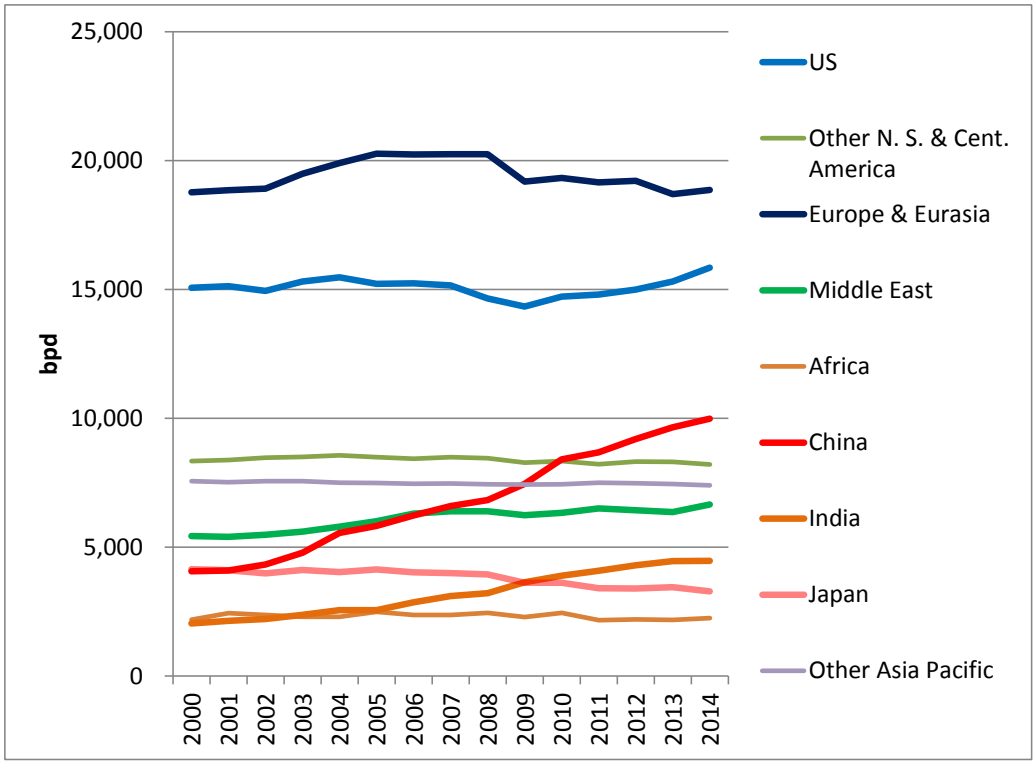
According to the BP Statistics, 37,682,000 bpd of crude oils were refined and converted to oil products in 2014. Among those, or 19,054,000 bpd or 50% of the oil products were sold through the oil product market. This fact shows that a market-impact free refinery is impossible, and that the import/export of oil product is also unavoidable.



Source: BP Statistics 2014

Figure 10-6 Crude Oil and Oil Products Trade

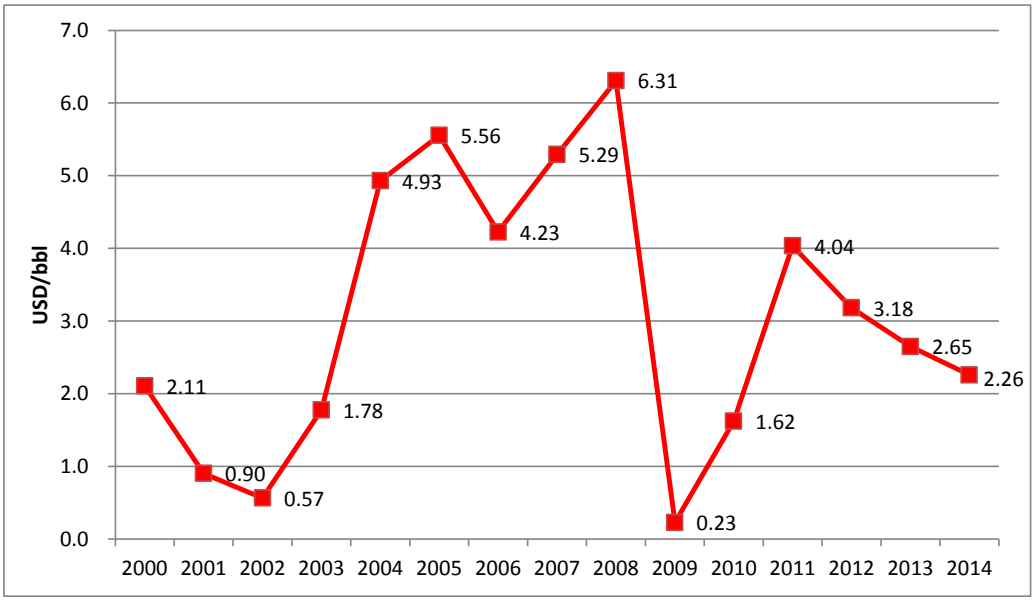
Oil product demand is growing in China, India and Middle East countries. However, demand in Japan, European countries and some other countries in Asia and Pacific region are declining. In Japan, significant refining facilities has been abandoned and demolished, such included 160,000 bpd of modern refinery in Muroran as part of restructuring of the refining industry in Japan. In Thailand, two advanced 160,000 bpd refineries in Map Ta Phut area, commissioned in 1996, were merged together in early 2000s to maintain competitiveness. In UK, several refineries are decommissioned and some of them were converted into tank terminals. UK tank terminal operators are benefited out from futures trading; such includes taking advantage of Contango situation.



Source: Prepared by the JICA Survey Team based on BP Statistics 2014

Figure 10-7 Refinery Throughput Trend

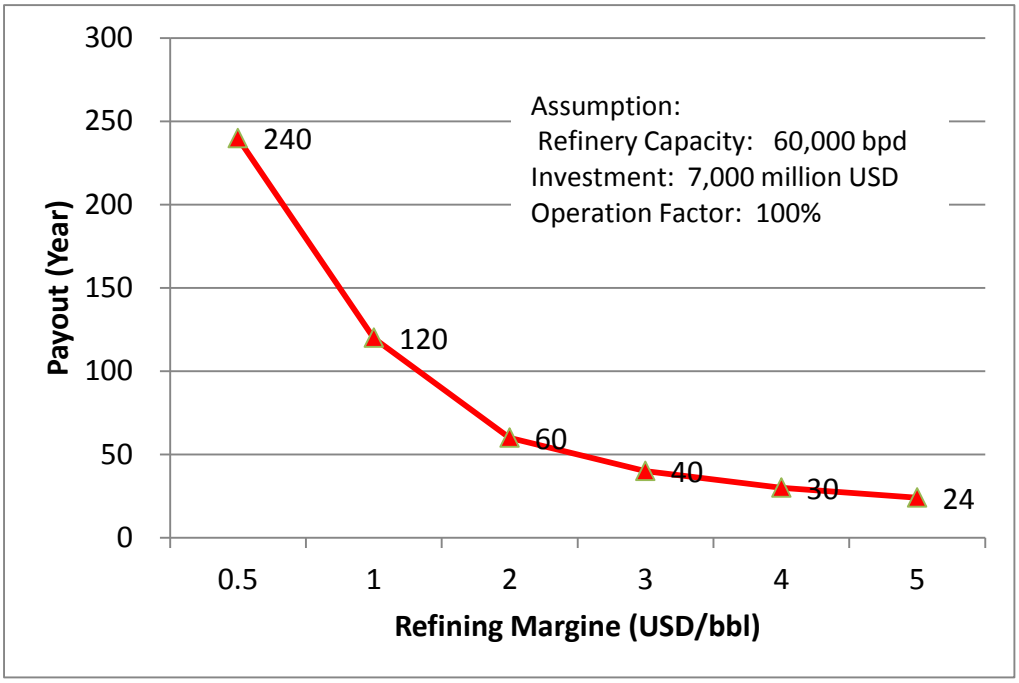
In fact, the refining industry has suffered from low refining margin for the last decade and forecast to continue:



Source: Prepared by the JICA Survey Team based on BP Statistics, 2014

Figure 10-8 Refining Margin

The refining margin has been in the range of almost zero to 6 USD/bbl for the last decade. Simple economics for constructing reasonably competitive refinery with 160,000 bpd capacity of heavy cracking capability, and assuming the investment cost of USD 7,000 million, would take more than 20 years to recover the capital investment at the refining margin of 5 USD/bbl.



Source: Prepared by the JICA Survey Team based on BP Statistics, 2014

Figure 10-9 Refinery Payout

Strategic storage of crude oil and refining capacity was once believed to be a key element for national energy security in Japan before 11 March 2011 (Japan earthquake and tsunami). These crude oil storage and refining capacity were proved to make no contribution to the supply of oil products in emergency, due to the difficulty of blending under such emergency situation. Alternatively, the robust oil product distribution infrastructure and local depots are now considered more important.

Under the low refining margin circumstances, following actions should be considered in parallel with a refinery development plan:

- Construct oil product storage facility,
- Reinforce/expand delivery infrastructure (road, local depots, product oil pipeline, etc.)
- Buy oil products from market,
- Construct refinery after confirming the improvement of refining margin

10.4 LPG

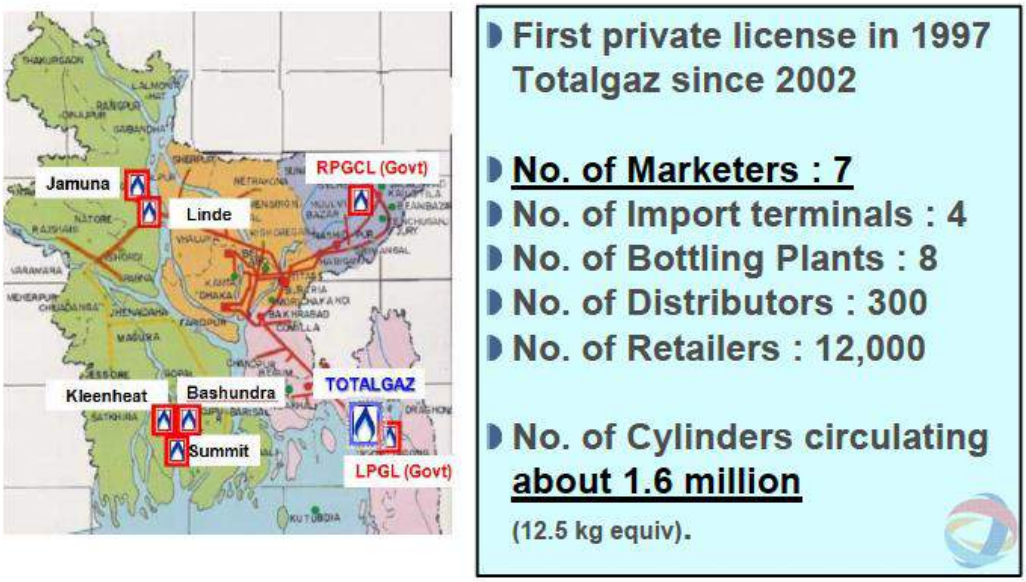
Alike other low and middle income countries, Bangladesh is increasing the reliance on LPG mainly as a proxy of modern household cooking fuel. It is in general a reasonable choice to convert to LPG from conventional solid biomass, because LPG is widely available, highly energy efficient, and less CO2 and air-polluting particles emission than combustion of conventional solid biomass and less risk of deforestation by overexploitation of forest resources[36].

In this section, the current LPG status, issues and countermeasures of LPG promotion are discussed.

10.4.1 LPG current status

The official holistic statistics on LPG is not available in Bangladesh; however, based on the publically available information, the LPG consumption in the last few years approximately 110,000 ton/year, where the private sector distributes 90,000 ton and public sector (i.e. BPC) sells 20,000 ton year[37]. This volume is still quite small 2% compared to the total oil demand in Bangladesh (110,000 ton out of 5.1 million ton mentioned in the previous Section).

In supply side, currently there are four import terminals and seven LPG private operators in Bangladesh, who deals with LPG import, shipping and distribution. Also the government has guaranteed to issue licenses to thirty new private operators[38]. For further downstream value chain, there are 12,000 retailers and about 1.6 million cylinders (12.5kg) in the market, which stands for only 4% household penetration[39].



Source: TotalGaz Presentation (ibid.)

Figure 10-10 LPG Status in Bangladesh

[36] IEA World Energy Outlook 2006 Chapter 15, "Energy for Cooking in Developing Countries"

[37] Ministry of Planning, "A Paradigm Shift in Bangladesh Energy Sector towards SDG-7: A Few Insights of Energy Statistics in Bangladesh", November 2015 (http://www.unosd.org/content/documents/14698_SDGs-Incheon-2015-Bangladesh.pdf)

[38] Financial Express "Encouraging the use of LPG by households", April 28, 2016 (http://www.thefinancialexpressbd.com/2016/04/28/28116/EncouragingtheuseofLPGbyhouseholds)

[39] TotalGaz Presentation in the World LPG Conference, February 2012 http://www.wlpga.org/wp-content/uploads/2015/09/Bangladesh_Renzo_Bee_Totalgaz.pdf

10.4.2 LPG policy

Since Bangladesh is facing a serious shortage of the domestic natural gas, the government has stipulated the pipelined gas access limit policy and encourages LPG alternatively (no new gas connections for new household and commercial buildings, and reducing hours for gas distribution). At the same time, Energy Division of GoB has developed the following fifteen items as part of "LPG Strategy Paper", which has obtained the approval of Prime Minister as an authorized policy[40].

1. Natural gas price should be raised to an appropriate level,
2. No further new connection for domestic (residential) customers,
3. LPG price should be at international market level,
4. Gas connection monitoring system should be developed,
5. Natural gas raiser at building should be utilized for LPG,
6. Import tax/duty for LPG cylinder material should be lowered,
7. Land acquisition for LPG business should be promoted,
8. Government's LPG storage capacity should secured and expanded,
9. Tax incentive for LPG import facilities (e.g. LPG road tanker) should be introduced,
10. LPG guideline for customer protection should be introduced (e.g. LPG quality standard, safety measures),
11. Conversion from CNG vehicle to LPG ones should be promoted (should be started from Gov't vehicle),
12. LPG business license fee for private enterprises should be lowered. Currently LPG storage tank development requires 50 lack taka for license,
13. Quality standard, regulation and monitoring for LPG cylinder. Currently poor quality of illegal cylinders caused many explosion accidents,
14. LPG statistics and database, and preceding survey should be implemented,
15. Customer awareness raising for LPG usage should be conducted

Out of above fifteen items, No. 1, 3 and 4 are consisted with the JICA Survey Team's recommendations (refer to Chapter 7 and Chapter 8.) In addition, the JICA Survey Team's assumptions employed in Chapter 6 are found to be consistent with GoB's policy on LPG (e.g. LPG will be mainly consumed in residential sector. For the assumption of the transport sector's LPG demand can be referred in 10.4.4).

It should be noted that BERC does not have explicit regulatory functions (including pricing) on LPG, while BERC Act 2003 does not deny it. Alternatively Energy Division currently takes regulatory roles on LPG. Energy Division may consider such function at BERC in future.

Other LPG regulations will also be defined or revised within the year 2016, such as LPG Rules (2014) to be revised, LPG Bottling Plant Guideline and LPG Conversion Workshop Establishment Guideline to also be developed.

[40] Interview with Energy Division and JICA Survey Team (June 2016). The Strategy Paper accompanies with Action Plan and Roadmap, which are yet approved as of June 2016 hence not disclosable.

10.4.3 LPG price

As mentioned earlier, Bangladesh has two groups of LPG distributors; one is private and the other one is public (BPC). Between these two groups, there is noticeable price difference: privately distributed price is about 1100～1400 Tk/cylinder (12kg/cylinder) , and publically distributed one is 750 Tk/cylinder (12.5kg/cylinder). While the Energy Division well recognizes the gap, they expects that the competition among private distributes drives the price down to somewhere around 800 Tk./cylinder, given the large market share of private distributors. JICA Survey team believes that there should be some corrective actions for this price gap.

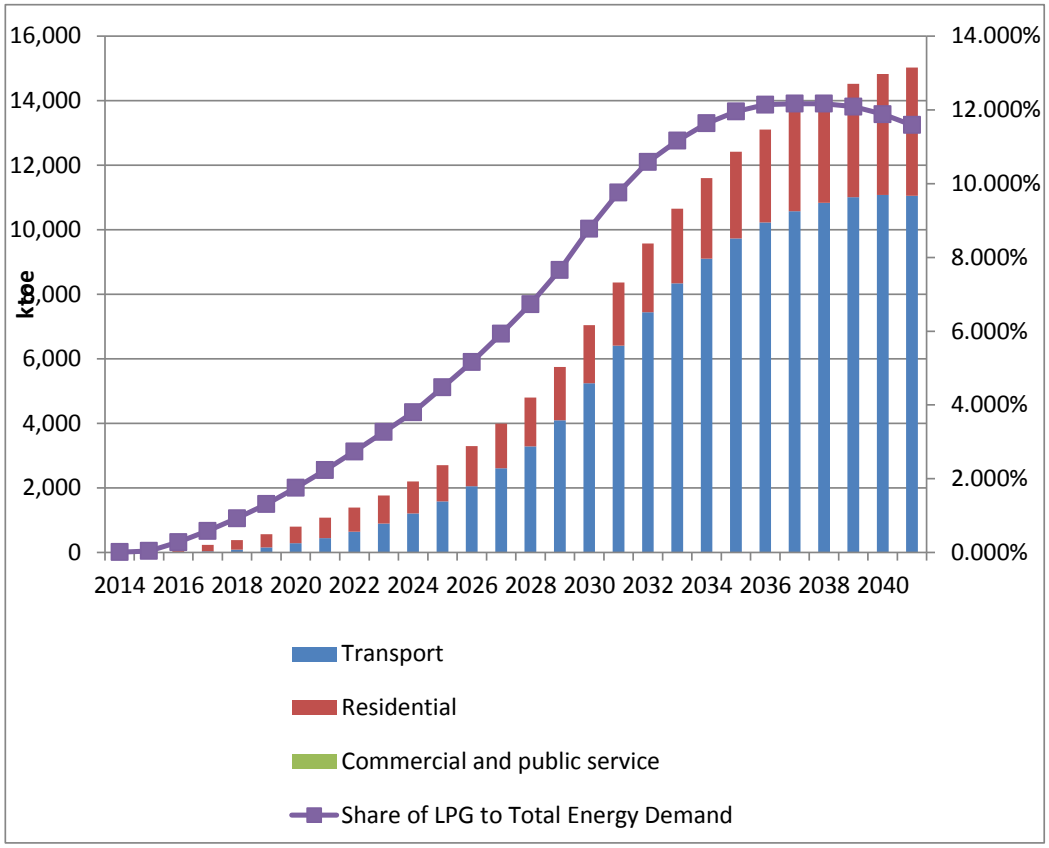
Energy Division also points out that the current difference of one unit of LPG cylinder between private and public (private cylinder is 12kg and public cylinder is 12.5kg) will be standardized to 12kg per cylinder.

10.4.4 LPG future demand

It should be pointed out that, although the government has policy to encourage LPG for household use, there is still no articulated policy or direction on LPG in the holistic picture of energy supply. This means that, in face of the decline of domestic natural gas and prospected sharp LNG import increase, the position of LPG to meet the growing energy demand, not only from the household but demand of all consumer sectors (especially transport sector), is yet clear.

Alternatively, for the purpose of the demand projection, the JICA Survey Team assumes that LPC will be used mainly in the household and transport sector to meet the energy demand-supply gap. More precisely, the team has taken the following assumptions; 1) as for the residential sector, the study team assumed that the natural gas supply will be maintained only for the existing customers and that new houses and apartments are obliged to use LPG instead, and 2) as for the transport sector, the current final consumption amount ratio of oil products and natural gas is roughly 2 to 1. The sharp increase of transportation fuel demand is met by oil products and natural gas (including LNG) at the same ratio (2-to-1), and the transportation fuel demand on gasoline will increase at higher pace than in the past, and the LPG meets the demand-supply gap.

As a result, the demand on LPG is projected to increase drastically at the growth rate almost 35% p.a., 15 times higher in 2041 than in 2016, as shown in the below figure.



Source: JICA Survey Team

Figure 10-11 LPG Demand Projection (Household + Transport) from 2014 to 2041

This demand projection is merely the Survey team's assumption and it could largely vary depending on the policy making; however, it is still noticeable that the oil demand from transport sector – regardless of it would be gasoline, LPG or other oil products, will grow radically.

10.4.5 LPG supply future plan

In order to respond to the anticipated future LPG demand growth, the Government has taken initiative to cooperate with India. It is reported that BPC and Indian Oil Corporation Limited (IOCL) had an MOU in April 2016 for a future LPG plant in Chittagong, which will be the largest plan in Bangladesh[41]. The details of the project (e.g. capacity of the terminal, or construction schedule) are yet disclosed. However, it is reported that the LPG received or produced in Chittagong will be transferred to Tripura, in the northeast India, thorough a pipeline to be developed in the Bangladesh territory. In exchange for this, oil products from a refinery in Numaligarh, Assam India will be received at Parbatipur in the northwest Bangladesh (there is some 700km distance in between).

However, in fact, in Bangladesh, some 80% of LPG is produced and delivered by private companies, including international oil companies. The government role can be, not to invest the capital intensive projects, but appropriate LPG regulation to accommodate healthy market competition and protect consumers.

[41] Financial Express, "BPC, Indian corpn sign MoU on LPG plant today", April 18, 2016 (http://www.thefinancialexpress-bd.com/2016/04/17/26591/BPC,-Indian-corpn-sign-MoU-on-LPG-plant-today)

10.4.6 Issue of LPG

(1) Absence of strategic position of LPG in the energy policy

As pointed out earlier (10.4.2), Bangladesh government has indicated a direction of LPG usage in Household (Domestic) sector and Transport Sector; however, it is yet enough. In fact, the strategic positioning of LPG calls for the strategic positioning of LNG, which will also meet the deficient domestic natural gas supply. The new energy policy should clearly define how LNG and LPG will meet the supply shortage of domestic natural gas, and which sector should be a main consumer of each import fuel.

Simultaneously, pricing policy of LPG and LNG also needs be established.

(2) The gap between household fixed gas tariff

As mentioned earlier, private dealers offer for one 12kg cylinder, ranging from some 1050 Taka to 1300 Taka, while public dealer offers only 750 Taka. Although the GoB (Energy Division) expects the market competition among private dealers drive down the price, it is recommendable to take corrective actions, if GoB wishes to disseminate LPG.

Furthermore, there are striking difference between the LPG marketed price and the current pipelined natural gas (fixed tariff, 450 Taka for one burner for month)- approximately 8 to 1 as seen the below Table 10-4 . GoB has well recognized this issue and will take corrective actions (10.4.2).

Table 10-4 Per MJ Price Difference between LPG Marketed Price and Pipelined Gas for Household

	Fixe Price for one burner		Unit Sales Price		Heat Value per Unit		Unit Price per MJ	
Natural Gas	Tk 600	Tk/month	Tk 8.33	/m3	39.59	MJ/m3	Tk 0.21	/MJ
LPG	Tk 1,050	Tk/12 kg (1 cylinder)	Tk 87.50	/kg	50.80	MJ/kg	Tk 1.72	/MJ

Source: JICA Survey Team

As mentioned in the Chapter 7, Bangladesh's pipeline gas tariff for household itself has long been an issue for energy sector, which has been pointed out in many studies including JICA's, to improve energy efficiency in Bangladesh. In fact, the Government has taken initiatives to improve the situation, and pre-paid gas meter installment supported by JICA and other development partners.

(3) Affordability for households

Even though the government intends to encourage LPG for household as an alternative of pipeline natural gas, the substantial deployment of LPG would be difficult without corrective actions for this price difference. Also, the actually expensive LPG may not be affordable for low income families, especially for the rural ones.

Assuming that one household consumes two cylinders a month, the fuel cost for cooking would be some 2,100 to 2,600 Taka. As per BBS's survey in 2010, the national average monthly income is

11,479 Taka, while the rural one is 9,648 Taka[42]. According to the World Bank's study using 2005 data, Bangladesh rural households spend some 2 to 6 % of their monthly income for biomass fuels[43]. If this expenditure pattern remains almost equal today, the LPG fuel cost would be about 25 % to an average rural household, and give a big pressure to the household expenditure compared to the conventional solid biomass, and LPG dissemination to the rural area would be very difficult. As mentioned in the Chapter 13, Bangladesh's access to modern energy is quite limited (the only 8% of pipelined gas consumers are urban centric, especially in Dhaka area). According to the BBS statistics in 2014, more than 94% of the rural population in Bangladesh uses traditional solid biomass for cooking. However, LPG cannot be affordable to rural household nor contribute to the improvement of the access of the modern energy for all.

This LPG affordability issue must be addressed, not only the LPG tariff or household gas tariff issue, but also from the national energy strategy viewpoint. "LPG subsidy" maybe an easy solution to address the price issue, but should be analyzed carefully.

At the same time, in order to address the LPG affordability issue, biogas should be considered as a domestically and richly available resource. For detailed discussion of potential of biogas and its economic competitiveness over LPG is discussed in Chapter 13 [44].

10.4.7 Pressure to the national coffer

Despite efforts of JICA Survey Team to collect information on LPG subsidies, no GoB official information was provided. However, it is clear that GoB intends to shrink the oil subsidy including LPG in future. Given the LPG future demand projection, this oil subsidy policy is quite important and valuable decision.

[42] BBS, "Report of the household income & expenditure survey 2010"

[43] World Bank, "Expenditure of Low-Income Households on Energy", June 2010, Figure E.2 Monthly Urban Household Expenditure on Biomass.

[44] In the interview with Energy Division in June 2016, they replied that the biogas potential in rural areas is worth for further consideration.

PART IV POWER BALANCE

Chapter 11 Power Development Plan

11.1 Power demand forecast

The power demand forecast is an important factor in the formulation of a future power development plan (PDP). It is not very difficult to find the most efficient way to develop facilities to meet the forecast demand.

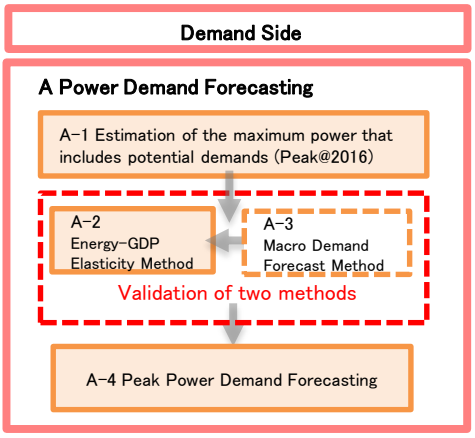
However, the accuracy of the actual demand forecast is at such a level that it is difficult to forecast even the demand for the next day accurately and, in fact, it is almost impossible to accurately forecast the power demand for several years or longer.

Because of this unreliability of the demand forecast, it is not advisable to formulate a PDP optimal for a certain condition in future and promote actual power development in accordance with this PDP. In other words, it is very important in formulating a future PDP to consider all the elements, including the demand variables in the estimation, conduct a sensitivity analysis while changing these variables within their respective reasonable ranges for a certain system, and analyze the relationship between power generating facilities in the system and the economic, environmental and energy security values of the system.Therefore, a long-term vision for the power source composition created by making a rough estimation of the future demand based on a scenario of the macro economic growth, simulating a demand/supply operation somewhat simply using the estimated demand scenario as a variable and formulating the optimal PDP is presented as a recommendation in this chapter.

11.2 Peak demand projection

11.2.1 Implementation flow

As for the methodology of peak demand projection for PSMP2016, this study adopted the “GDP elasticity method”, which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan. However, it has to be noted that this methodology disregards various factors that may also affect the power demand; hence, the results may differ significantly from other methodologies. This study therefore also tried the peak demand projection based on the “Sectorial analysis method” to confirm the appropriateness of the “GDP elasticity method”. This peak demand projection referred to the economic development projection that was discussed in Chapter 5. Following the aforementioned, this study compared the results of the peak demand projection with the projection for energy supply and demand balance that was discussed in Chapter 6 to check consistency, and then integrated both projections and completed a unified “energy & power supply-demand projection”[45]. The following shows the flow chart for power demand forecasting.



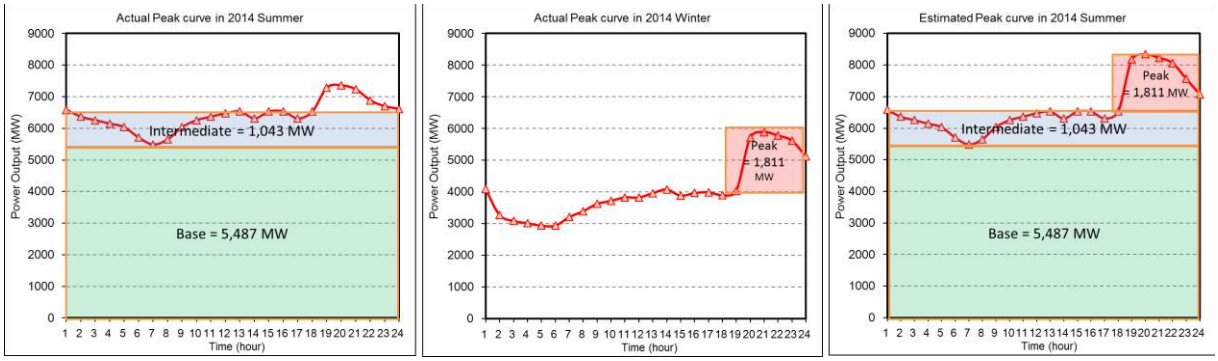
Source: JICA Study Team

[45] The energy supply and demand projection in Chapter 6 shows the results after comparing the peak demand projection in this chapter and confirming the consistency between them.

Figure 11-1 Power demand forecasting flow

11.2.2 Assumptions

Deciding the level at which the baseline is to be set is an important factor in peak power demand forecasting. Because of the particular situation in Bangladesh whereby rolling blackouts have been used as a measure to circumvent power shortages at the peak hours, the recorded maximum power consumption does not include such potential power demand. Therefore, an accurate forecast of the maximum demand including the potential demand requires a theoretical estimation of load curves from the daily operational data with particular attention on the characteristics of the seasonal changes in the daily load curve and the frequency and durations of rolling blackouts.
Because rolling blackouts have been relatively rare on weekends and holidays in the winter (between November and January), a daily load curve gives an actual peak load (at the hours of the peak power consumption for lighting) that is quite accurate. A daily load curve in the summer gives estimates of the base and intermediate loads close to the recorded values.
Therefore, a composite daily load curve representing the peak power demand was created from the daily load curve in the summer with part of the peak hours replaced by the same part of the daily load curve in the winter as shown in the figure below. The peak power demand in FY 2014, which was used as the baseline for the peak demand forecast, was set at 8,039 MW by adding the base and intermediate load in the summer (5,487 MW and 1,043 MW, respectively) and the peak load in the winter (1,811 MW) recorded in FY 2015. The peak power demand in FY 2016 was estimated at 8,921 MW in the same way and this value was used as the reference value in the peak power demand forecast.



Source: JICA Study Team

Figure 11-2 Estimated Composite Daily Load Curve in the summer in Bangladesh

The table below shows the results of the maximum load analysis. The maximum load recorded in FY 2015 was 7,500 MW, while a maximum load of approximately 8,921 MW was estimated from the estimated base load of 6,170 MW, the potential intermediate and peak-hour loads and the actual net/gross ratio. Therefore, the 8,291 MW obtained in this analysis was used as the reference value in the long-term demand forecast up to 2041.

Table 11-1 Peal load estimation 2005-2015

Fiscal Year	Estimated Base Load (MW)	Estimated Intermediate Load (MW)	Estimated Base Over Peak Load (MW)	Estimated Peak Load (MW)	Actual Net/Gross	Estimated Net Peak Load (MW)	Growth (%)	Actual Net Peak Load (MW)	Growth (%)
2005	3,097	-	1,379	4,476	0.95	4,230		3,900	
2006	3,600	-	1,413	5,013	0.95	4,737	12.0%	4,200	7.7%
2007	4,050	-	1,063	5,113	0.95	4,832	2.0%	4,500	7.1%
2008	4,190	-	1,484	5,674	0.95	5,362	11.0%	4,600	2.2%
2009	4,150	-	1,500	5,650	0.95	5,339	-0.4%	5,050	9.8%
2010	4,300	817	1,462	6,579	0.95	6,258	16.4%	5,550	9.9%
2011	4,400	836	1,496	6,732	0.95	6,411	2.3%	5,550	0.0%
2012	5,000	950	1,700	7,650	0.96	7,326	13.6%	6,600	18.9%
2013	5,300	1,007	1,802	8,109	0.96	7,764	6.0%	6,600	0.0%
2014	5,487	1,043	1,811	8,341	0.96	8,039	2.9%	7,356	11.5%
2015	6,170	1,111	1,974	9,255	0.96	8,921	11.0%	7,500	2.0%

Source: JICA Study Team

11.3 Peak demand projection using gdp elasticity method

The peak demand up to 2041 was estimated by multiplying the GDP projection based on the economic development prospects in Chapter 5 by the GDP elasticity of peak demand, taking also into consideration the effect of peak demand reduction referring to the Bangladesh government's target for energy efficiency.

11.3.1 Economic development projection

The projection for GDP discussed in Chapter 5 was adopted regarding the economic development prospects. Not only the "Base Scenario" but also the "High-growth scenario" and the "Low-growth scenario" were referred to in the simulation. All of these scenarios assumed that the GDP growth target up to 2020 as stipulated in the Seventh Five-Year Plan would be achieved. After the 2020s, when the growth rate becomes gradually more moderate in the course of maturity of economic development, the pace of the declining growth rate is relatively slow in the "High-growth Scenario", whereas in the "Low-growth Scenario" it is relatively rapid.
As a result, whereas the "Base Scenario" assumed that the average growth rate of GDP (real price) from 2036 to 2041 becomes 4.4% p.a., the "High-growth scenario" assumed 5.0% p.a. and the "Low-growth Scenario" assumed 4.0% p.a.

Table 11-2 Real GDP Growth Rate Projection (constant at 2005 price)

	2010	2015	2020	2025	2030	2035	2041
Base Scenario	6.1%	6.3%	7.4%	7.4%	6.3%	5.3%	4.4%
High-growth Scenario	6.1%	6.3%	7.4%	7.5%	6.6%	5.7%	5.0%
Low-growth Scenario	6.1%	6.3%	7.4%	7.3%	6.1%	4.9%	4.0%

Source: JICA Survey Team

Table 11-3 Nominal GDP Growth Rate Projection (current price)

		2010	2015	2020	2025	2030	2035	2041
Base Scenario	USD	10.7%	11.0%	11.9%	11.4%	10.0%	8.6%	7.3%
	BDT	13.3%	13.7%	13.3%	12.7%	11.1%	9.5%	8.0%
High-growth scenario	USD	10.7%	11.0%	11.9%	11.6%	10.3%	9.1%	7.9%
	BDT	13.3%	13.7%	13.3%	12.8%	11.4%	9.9%	8.6%
Low-growth Scenario	USD	10.7%	11.0%	11.9%	11.4%	9.8%	8.3%	6.9%
	BDT	13.3%	13.7%	13.3%	12.7%	10.9%	9.1%	7.6%

Source: JICA Survey Team

11.3.2 Validation of gdp elasticity

The table below shows the historical trend for GDP elasticity of power demand in Bangladesh for the last 10 years, and the average was 1.27. Considering that the elasticity in some other ASEAN countries (Thailand, Indonesia, Malaysia) also fell in the range between 1.1 and 1.3, this study assumes that this 1.27 will continue in the BAU (business-as-usual) case.

Table 11-4 Historical Trend of GDP Elasticity of Power Demand in Bangladesh

Year	GDP at Constant Market Price (Million Taka)	GDP Growth Rate (%)	Actual Net Energy Generation (GWH)	Energy Not served	Forecasted Net Generation (GWH)		GWH Growth	Elasticity
2005	2,669,740		21,408	260	21,668	21,798		
2006	2,846,726	6.6%	22,978	843	23,821	24,243	7.3%	1.1
2007	3,029,709	6.4%	23,268	2,264	25,532	26,664	1.3%	0.2
2008	3,217,855	6.2%	24,946	1,107	26,053	26,606	7.2%	1.2
2009	3,406,524	5.9%	26,533	1,363	27,896	28,577	6.4%	1.1
2010	3,608,450	5.9%	29,247	1,829	31,076	31,991	10.2%	1.7
2011	3,850,500	6.7%	31,355	1,899	33,254	34,204	7.2%	1.1
2012	4,090,530	6.2%	35,118	1,647	36,765	37,588	12.0%	1.9
2013	4,337,200	6.0%	38,229	1,070	39,299	39,834	8.9%	1.5
2014	4,601,770	6.1%	42,195	515	42,710	42,968	10.4%	1.7
								1.27

Source: JICA Survey Team and BPDB

Table 11-5 Actual Energy-GDP Elasticity in ASEAN Countries

Thailand	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	170,956,863,507	181,708,833,946	189,318,499,954	198,723,685,564	209,524,501,833	213,140,198,921	211,566,627,910	227,448,322,637	229,344,519,381	246,139,191,582	
	Electricity consumption (GWh)	106,959	115,044	121,229	127,811	133,178	135,450	135,209	149,320	148,700	161,749	
	(A) GDP growth	7.2%	6.3%	4.2%	5.0%	5.4%	1.7%	-0.7%	7.5%	0.8%	7.3%	
	(B)Electricity growth	6.8%	7.6%	5.4%	5.4%	4.2%	1.7%	-0.2%	10.4%	-0.4%	8.8%	
	(A)/(B)	0.94	1.20	1.28	1.09	0.77	0.99	0.24	1.39	-0.50	1.20	
	(A') 5-year average GDP	5.2%	5.5%	5.4%	5.8%	5.6%	4.5%	3.1%	3.7%	2.9%	3.3%	
	(B') 5-year average Electricity	5.9%	7.2%	6.6%	6.7%	5.9%	4.8%	3.3%	4.3%	3.1%	4.0%	
	(A')/(B')	1.1	1.3	1.2	1.2	1.0	1.1	1.1	1.1	1.1	1.2	1.1
Indonesia	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	257,516,488,195	270,471,818,103	285,868,619,206	301,594,114,117	320,730,327,692	340,018,098,955	355,757,098,753	377,898,901,817	401,214,448,583	425,407,883,059	
	Electricity consumption (GWh)	90,441	100,097	107,705	113,415	121,614	128,810	136,053	147,972	159,867	175,329	
	(A) GDP growth	4.8%	5.0%	5.7%	5.5%	6.3%	6.0%	4.6%	6.2%	6.2%	6.0%	
	(B)Electricity growth	3.9%	10.7%	7.6%	5.3%	7.2%	5.9%	5.6%	8.8%	8.0%	9.7%	
	(A)/(B)	0.81	2.12	1.34	0.96	1.14	0.98	1.21	1.41	1.30	1.60	
	(A') 5-year average GDP	3.7%	4.6%	4.7%	5.1%	5.5%	5.7%	5.6%	5.7%	5.9%	5.8%	
	(B') 5-year average Electricity	6.7%	7.0%	6.4%	6.1%	6.9%	7.3%	6.3%	6.6%	7.1%	7.6%	
	(A')/(B')	1.8	1.5	1.3	1.2	1.3	1.3	1.1	1.1	1.2	1.3	1.3
Malaysia	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	127,611,641,758	136,268,098,017	143,534,102,611	151,550,262,734	161,096,089,356	168,879,881,704	166,323,572,126	178,674,711,521	188,133,365,986	198,430,759,593	
	Electricity consumption (GWh)	73,420	77,252	80,755	84,573	89,358	92,881	102,920	110,853	111,852	120,637	
	(A) GDP growth	5.8%	6.8%	5.3%	5.6%	6.3%	4.8%	-1.5%	7.4%	5.3%	5.5%	
	(B)Electricity growth	6.6%	5.2%	4.5%	4.7%	5.7%	3.9%	10.8%	7.7%	0.9%	7.9%	
	(A)/(B)	1.14	0.77	0.85	0.85	0.90	0.82	-7.14	1.04	0.17	1.43	
	(A') 5-year average GDP	5.3%	5.4%	4.7%	5.8%	6.0%	5.8%	4.1%	4.5%	4.4%	4.3%	
	(B') 5-year average Electricity	6.6%	6.6%	5.7%	5.4%	5.3%	4.8%	5.9%	6.5%	5.8%	6.2%	
	(A')/(B')	1.3	1.2	1.2	0.9	0.9	0.8	1.5	1.5	1.3	1.5	1.2

Source: JICA Survey Team

11.3.3 Assumption of the effects of peak demand reduction

As discussed in Chapter 6, "Energy Efficiency and Conservation Master Plan up to 2030" (EECMP) was published by the Sustainable and Renewable Energy Development Authority (SREDA) and Power Division in March 2015 with technical assistance by JICA. This master plan set a target for energy efficiency to "reduce the energy intensity of GDP by 15% by 2021 and by 20% by 2030, compared to 2014".

The energy efficiency target in EECMP is in terms of energy consumption (ktoe), but calculating the effect of achieving this target on the reduction of peak power demand (MW) requires a complicated conversion considering the electrification rate and annual load factor (= annual electricity consumption/peak demand) on a timeline.

Following discussion with the Power Division and BPDB, this study therefore set a more simplified target of "reducing the peak power demand by 20% from the BAU case (GDP elasticity = 1.27) referring to EECMP" and formulated the projection of peak power demand. Then, the results were compared with the primary energy supply and demand projection that was discussed in Chapter 6, and adjustments made if there were inconsistencies between them.

11.3.4 Peak demand projection using gdp elasticity method

The peak demand projections considering the aforementioned factors are shown in the following tables.

Table 11-6 Peak Demand Projection Using GDP Elasticity Method (base cases)

Model	GDP Elasticity Method								Sectorial Analysis Method
FY	GDP growth rate	Elasticity	Electricity growth rate	Total Demand without EE&C	Effect of EE&C	Total Demand with EE&C	Captive power to the grid	GDP Elasticity Method	Sectorial Analysis Method
2015	6.5%	1.27	8.3%	8,920	0.0%	8,920	-	8,920	8,900
2016	7.0%	1.27	8.9%	9,713	1.3%	9,583	-	9,584	9,500
2017	7.2%	1.27	9.1%	10,601	2.7%	10,318	-	10,400	10,400
2018	7.4%	1.27	9.4%	11,597	4.0%	11,134	-	11,200	11,300
2019	7.6%	1.27	9.7%	12,717	5.3%	12,039	-	12,100	12,300
2020	8.0%	1.27	10.2%	14,009	6.7%	13,075	149	13,300	13,400
2021	7.8%	1.27	9.9%	15,394	8.0%	14,163	297	14,500	14,600
2022	7.6%	1.27	9.6%	16,875	9.3%	15,300	446	15,800	15,800
2023	7.4%	1.27	9.4%	18,453	10.7%	16,485	594	17,100	17,100
2024	7.2%	1.27	9.1%	20,129	12.0%	17,714	743	18,500	18,500
2025	6.9%	1.27	8.8%	21,903	13.3%	18,983	891	19,900	19,900
2026	6.7%	1.27	8.5%	23,776	14.7%	20,288	1,040	21,400	21,400
2027	6.5%	1.27	8.3%	25,744	16.0%	21,625	1,188	22,900	22,900
2028	6.3%	1.27	8.0%	27,806	17.3%	22,986	1,337	24,400	24,500
2029	6.1%	1.27	7.7%	29,959	18.7%	24,367	1,486	25,900	26,000
2030	5.9%	1.27	7.5%	32,198	20.0%	25,759	1,634	27,400	27,700
2031	5.7%	1.27	7.2%	34,520	20.0%	27,616	1,634	29,300	29,400
2032	5.5%	1.27	6.9%	36,916	20.0%	29,533	1,634	31,200	31,100
2033	5.3%	1.27	6.7%	39,381	20.0%	31,505	1,634	33,200	32,900
2034	5.0%	1.27	6.4%	41,906	20.0%	33,525	1,634	35,200	34,600
2035	4.8%	1.27	6.1%	44,483	20.0%	35,587	1,634	37,300	36,400
2036	4.6%	1.27	5.9%	47,101	20.0%	37,681	1,634	39,400	38,200
2037	4.4%	1.27	5.6%	49,750	20.0%	39,800	1,634	41,500	39,900
2038	4.4%	1.27	5.6%	52,526	20.0%	42,021	1,634	43,700	41,800
2039	4.4%	1.27	5.5%	55,436	20.0%	44,349	1,634	46,000	43,700
2040	4.3%	1.27	5.5%	58,486	20.0%	46,789	1,634	48,500	45,700
2041	4.3%	1.27	5.5%	61,681	20.0%	49,345	1,634	51,000	47,800

EE&C: Energy Efficiency and Conservation

Source: JICA Survey Team and BPDB

Table 11-7 Peak Demand Projection Using GDP Elasticity Method (high cases)

Model	GDP Elasticity Method								Sectorial Analysis Method
FY	GDP growth rate	Elasticity	Electricity growth rate	Total Demand without EE&C	Effect of EE&C	Total Demand with EE&C	Captive power to the grid	GDP Elasticity Method	Sectorial Analysis Method
2015	6.5%	1.27	8.3%	8,920	0.0%	8,920	-	8,920	8,900
2016	7.0%	1.27	8.9%	9,713	1.3%	9,583	-	9,600	9,500
2017	7.2%	1.27	9.1%	10,601	2.7%	10,318	-	10,400	10,400
2018	7.4%	1.27	9.4%	11,597	4.0%	11,134	-	11,200	11,300
2019	7.6%	1.27	9.7%	12,717	5.3%	12,039	-	12,100	12,300
2020	8.0%	1.27	10.2%	14,009	6.7%	13,075	149	13,300	13,500
2021	7.8%	1.27	9.9%	15,401	8.0%	14,169	297	14,500	14,700
2022	7.6%	1.27	9.7%	16,896	9.3%	15,319	446	15,800	15,900
2023	7.5%	1.27	9.5%	18,499	10.7%	16,526	594	17,200	17,200
2024	7.3%	1.27	9.3%	20,212	12.0%	17,787	743	18,600	18,700
2025	7.1%	1.27	9.0%	22,040	13.3%	19,101	891	20,000	20,100
2026	6.9%	1.27	8.8%	23,984	14.7%	20,466	1,040	21,600	21,700
2027	6.8%	1.27	8.6%	26,045	16.0%	21,878	1,188	23,100	23,300
2028	6.6%	1.27	8.4%	28,225	17.3%	23,333	1,337	24,700	25,000
2029	6.4%	1.27	8.1%	30,525	18.7%	24,827	1,486	26,400	26,700
2030	6.2%	1.27	7.9%	32,945	20.0%	26,356	1,634	28,000	28,500
2031	6.1%	1.27	7.7%	35,484	20.0%	28,387	1,634	30,100	30,400
2032	5.9%	1.27	7.5%	38,139	20.0%	30,512	1,634	32,200	32,300
2033	5.7%	1.27	7.3%	40,910	20.0%	32,728	1,634	34,400	34,300
2034	5.5%	1.27	7.0%	43,791	20.0%	35,033	1,634	36,700	36,300
2035	5.4%	1.27	6.8%	46,780	20.0%	37,424	1,634	39,100	38,400
2036	5.2%	1.27	6.6%	49,871	20.0%	39,896	1,634	41,600	40,500
2037	5.0%	1.27	6.4%	53,057	20.0%	42,445	1,634	44,100	42,700
2038	5.0%	1.27	6.3%	56,424	20.0%	45,139	1,634	46,800	44,900
2039	5.0%	1.27	6.3%	59,982	20.0%	47,986	1,634	49,700	47,300
2040	4.9%	1.27	6.3%	63,741	20.0%	50,993	1,634	52,700	49,800
2041	4.9%	1.27	6.2%	67,710	20.0%	54,168	1,634	55,900	52,400

EE&C: Energy Efficiency and Conservation

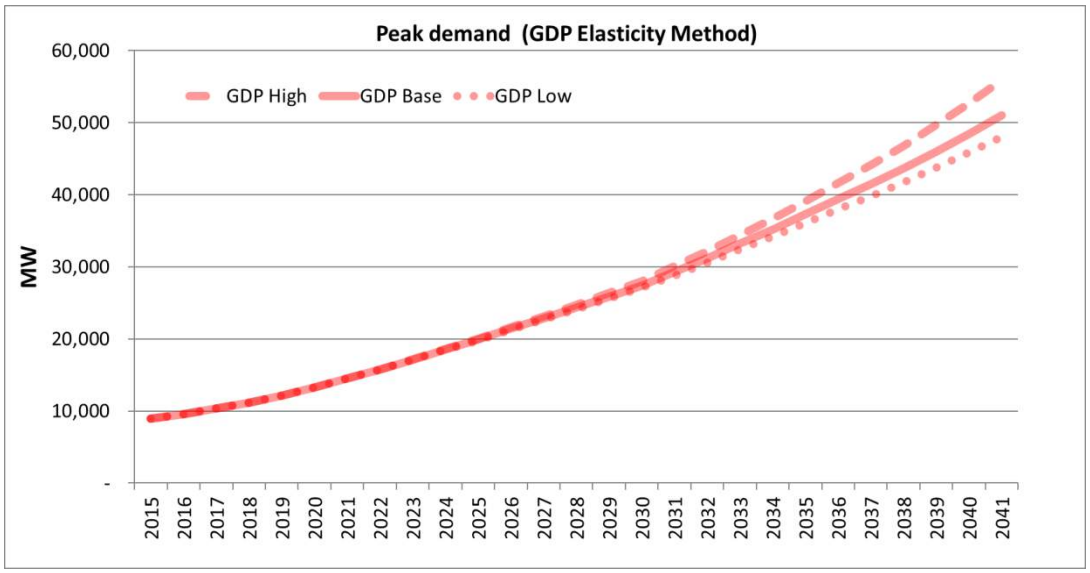
Source: JICA Survey Team and BPDB

Table 11-8 Peak Demand Projection Using GDP Elasticity Method (low cases)

Model	GDP Elasticity Method								Sectorial Analysis Method
FY	GDP growth rate	Elasticity	Electricity growth rate	Total Demand without EE&C	Effect of EE&C	Total Demand with EE&C	Captive power to the grid	GDP Elasticity Method	Sectorial Analysis Method
2015	6.5%	1.27	8.3%	8,920	0.0%	8,920	-	8,920	8,900
2016	7.0%	1.27	8.9%	9,713	1.3%	9,583	-	9,600	9,500
2017	7.2%	1.27	9.1%	10,601	2.7%	10,318	-	10,400	10,300
2018	7.4%	1.27	9.4%	11,597	4.0%	11,134	-	11,200	11,200
2019	7.6%	1.27	9.7%	12,717	5.3%	12,039	-	12,100	12,200
2020	8.0%	1.27	10.2%	14,009	6.7%	13,075	149	13,300	13,300
2021	7.8%	1.27	9.9%	15,390	8.0%	14,159	297	14,500	14,400
2022	7.5%	1.27	9.6%	16,861	9.3%	15,288	446	15,800	15,600
2023	7.3%	1.27	9.3%	18,423	10.7%	16,458	594	17,100	16,900
2024	7.1%	1.27	9.0%	20,074	12.0%	17,665	743	18,500	18,200
2025	6.8%	1.27	8.7%	21,813	13.3%	18,904	891	19,800	19,500
2026	6.6%	1.27	8.4%	23,638	14.7%	20,171	1,040	21,300	20,900
2027	6.4%	1.27	8.1%	25,545	16.0%	21,458	1,188	22,700	22,300
2028	6.1%	1.27	7.8%	27,529	17.3%	22,758	1,337	24,100	23,800
2029	5.9%	1.27	7.5%	29,586	18.7%	24,063	1,486	25,600	25,300
2030	5.6%	1.27	7.2%	31,709	20.0%	25,367	1,634	27,100	26,700
2031	5.4%	1.27	6.9%	33,890	20.0%	27,112	1,634	28,800	28,300
2032	5.2%	1.27	6.6%	36,120	20.0%	28,896	1,634	30,600	29,800
2033	4.9%	1.27	6.3%	38,391	20.0%	30,713	1,634	32,400	31,300
2034	4.7%	1.27	6.0%	40,691	20.0%	32,553	1,634	34,200	32,900
2035	4.5%	1.27	5.7%	43,010	20.0%	34,408	1,634	36,100	34,400
2036	4.3%	1.27	5.4%	45,334	20.0%	36,267	1,634	38,000	36,000
2037	4.0%	1.27	5.1%	47,652	20.0%	38,121	1,634	39,800	37,500
2038	4.0%	1.27	5.1%	50,068	20.0%	40,054	1,634	41,700	39,000
2039	4.0%	1.27	5.0%	52,587	20.0%	42,069	1,634	43,800	40,700
2040	3.9%	1.27	5.0%	55,211	20.0%	44,169	1,634	45,900	42,300
2041	3.9%	1.27	5.0%	57,946	20.0%	46,356	1,634	48,000	44,000

EE&C: Energy Efficiency and Conservation

Source: JICA Survey Team and BPDB



Source: JICA Survey Team and BPDB

Figure 11-3 Peak Demand Projection Using GDP Elasticity Method (case comparision)

11.4 Verifying the peak demand projection using sectorial analysis method

Next, this study also attempted an estimation of peak demand by projecting the total sum of power consumption in each sector. To serve for this, Simple.E software, which is an add-in module for MS-Excel, was used as the simulation program.

11.4.1 Steps in power demand projection

This program forecasts the energy demand for each sector using autocorrelation analysis on the energy intensity of GDP for each sector (and energy consumption per capita for the residential sector) while setting upper and lower limitations, and then formulates the future projection for peak demand.

Step 1 Sectoral energy consumption (A)
= Sectoral energy consumption intensity
× Sectoral GDP (Population for residential sector)
Step 2 Sectoral power demand (B)
= Sectoral total energy consumption (A) × Electrification ratio
× Power tariff elasticity × EE&C factor (Energy efficiency & conservation)
Step 3 Final electricity consumption (C)
= Sum of (B) for each sector, e.g. agriculture, industrial, commercial & public services and residential
Step 4 Electricity sent from the grid (net generation) (D)
= Final electricity consumption (C) + Transmission & distribution losses
Step 5 Peak demand (E)
= Electricity sent from the grid (D) / Load factor / 24 hours / 365 days

11.4.2 Peak Demand Projection Using Sectorial Analysis Method

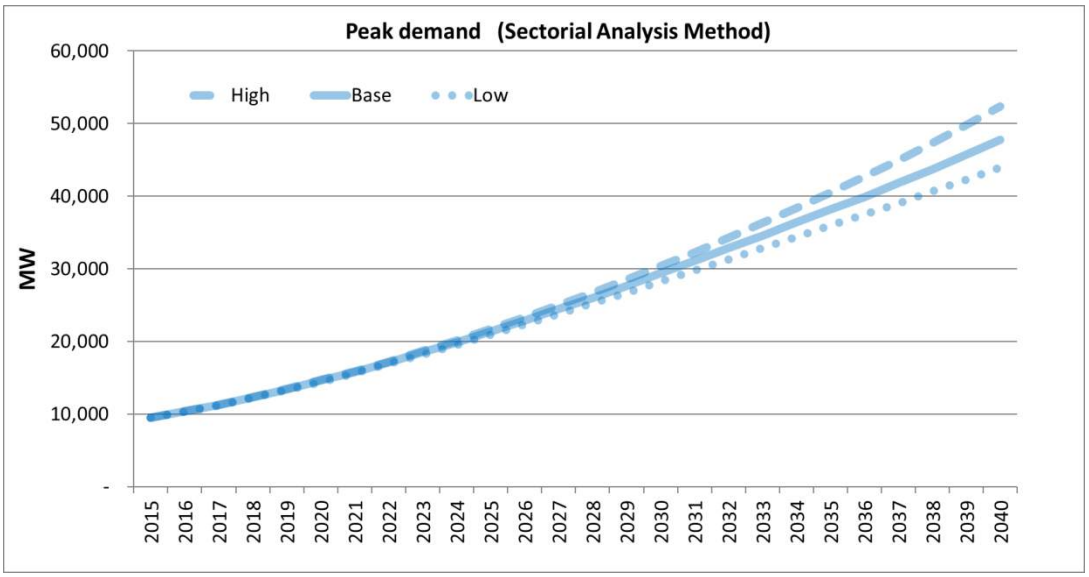
The results of peak demand projection in “High-growth Scenario”, “Base Scenario” and “Low-growth Scenario” are shown in Table 11-9 and Figure 11-4. While the average GDP growth rates from 2015 to 2041 are 6.4% in the “High-growth”, 6.1% in the “Base” and 5.9% in the “Low-growth” scenarios, the peak demand in each scenario in 7.0% p.a. in “High-growth”, 6.7% p.a. in “Base” and 6.3% p.a. in

"Low-growth".

Table 11-9 Peak Demand Projection for Each Scenario Using Sectorial Analysis Method

	Unit	2015	2020	2025	2030	2035	2040	2041
High	MW	8,920	13,400	20,100	28,500	38,400	49,800	52,400
Base	MW	8,900	13,400	19,900	27,700	36,400	45,700	47,800
Low	MW	8,900	13,200	19,500	26,700	34,400	42,300	44,000
	Unit	2015/10	2020/15	2025/20	2030/25	2035/30	2040/35	2041/15
High	%	7.3	8.5	8.4	7.2	6.1	5.3	7.0
Base	%	7.3	8.5	8.2	6.8	5.6	4.7	6.7
Low	%	7.3	8.5	8.1	6.5	5.2	4.2	6.3

Source: JICA Survey Team



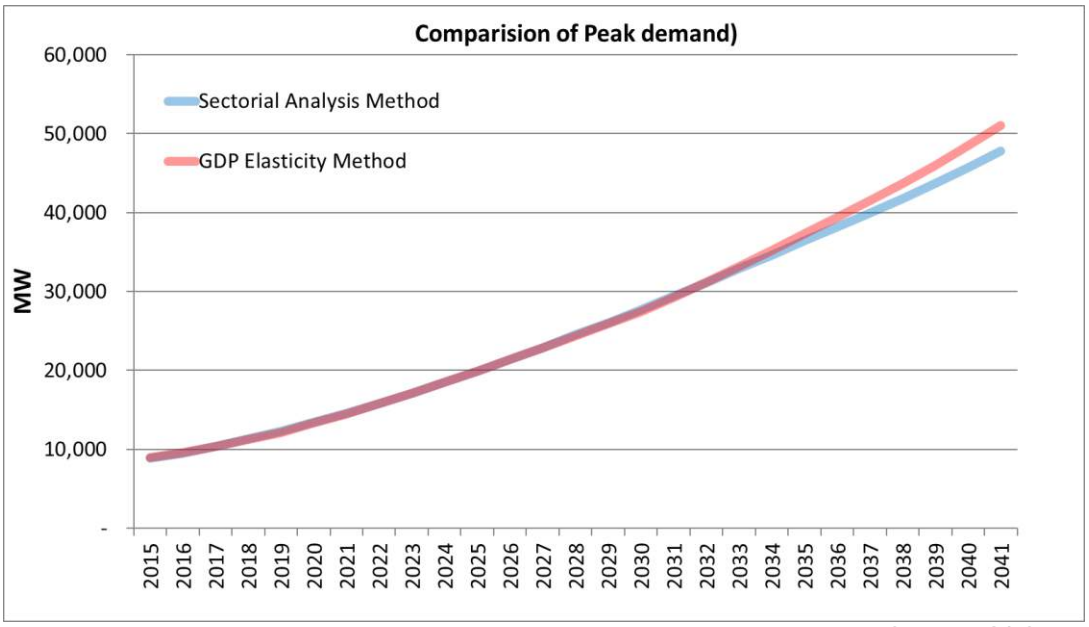
Source: JICA Survey Team

Figure 11-4 Peak Demand Projection for Each Scenario Using Sectorial Analysis Method

11.5 Verifying the peak demand forecasting model

11.5.1 Peak demand for PSMP 2016

In comparing the power demand projection between the "GDP elasticity method" and the "Sectorial analysis method", this study concluded that the results are almost identical, though the latter exceeded the former by about 5%. Therefore, this study adopted a peak demand projection using the "GDP elasticity method", which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan.



Source: JICA Survey Team

Figure 11-5 Comparison of Peak Demand Projection Results

11.5.2 Integration of peak power demand projection and energy supply-demand projection

Following the projection of peak power demand as formulated above, this study calculated the available electricity supply from the power grid by multiplying the annual load factor, and then compared this with the projection of total electricity consumption that was discussed in chapter 6 in the projection of primary energy supply and demand. The results are shown in Table 11-10 and 6. Because the "Total electricity consumption (B)" includes the factories' own consumption from captive power generation, it becomes larger than the "Available supply from the grid (A)". (C), which is the difference between (B) and (A), indicates the own consumption of electricity from captive power generation.

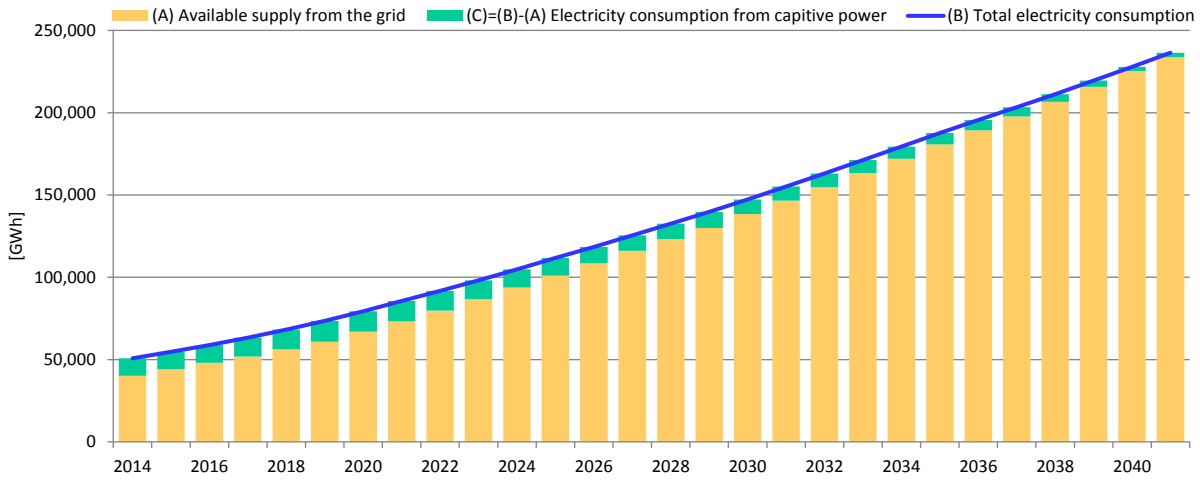
As discussed in chapter 6, this study confirmed that the electricity consumption using captive power generation accounts for a considerable share in the industrial sector at this moment because of the insufficient supply from the grid and the low price of natural gas. It is desired that, in the future, utilization of captive power generation will decline and shift to electricity purchase from the grid, , except for the case of factories using a highly efficient cogeneration system, as the supply capacity of the grid will be strengthened and the revision of gas price for captive power. In order to achieve this, the supply capacity of the grid needs be expanded beyond the growth of total electricity demand.

As shown in the following table and figure, the gap between the "Available supply from the grid (A)" and the "Total electricity consumption (B)" including the own consumption from captive power will be narrowed after 2020, which implies that the grid will gradually gain capacity to absorb the captive consumption. This study therefore confirms, by overviewing the "energy & power supply-demand projection", which is the integration of the power demand projection in this chapter, and the energy supply and demand projection in chapter 6, that this power demand projection complies with the long-term policy of the GoB to reduce the dependence on captive power generation by expanding and modernizing the electricity supply from the grid.

Table 11-10 Projection of Available Power Supply from the Grid, Total Electricity Consumption and Consumption from Captive Power Generation

		2015	2020	2025	2030	2035	2041
(A) Available supply from the grid		**44,171**	**66,937**	**101,036**	**138,439**	**180,715**	**233,677**
(B) Total electricity consumption		**54,743**	**79,370**	**111,735**	**147,274**	**187,721**	**236,391**
	Residential	19,636	26,500	34,658	42,429	51,984	62,800
	Industrial	30,103	46,302	68,511	94,297	122,958	158,246
	Commercial and public services	3,165	4,305	5,738	7,183	8,915	10,946
	Others (agriculture etc.)	1,839	2,263	2,828	3,365	3,864	4,399
(C)=(B)-(A) Electricity consumption from captive power		**10,572**	**12,433**	**10,699**	**8,835**	**7,006**	**2,715**

Source: JICA Survey Team



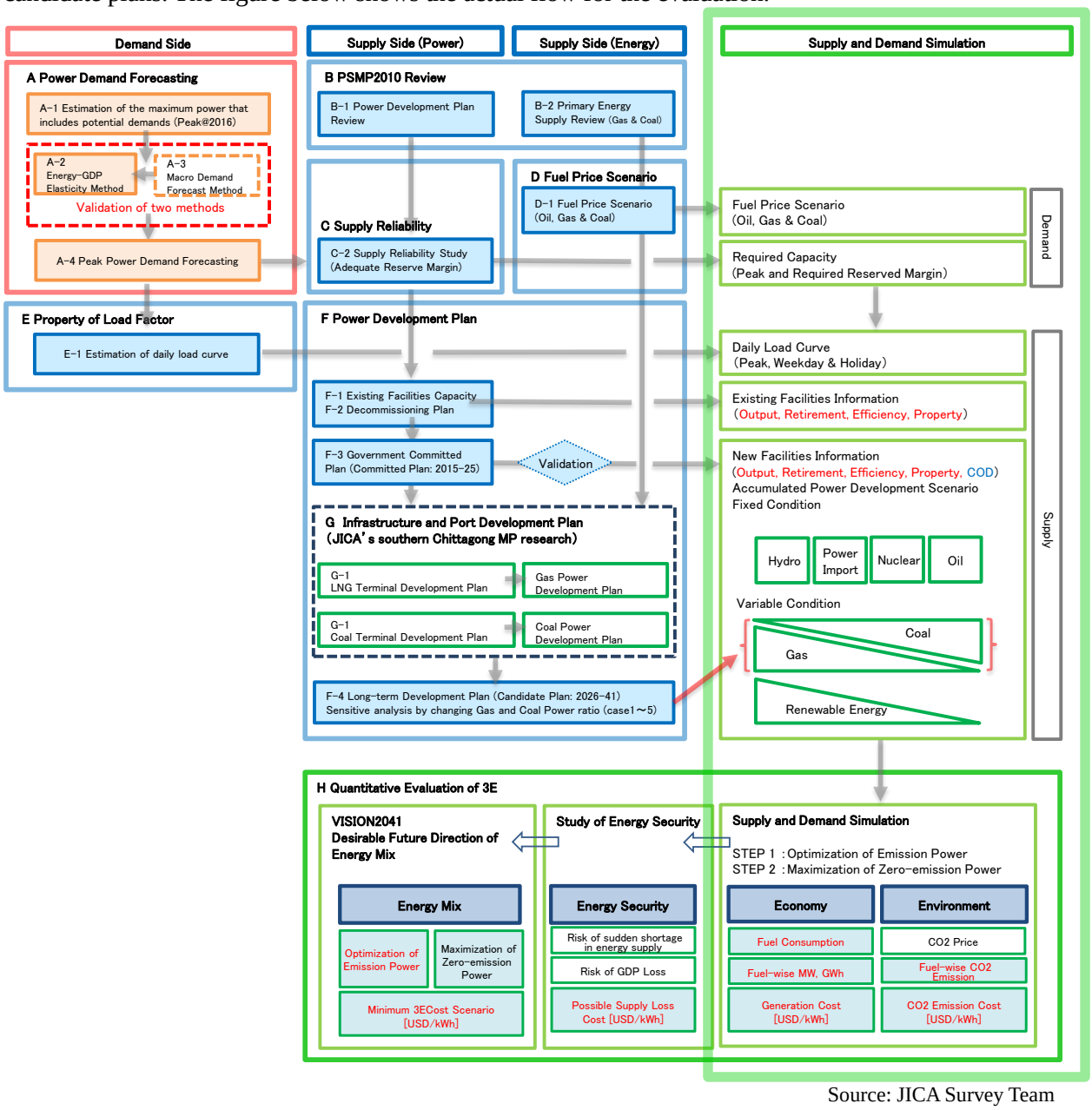
Source: JICA Survey Team

Figure 11-6 Projection of Total Electricity Consumption (Power Supply from the Grid, Total Electricity Consumption and Consumption from Captive Power Generation)

11.6 Power development planning

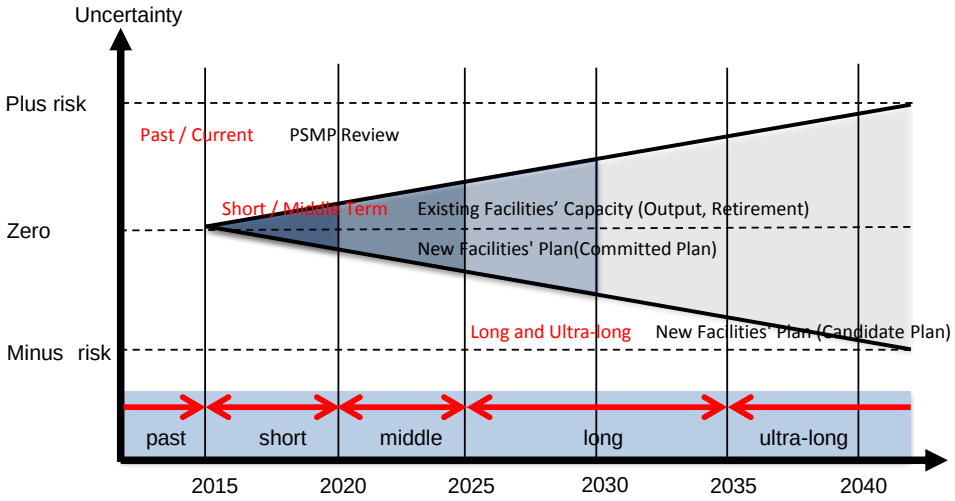
Short-term and medium-term power development plans are to be formulated after verifying the appropriateness of matters with a little short-term uncertainty (the state and retirement plans of the existing facilities and the plans approved by the Government) in the formulation of a long-term power development plan. The basic CODs of the gas and coal power plants in the long-term and candidate plans are to be determined in conformity with the port and fuel depot infrastructure development plan to be formulated separately in the "Data Collection Survey on Integrated Development for Southern Chittagong Region (Southern Chittagong MP Survey)."

The optimum power source composition is to be determined in the preparation of the future vision of the power source composition by conducting a quantitative evaluation of the economic, environmental and energy security (3E) values of scenarios with different composition ratios for the gas and coal power generation. Different composition ratios for the gas and coal power generation within ranges that are consistent with the infrastructure development plan in the Southern Chittagong MP Survey are to be used in the scenarios, particularly for the highly unpredictable periods for the long-term and candidate plans. The figure below shows the actual flow for the evaluation.



Source: JICA Survey Team

Figure 11-7 Power Development Planning flow



Source: JICA Survey Team

Figure 11-8 Relationship between the Time Scale and the Change in Risk in the Formulation of the Power Development Plan

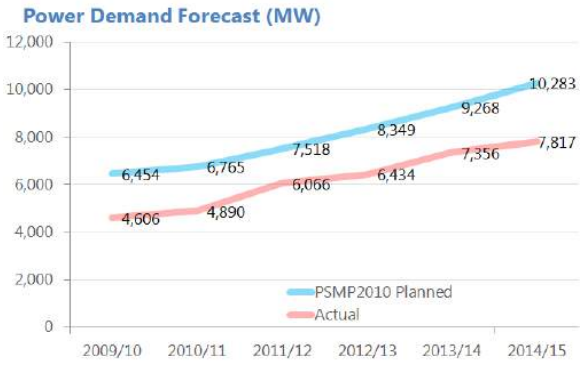
11.7 Review of PSMP 2010

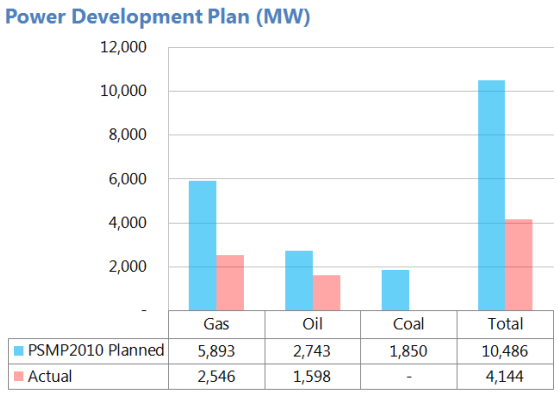
11.7.1 Review of the power development plan

The figure below shows the five-year power demand forecast in PSMP 2010 and the actual power demand. When PSMP 2010 was formulated five years ago, the demand was estimated to increase to around 10,000 MW by 2015. However, the actual demand in 2015 was approximately 80% of the estimate, around 8,000 MW.

The increase in the power demand, including potential demand driven by the rapid economic development in recent years, is expected to continue. The shortage of supply is considered to be the main cause of the continuation of this imbalance between the supply and demand. The figure below shows that the actual outputs of the gas and coal thermal power generation were only at 40% and 60% of the outputs described in PSMP 2010, respectively. In the case of the coal thermal power generation, a very important base load power source in the energy mix, while the output in 2015 was forecast at 1,850 MW in PSMP 2010, even the construction of coal power plants has not been commenced five years after the formulation of the plan. The lack of integrated planning and implementation for the construction of large-scale port facilities, indispensable for the stable import of fuel, and the construction of the power plants and the increased difficulty in fundraising for such a large-scale infrastructure development are considered to be major factors in the failure to develop power generating facilities as planned.

Therefore, it is considered necessary for the Energy Division and the Power Division to develop an organizational structure and operating system more integrated than before. They must also make concerted efforts to formulate a joint infrastructure development plan, to raise funds in the public-private partnership and to develop infrastructure systematically in order to achieve a stable energy supply, a source of future economic development.





	Gas	Oil	Coal	Total
PSMP2010 Planned	5,893	2,743	1,850	10,486
Actual	2,546	1,598	-	4,144

Source: JICA Survey Team

Figure 11-9 Review of the power development plan

11.7.2 Review of gas supply

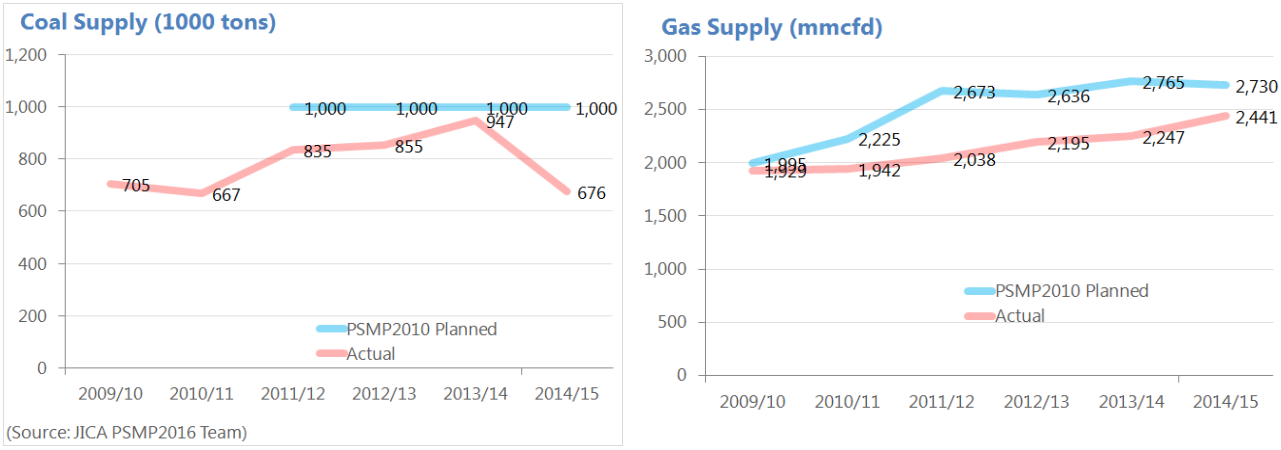
5-year gas supply projection in the PSMP 2010 was reviewed against the actual supply records from 2009/10 through to 2014/15. The results show that the actual supply figure is 15 points lower than that of the projected figures. The projection was made based on the gas reserve data by Hydrocarbon Unit (HCU) (2011); however, the projection did not reflect the gas field development plan or investment plan for new and/or existing gas fields after 2010/11. There are also differences in the gas reserve data between Hydrocarbon Unit (HCU) (2011) and USGD/Petrobangla. Hydrocarbon Unit (HCU) (2011) uses P90/P50/P10 while USGD/Petrobangla uses P95/Mean/P05 for gas reserve assessment; hence, the USGD/Petrobangla gas reserve appears smaller. The difference between the projection and actual is considered a combination of all these factors.

11.7.3 Review of coal supply

The figure and table below show the performance and the forecast for coal production in PSMP 2010. Annual production of 1 million tons will be possible using existing facilities. New long-wall mining equipment called LTCC (Long-wall Top Coal Caving) for thick coal seams was introduced in May 2013 from China and the mining was height increased from 3 meters to about double this. Actual mining height is not clear, but mining efficiency was obviously improved. The coal production in 2013/14 achieved 0.947million tons. However, in 2014/15, the figure decreased to 0.676 tons. The main reason was the delay in withdrawal and installation of the new equipment at sites. It is normal for it to take time for people to become skilled in the use of new equipment. If they can master the operation technology of the new facilities, it is surmised that 1,000,000t is quite possible.

11.7.4 Relationship between fuel consumption in power and primary energy balance

In this Manter Plan, it is very much important to establish a link between the energy balance and the power balance taken into account in order to maintain consistency between the fuel consumption expected in the power development plan up to 2041 and the energy balance described in detail in the previous chapter.



Source: JICA Survey Team

Figure 11-10 Review of the coal and gas supply

11.8 Examination of existing generation capacity

11.8.1 Existing capacity (Total)

The installed capacity of existing plants was determined as described below after discussions with the organizations concerned in Bangladesh. The installed capacity of existing plants is 10,895MW as of 2015. Lists of existing plants for each fuel type are shown below.

Table 11-11Existing capacity as of FY2015 [MW]

Gas	Existing	6,780
Oil	Existing	3,202
Coal	Existing	182
Sub Total	Existing	10,165
Hydro	Existing	230
Power Imports	Existing	500
Grand Total	Existing	10,895

Source: JICA Survey Team

11.8.2 Gas-based power

The list of existing gas-fired power plants is as follows and the total capacity is 6,780MW.

Table 11-12 Existing gas-based capacity as of FY2015 [MW]

No.	Gas Plant (Existing)	Type			COD	Retirement	Operation Period	Output (MW)
1	Raojan (Chittagong) 2x210 MW	Public	ST	Gas	1993	2023	31	166
2	Raojan (Chittagong) 2x210 MW	Public	ST	Gas	1993	2023	31	166
3	SIKALBAHA (Chittagong) (60 MW)	Public	ST	Gas	N/A	2016	-	39
4	Shikalbaha 150 MW PP	Public	GT	Gas	2010	2030	21	147
5	Ashuganj (B.Baria) 2x64 MW ST	Public	ST	Gas	1970	2017	48	89
6	Ashuganj (B.Baria) 3x150 MW ST	Public	ST	Gas	1986	2021	36	366
7	Ashuganj (B.Baria) 56 MW GT)	Public	CC	Gas	1986	2017	32	39
8	Ashugonj 50 MW Engine	Public	RE	Gas	2011	2031	21	44
9	Ashugonj 225 CCPP	public	GT	Gas	N/A	2040	-	218
10	Chandpur 150 MW CCPP	Public	CC	Gas	2012	2038	27	158
11	Ghorasal (Polash, Norshindi) 2x55 MW ST 1&2	Public	ST	Gas	1974	2019	46	78
12	Ghorasal (Polash, Norshindi) 210 MW ST 3,4,5&6	Public	ST	Gas	1986	2026	41	672
13	SIDDHIRGANJ (210 MW)	Public	ST	Gas	2004	2035	32	138
14	SIDDHIRGANJ 2x120 MW)	Public	GT	Gas	2012	2032	21	206
15	HARIPUR (96 MW) (Narayangonj)	Public	GT	Gas	1987	2017	31	59
16	Haripur 412 MW CCPP (EGCB)	Public	CC	Gas	2014	2039	26	400
17	TONGI (105 MW) (Dhaka)	Public	GT	Gas	2005	2025	21	103
18	Shahjibazar (Hobigonj) 2x35 MW GT 8&9	Public	GT	Gas	N/A	2019	-	65
19	Lump GT Publick Gas ~30MW (SYLHET (20 MW)□	Public	GT	Gas	1986	2018	33	19
20	SYLHET (150 MW) PP	Public	GT	Gas	2012	2018	7	139
21	Fenchuganj 97 & 104 MW CC BPDB	Public	CC	Gas	2011	2020	10	165
22	p GT Publick Gas ~100MW (Baghabari (Sirajgonj) 71 MW	Public	GT	Gas	1991	2020	30	69
23	Baghabari (Sirajgonj) 100 MW GT	Public	GT	Gas	2001	2025	25	98
24	Sirajgonj 210 MW CCPP (1st Unit)	Public	GT	Gas	N/A	2037	-	204
25	RPCL (Mymenshing) (210 MW)	Private		Gas	2006	2031	26	202
26	Haripur Power Ltd. (360 MW)	Private		Gas	2001	2026	26	360
27	Meghnaghat power Ltd. (450 MW)	Private		Gas	2002	2027	26	450
28	Ghorasal 108 MW IPP (Regent Power))	Private		Gas	2014	2029	16	108
29	Ashugonj 195 MW Modular PP	Private		Gas	N/A	2035	-	195
30	Bibiana-II 341 MW CCPP (Summit)	Private		Gas	N/A	2040	-	341
31	Bogra 15 Years RPP (GBB)	Private		Gas	2009	2023	15	22
32	Kumargoan, Sylhet RPP (Energyprima)	Private		Gas	N/A	2018	-	50
33	Shahjibazar 15 Yrs RPP (Shahjibazar Power)	Private		Gas	2009	2024	16	86
34	Shahjibazar RPP (Energyprima)	Private		Gas	2008	2017	10	50
35	Tangail SIPP (Doreen)	Private		Gas	2008	2024	17	22
36	Feni SIPP (Doreen)	Private		Gas	2009	2024	16	22
37	s Rental ~50 MW (Kumkargoan, Sylhet 15 Years RPP (Des	Private		Gas	2009	2024	16	10
38	Barobkundo SIPP (Regent Power)	Private		Gas	2009	2024	16	22
39	Bhola 3 Years RPP (Venture)	Private		Gas	2009	2017	9	33
40	Jangalia, Comilla SIPP (Summit))	Private		Gas	2009	2024	16	33
41	Fenchuganj 15 Years RPP (Barakatullah)	Private		Gas	2009	2024	16	51
42	Ashugong 55 MW RPP (Precision Energy))	Private		Gas	2010	2018	9	55
43	Fenchugonj RPP (Energy Prima)	Private		Gas	2012	2017	6	44
44	Ghorasal 45 MW QRPP (Aggreko)	Private		Gas	2010	2018	9	45
45	Ghorasal 100 MW QRPP (Aggreko)	Private		Gas	2012	2018	7	100
46	B. Baria 70 MW QRPP (Aggreco)	Private		Gas	2011	2017	7	85
47	p Gas Rental ~100 MW (Ghorasal 78 MW QRPP (Max Pov	Private		Gas	2011	2020	10	78
48	Ashugonj 80 MW QRPP (Aggreko)	Private		Gas	2011	2016	6	95
49	Ashugonj 53 MW QRPP (United Power)	Private		Gas	2011	2019	9	53
50	Shajahanullah Power Com. Ltd.	Private		Gas	2010	2020	11	25
51	Summit Power(REB)	Private		Gas	1984	2022	39	105
52	Bogra RPP (Energy Prima)	Private		Gas	2011	2024	14	20
53	Lump SIPP Gas (Hobiganj SIPP (REB) (Confi-Energypac)	Private		Gas	2011	2024	14	11
54	Ullapara SIPP (REB) (Summit)	Private		Gas	2009	2024	16	11
55	Narsindi SIPP (REB) (Doreen)	Private		Gas	2008	2024	17	22
56	Feni SIPP (REB) (Doreen)	Private		Gas	2008	2024	17	11
57	Mouna, Gazipur SIPP (REB) (Summit)	Private		Gas	2009	2024	16	33
58	Rupganj , Narayanganj SIPP (REB) (Summit)	Private		Gas	2009	2024	16	33
59	Ashugonj 51 MW IPP (Midland)	Private		Gas	N/A	2028	-	51
							Total MW	6,780

Source: JICA Survey Team

11.8.3 Coal-based power

The list of existing coal-fired power plants is as follows and the total capacity is 182MW.

Table 11-13Existing coal-based capacity as of FY2015 [MW]

No.	Coal Plant (Existing)	Type	COD	Retirement	Operation Period	Output (MW)
1	Barpapukuria 250MW (Unit 1&2)	Coal Domestic	2000	2036	37	182

Source: JICA Survey Team

11.8.4 Oil-based power

The list of existing oil-fired power plants is as follows.

Table 11-14Existing oil-based capacity as of FY2015 [MW]

No.	Oil Plant (Existing)	Type			COD	Retirement	Operation Period	Output (MW)
1	Hathazari 100 MW Peaking PP	Public	RE	F.oil	2011	2032	22	96
2	Sangu, Dohazari 100 MW Peaking PP	Public	RE	F.oil	2012	2033	22	99
3	Lump HFO Public ~50 MW (Raojan 25 MW Peaking PP)	Public	RE	F.oil	2013	2033	21	25
4	Gazipur 52 MW PP	Public	RE	F.oil	2012	2032	21	51
5	Titas, Doudkandi 50 MW Peaking PP	Public	RE	F.oil	2011	2031	21	51
6	KHULNA (110 MW)	Public	ST	F.oil	1984	2016	33	50
7	Lump GT Public HSD ~20MW (BARISAL (40MW)	Public	GT	HSD	1984	2016	33	30
8	BHERAMARA (Kustia) (60 MW)	Public	GT	HSD	1976	2016	41	46
9	Khulna 150 MW PP (NWPGCL)	Public	GT	HSD	2013	2017	5	155
10	Faridpur 50 MW Peaking PP)	Public	RE	F.oil	2011	2031	21	52
11	Gopalgonj 100 MW Peaking PP)	Public	RE	F.oil	2011	2032	22	107
12	BAGHABARI 50 MW Peaking PP	Public	RE	F.oil	2011	2031	21	51
13	Lump HFO Public ~100 MW (BERA 70 MW Peaking PP	Public	RE	F.oil	2011	2032	22	70
14	RANGPUR (20 MW)	Public	GT	HSD	1988	2016	29	19
15	SAIDPUR (20 MW) (Dinajpur)	Public	GT	HSD	1987	2016	30	19
16	Santahar 50 MW Peaking PP	Public	RE	F.oil	2012	2032	21	49
17	Katakhali 50 MW Peaking PP	Public	RE	F.oil	2012	2032	21	49
18	KPCL BMPP 15 Years (Khulna) (Summit-United)	Private		F.oil	1998	2018	21	110
19	NEPC (110 MW) (Haripur BMPP)	Private		F.oil	1999	2019	21	110
20	Natore 52 MW IPP (Raj-Lanka)	Private		F.oil	2014	2029	16	52
21	Summit Meghnaghat Power Company Ltd. CCPP	Private		HSD	2015	2040	26	305
22	Gognagar 102 MW PP (Summit)	Private		F.oil	2014	2029	16	102
23	Baraka-Potenga 50 MW IPP	Private		F.oil	2014	2029	16	50
24	Potiya, Chittagong 100 MW Power Plant	Private		F.oil	2015	2030	16	108
25	Jangalia, Comilla (Lakdanvhi)	Private		F.oil	N/A	2030	-	52
26	Kathpotty, Munshigonj 53 MW PP (Sinha)	Private		F.oil	2015	2030	16	51
27	Lump Private Existing RE HFO ~50 (Shikal Baha RPP(Energ	Private		F.oil	2014	2018	5	40
28	Thakurgaon RPP (RZ Power)	Private		HSD	2015	2018	4	40
29	Khulna 55 MW QRPP (Aggreko))	Private		HSD	2010	2018	9	55
30	Lump HSD Rental ~50 MW (Pagla 50 MW QRPP (DPA)	Private		HSD	2010	2018	9	50
31	Bheramara 110 MW RPP (Quantum Power))	Private		HSD	2010	2018	9	105
32	Lump HSD Rental ~100 MW (Shiddirgonj 100 MW QRPP (	Private		HSD	2011	2019	9	98
33	Lump Private Existing RE HFO ~100 (Madangonj 102 MW	Private		F.oil	2011	2021	11	100
34	Khulna 115 MW QRPP (KPCL) (Summit-United)	Private		F.oil	2011	2021	11	115
35	Noapara 40 MW QRPP (Khan Jahan Ali)	Private		F.oil	2011	2029	19	40
36	Noapara 105 MW RPP (Quantum Power)	Private		F.oil	2011	2016	6	101
37	Meghnaghat 100 MW QRPP (IEL)	Private		F.oil	2011	2021	11	100
38	Siddirganj 100 MW QRPP (Dutch Bangla Power)	Private		F.oil	2011	2021	11	100
39	Amnura 50 MW QRPP (Sinha Power)	Private		F.oil	2012	2018	7	50
40	Keranigonj 100 MW QRPP (Power Pak)	Private		F.oil	2012	2017	6	100
41	Julda100 MW QRPP (Acron Infra Servicw)	Private		F.oil	2012	2018	7	100
42	Katakhali 50 MW QRPP (NPSL)	Private		F.oil	2012	2019	8	50
							Total MW	3,202

Source: JICA Survey Team

11.8.5 Hydropower

The list of existing hydropower plants is as follows and the total capacity is 230MW by only Kaptai Hydro Power Plant.

Table 11-15Existing hydropower capacity as of FY2015 [MW]

No.	Hydro Plant (Existing)	Type	COD	Retirement	Output (MW)
1	Kaptai Hydro Power Plant	Hydro	2000	9999	230

Source: JICA Survey Team

11.8.6 Power import

The list of existing power import is as follows and the total capacity is 500MW by only Bheramara-Bharampur HVDC (phase 1).

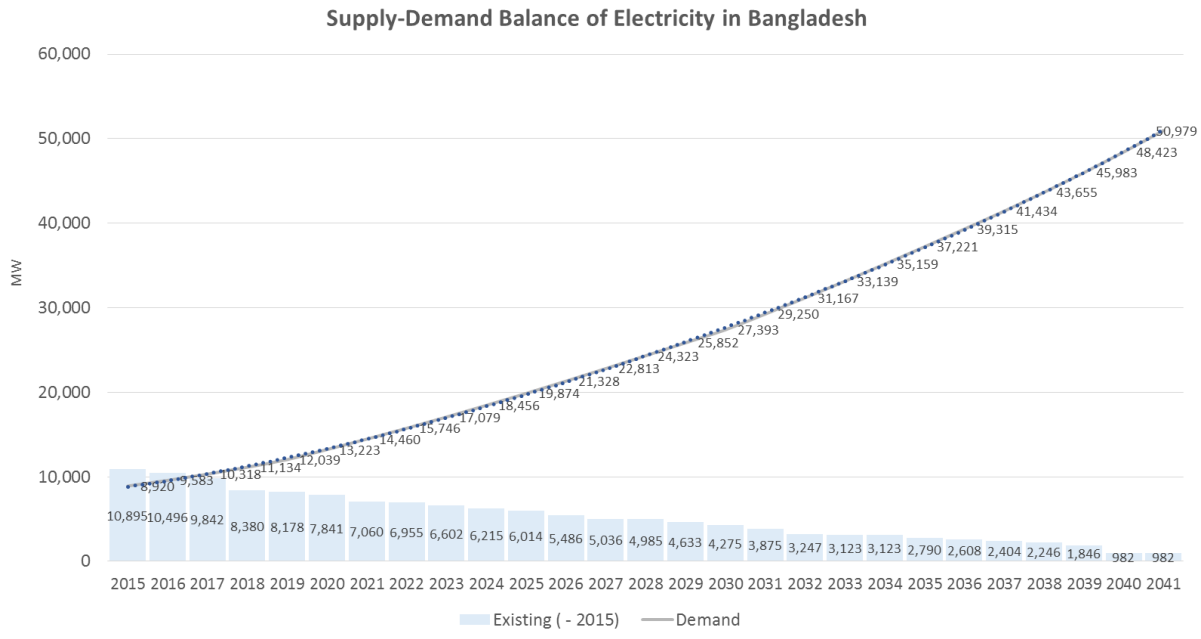
Table 11-16 Existing power import capacity as of FY2015 [MW]

No.	Power Import (Existing)	Type	COD	Retirement	Output (MW)
1	Bheramara-Bharampur HVDC Phase 1(from India)	HDVC	2013	9999	500

Source: JICA Survey Team

11.8.7 Retirement Plan

The lists of the existing power generation facilities above show their CODs, retirement years and operation periods. Analysis of these data has revealed that the average operation period for these power plants is approximately 20 years. It is difficult to improve the efficiency of the existing inefficient plants significantly because of the large cost required for such improvements. For these reasons, it has been concluded that the retirement plans prepared by the government are appropriate. The adoption of a strategy aiming at improving the efficiency of the entire power supply network by retiring the existing inefficient power plants gradually and replacing them with new, efficient facilities is considered essential for realizing the maximum use of the limited resources.



Source: JICA Survey Team

Figure 11-11 Esisting capacity considering retirement plan

11.9 Evaluation of the Plan Approved by the Government (Committed Plan)

Some of the facilities to be constructed are mentioned in the plan approved by the government (Committed Plan), confirmed by the Survey Team jointly with the persons involved in power development in the Bangladeshi Government, while the others are mentioned in a plan to be approved that is subject to changes (Candidate Plan).
The table below shows the capacities by fuel type of the power plants mentioned in the Committed Plan. Power plants with a total output capacity of approximately 14,000 MW are to be constructed in the next ten years.

Table 11-17 Comitted generation plan [MW]

Fuel type	Status	Capacity (MW)
Gas	committed	5,126
Coal	committed	6,543
Oil	committed	2,545
Total	committed	14,213

Source: JICA Survey Team

11.9.1 Gas-bsed power

The list of committed gas-fired power is as follows.

Table 11-18 Comitted plan of gas-fired generation [MW]

No.	Gas Plant (Committed)	Type		COD	Retirement	Output (MW)
1	Bhola 225 MW CCPP: SC GT Unit	BPDB	Gas	2016	2041	189
2	Siddirganj 335 MW CCPP: SC GT Unit	EGCB	Gas	2016	2041	328
3	Ashuganj (South) 450 MW CCPP	APSCL	Gas	2017	2042	370
4	Ashuganj (South) 450 MW CCPP	APSCL	Gas	2016	2041	361
5	Ghorasal 363 MW (7th Unit) CCPP	BPDB	Gas	2017	-	352
6	Shajibazar CCPP	-	Gas	2016	2041	322
7	Shikalbaha 225 MW CCPP	-	Gas	2017	-	218
8	Bibiana South CCPP BPDB	-	Gas	2018	-	372
9	Bibiana Ⅲ CCPP BPDB	-	Gas	2019	-	388
10	Bheramara 414 MW CCPP	NWPGC	Gas	2018	2042	402
11	Fenchugonj 50 MW Power Plant	IPP/NRB	Gas	2019	2034	50
12	Sylhet 150 MW PP Conversion (Additional 75MW)	BPDB	Gas	2018	2042	221
13	Ghorasal 3rd Unit Repowering (Capacity Addition)	BPDB	Gas	2018	2042	776
14	Kusiara 163 MW CCPP	IPP	Gas	2018	-	163
15	Bagabari 100 MW PP Conversion	BPDB	Gas	2020	2042	102
16	Sirajganj 414 MW CCPP (4th unit)	-	Gas	2020	2043	414
17	Shahajibazar 100 MW	-	Gas	2018	2038	98
					Total MW	5,126

Source: JICA Survey Team

11.9.2 Coal-bsed power

The list of committed coal-fired power is as follows.

Table 11-19 Comitted plan of coal-fired generation [MW]

No.	Coal Plant (Committed)	Type				COD	Retirement	Output (MW)
1	Barapukuria 275MW (Unit 3)					2019	-	252
2	Matarbari#1,2	Public	CPGCBL	USC	Imp Coal	2023	-	1104
3	Rampal#1,2	Public	BIFPCL	SC	Imp Coal	2020	-	1214
4	Payra#1,2	Public	NWPGCL	SC	Imp Coal	2020	-	1214
5	Khulna	IPP	Orion Group	SC	Imp Coal	2020	-	630
6	Maowa	IPP	Orion Group	SC	Imp Coal	2020	-	522
7	Dhaka	IPP	Orion Group	SC	Imp Coal	2020	-	635
8	Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-1				Imp Coal	2020	-	612
9	Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-2				Imp Coal	2020	-	612
							Total MW	6,543

Source: JICA Survey Team

11.9.3 Oil-based power

The list of committed oil-fired power is as follows.

Table 11-20 Comitted plan of oil-fired generation [MW]

No.	Oil Plant (Committed)	Type	COD	Retirement	Output (MW)
1	Kodda, Gazipur 150 MW Power Plant	Oil	2016	2035	147
2	Chapai Nababganj 104 MW PP	Oil	2017	2032	102
3	Keranigonj 100 MW PP (Re from Khulna))	Oil	2019	2034	100
4	Bosila, Keranigonj 108 MW PP (CLC Power)	Oil	2017	2032	108
5	Jamalpur 100 MW Power Plant	Oil	2017	2032	95
6	Barisal 100 MW PP (Re. from Syedpur)	Oil	2016	2031	110
7	Lump HFO Private New ~50 MW (Madangonj 50 MW Peal	Oil	2016	2031	55
8	Manikgonj 55 MW PP	Oil	2016	2031	50
9	Kamalaghat 50 MW PP)	Oil	2017	2032	55
10	Nababgonj 55 MW PP	Oil	2016	2031	55
11	Satkhira 50 MW PP	Oil	2019	2034	50
12	Bhairab 50 MW PP	Oil	2019	2034	50
13	Upgradation of Khulna 150 MW to 225 MW	Oil	2017	2037	221
14	Khulna 200-300 MW CCPP	Oil	2019	2039	196
15	Patiya 100 Mw BOO FO power plant	Oil	2020	2035	100
16	Anwara 300 MW HFO plant	Oil	2022	2037	300
17	Julda 100 Mw BOO FO power plant	Oil	2020	2035	100
18	Sirajgonj 225 MW CCPP (2nd Unit)	Oil	2019	2039	216
19	Sirajgonj 225 MW CCPP (3rd Unit)	Oil	2020	2040	216
20	Bhola 220 MW CCPP Dual Fuel BOO power plant	Oil	2021	2041	220
				Total MW	2,545

Source: JICA Survey Team

11.9.4 Hydropower

The list of committed hydropower is as follows.

Table 11-21 Comitted plan of hydropower generation [MW]

No.	Hydro Plant (Committed)	Type	COD	Retirement	Output (MW)
1	New Kaptai Pumped Strage	Hydro	2030	9999	100

Source: JICA Survey Team

11.9.5 Power import

The list of committed power import is as follows.

Table 11-22 Comitted plan of power import [MW]

No.	Power Import (Committed)	Type	COD	Retirement	Output (MW)
1	Comilla - Tripura HVDC Phase 1-1 (100MW) (India)	PI	2016	9999	100

Source: JICA Survey Team

11.9.6 Nuclear power

The list of committed nuclear is as follows.

Table 11-23 Comitted plan of nuclear power [MW]

No.	Nuclear Plant (Committed)	Type	COD	Retirement	Output (MW)
1	Roopoor 1st Unit	Nuclear	2024	9999	1,116
2	Roopoor 2nd Unit	Nuclear	2025	9999	1,116

Source: JICA Survey Team

11.9.7 Validation of commissioning date

The current status of each thermal power development plan was confirmed based on the discussion with related companies, such as BPDB, BIFPCL, CPGCBL, NWPGCL, Orion Group, etc. The following tables shows the current status of thermal power plans for imported coal and LNG respectively.

(1) Coal-fired power generation

Matarbari #1 and 2, Matarbari/Maheshkhali #1, 2 and 3, Rampal #1 and 2, Payra #1 and 2, Maowa, Khulna and Chittagong projects are in progress. However, Rampal #1 and 2, Khulna and Maowa have some problems with environmental and financial issues. The location of Rampal #1 and 2 is near the Sundarbans, the largest Mangrove Forest in the world and a world heritage site as declared by UNESCO in 1997. Activists are concerned that the Rampal #1 and 2 projects, less than 10 miles from the protected Sundarbans mangrove forest, would lead to its environmental degradation from increased ship traffic, dredging and the pollution of air and water. The Khulna and Maowa projects also have financial issues with low tariffs for power supply and delays in EIA approval.

(2) Gas-fired power generation

a) Indian Reliance Power Limited

BPDB has signed an MOU with Indian Reliance Power Limited to install a 3,000MW regasified liquefied gas-based combined cycle power plant (Energy Bangla, on June 6, 2015).
Indian Reliance Power Limited has proposed two separate tariff structures between TK 7.99 and TK 8.22 per unit for implementing an LNG-based mega power project having the capacity to generate 3,000MW of electricity in three phases at Meghnaghat (Phase 1; 750MW), Chittagong (Phase 2; 1,500MW) and Maheshkhali (Phase 3; 750MW) (Energy Bangla, on September 14, 2015).

b) Adani Power limited

BPDB has signed an MOU with Adani Power Limited to install a 1,600MW ultra super critical coal-based power plant (Energy Bangla, on June 6, 2015).

c) Summit Group

Summit Group will invest at least $1 billion to install 1,310MW of electricity by 2020 (Energy Bangla, on June 28, 2015)

d) Shapoorji Pallonji Infrastructure Capital Company Ltd

Shapoorji Pallonji Infrastructure Capital Company Ltd proposed earlier to move its existing power project (225MW, dual-fuel power) at Udamsingnagar district under Uttarakhand Pradesh in India to Bhola (Energy Bangla, on August 19, 2015).

The current plans for the thermal power generation with imported coal and LNG are shown in the tables below. The Survey Team held sufficient discussion with the Government of Bangladesh and conducted a detailed study on the commissioning dates of individual power plants for the formulation of the power development plan. The team decided the dates on the basis of the outcomes of the discussion and study.

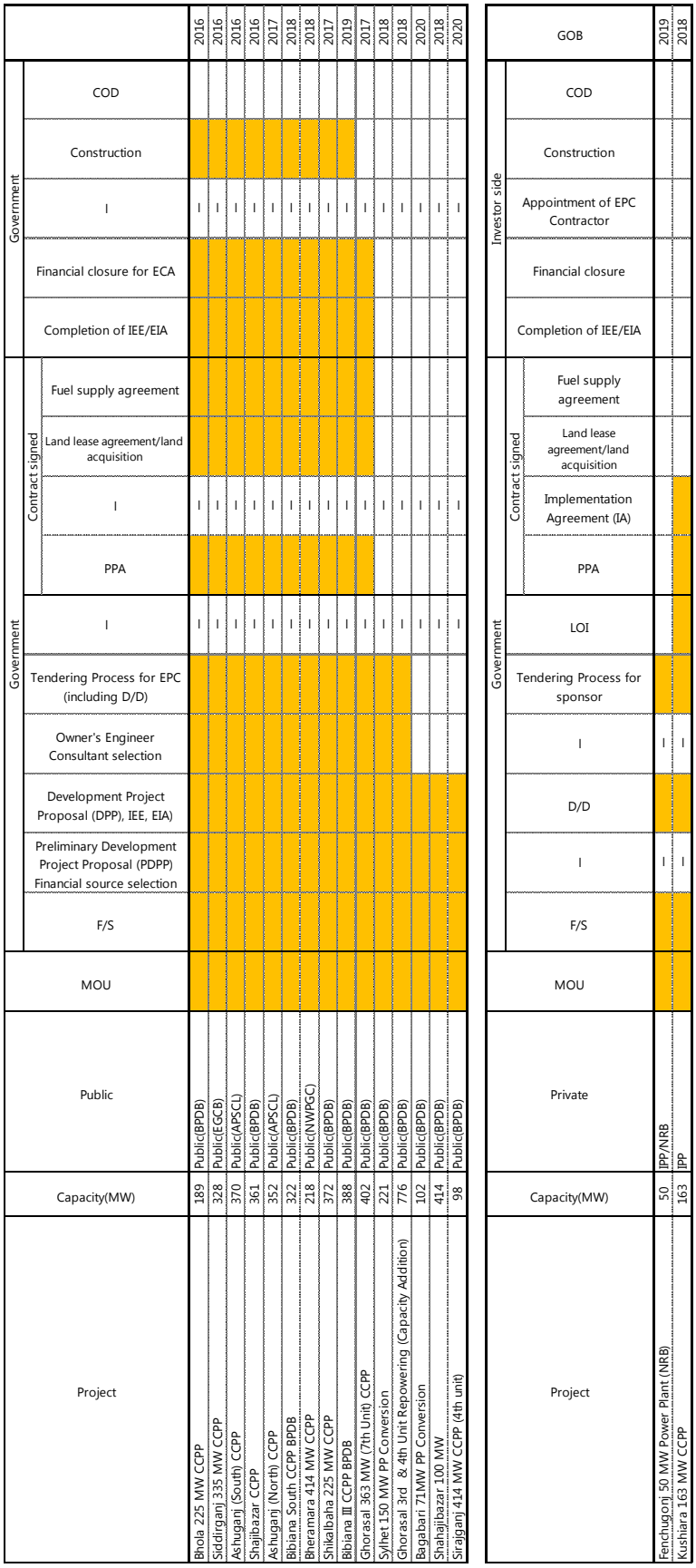
Table 11-24 Development status of gas-bsed power generation projects

Project	Capacity(MW)	Public	MOU	Government: Preliminary Development Project Proposal (PDPP) Financial source selection	Government: Development Project Proposal (DPP), IEE, EIA)	Government: Owner's Engineer Consultant selection	Government: Tendering Process for EPC (including D/D)	Government: I	Government: Contract signed: PPA	Government: Contract signed: I	Government: Contract signed: Land lease agreement/land acquisition	Government: Contract signed: Fuel supply agreement	Government: Completion of IEE/EIA	Government: Financial closure for ECA	Government: I	Government: Construction	Government: COD	GOB
Matarbari																		
Matarbari#1,2	1,200	Public(CPGCBL)						I		I					I			2023
Matarbari/Maheshkhali#1	600	Public(CPGCBL)						I		I					I			2026
Matarbari/Maheshkhali#2	600	Public(CPGCBL)						I		I					I			2027
Matarbari/Maheshkhali#3	600	Public(CPGCBL)						I		I					I			2027
Matarbari/Maheshkhali#4	600	Public(CPGCBL)						I		I					I			2032
Matarbari/Maheshkhali#5	600	Public(CPGCBL)						I		I					I			2033
Matarbari/Maheshkhali#6	600	Public(CPGCBL)						I		I					I			2034
Matarbari/Maheshkhali#7	600	Public(EGCB)						I		I					I			2036
Maheshkhali																		
Matarbari/Maheshkhali#8	1,000	Public(JV BPDB-Huadian)						I		I					I			2036
Matarbari/Maheshkhali#9	1,000	Public(BPDB,ADB)						I		I					I			2037
Matarbari/Maheshkhali#10	1,000	Public(JV BPDB-TNB)						I		I					I			2037
Matarbari/Maheshkhali#11	1,000	Public(BPDB)						I		I					I			2038
Matarbari/Maheshkhali#12	1,000	Public(BPDB)						I		I					I			2039
Matarbari/Maheshkhali#13	1,000	Public(JV BPDB-Kepco)						I		I					I			2040
Rampal																		
Rampal#1,2	1,214	Public(BIFPCL)						I		I					I			2020
Payra																		
Payra#1,2	1,214	Public(NWPGCL)						I		I					I			2020
Payra West#1	600	Public(NWPGCL)						I		I					I			2028
Payra West#2	600	Public(NWPGCL)						I		I					I			2031
Payra West#3	1,000	Public(NWPGCL)						I		I					I			2041
Payra West#4	1,000	Public(NWPGCL)						I		I					I			2041

Project	Capacity(MW)	Private	MOU	Investor side: F/S	Investor side: I	Investor side: D/D	Investor side: I	Investor side: Tendering Process for sponsor	Investor side: LOI	Investor side: PPA	Investor side: Contract signed: Implementation Agreement (IA)	Investor side: Contract signed: Land lease agreement/land acquisition	Investor side: Contract signed: Fuel supply agreement	Investor side: Completion of IEE/EIA	Investor side: Financial closure	Investor side: Appointment of EPC Contractor	Investor side: Construction	Investor side: COD	GOB
Others																			
Khulna	630	IPP(Orion Group)			I														2020
Maowa	522	IPP(Orion Group)			I														2020
Dhaka	635	IPP(Orion Group)			I														2020
Chittagong	612	IPP(S.Alam Group)			I														2020
Chittagong	612	IPP(S.Alam Group)			I														2020

Source: JICA Survey Team /JICA Southern Chittagong MP Team

Table 11-25 Development status of gas-bsed power generation projects

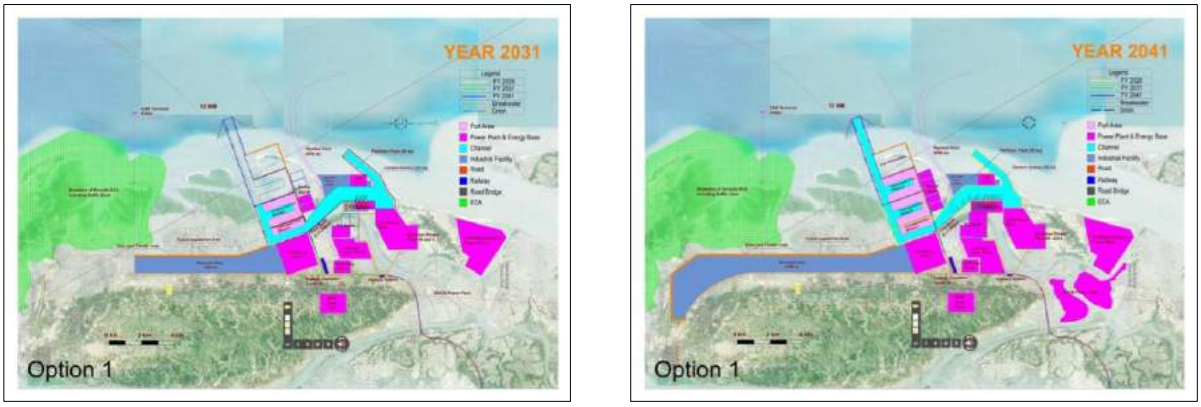


Source: JICA Survey Team /JICA Southern Chittagong MP Team

11.10 Consistency with port infrastructure planning

11.10.1 Port infrastructure plan by JICA Southern Chittagong Master Plan

Guarantee of the long-term stability of the fuel supply is a very important factor in the formulation of a power development plan. The existence of a port infrastructure required for the importing of fuels including gas and coal during operation has to be a precondition for the decision on the CODs of new power plants, in particular.
Therefore, the infrastructure and port development plan formulated with the consent of the Government of Bangladesh in the Southern Chittagong MP Survey, implemented by JICA, was used as reference in this analysis and the CODs of the power supply facilities were set in a way consistent with the plan. The figures below show the infrastructure and port development plan (2031/2041) in the Southern Chittagong Region formulated in the Southern Chittagong MP Survey by JICA.

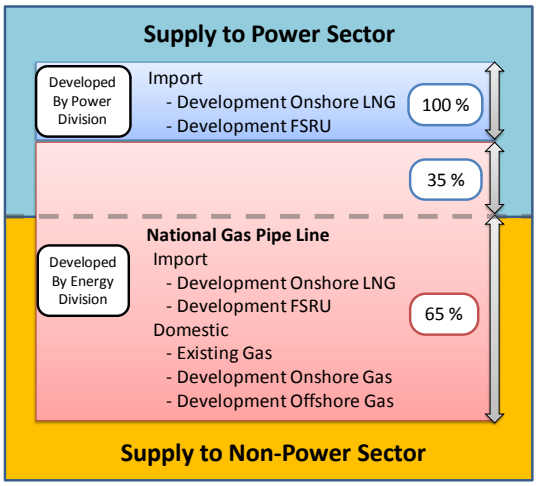


Source: JICA Southern Chittagong MP Team

Figure 11-12 Port infrastructure plan (2031/41) by JICA Southern Chittagong Master Plan

11.10.2 Allocation of natural gas supply

The following figure shows a scheme to develop natural gas in Bangladesh. The supply scheme is as follows. The gas facilities are divided into domestic gas facilities developed through the energy division, domestic on-shore and off-shore facilities to be developed in the future, on-shore LNG and off-shore FSRU facilities to be developed through the power division for imported gas.
Of the gas supplied through the energy division, 35% is supplied to the power sector and 65% to the non-power sector. The gas supplied through the power division is supplied 100% to the power sector.



Source: JICA Survey Team

Figure 11-13 Allocaion of natural gas

11.10.3 LNG terminal development scenario

The LNG development scenario will be adopted as per that which has been examined in the Southern Chittagong Master Plan Survey.

The LNG receiving terminals in the Matarbari area should be planned based on the following policies:

- There are no projects other than FSRU that are identified as "on-going".
- It can be said that, except in the Matarbari area, it is difficult to find a suitable site for developing the multi-purpose port required for receiving a large-scale LNG carrier.
- It is economical to develop LNG receiving terminals in conjunction with the development of a multi-purpose port.

Development of onshore terminals should be planned in conjunction with the development plan for a port facility that can receive a large-scale LNG carrier.

Onshore terminals generally require about four years for construction (not including land reclamation), and it is difficult to achieve early development considering the periods required for other activities such as FS, permits, design, tender, land reclamation, etc. Therefore, for FY2019 to FY2026, when the gas supply deficit emerges, FSRUs that require relatively short periods of time to begin operation (in addition to importing gas from India through a pipeline) should be introduced to correspond with the deficit. LNG receiving terminals should be developed in stages corresponding to demand increase. A standard capacity of 500 mmcfd should be adopted in each development stage.

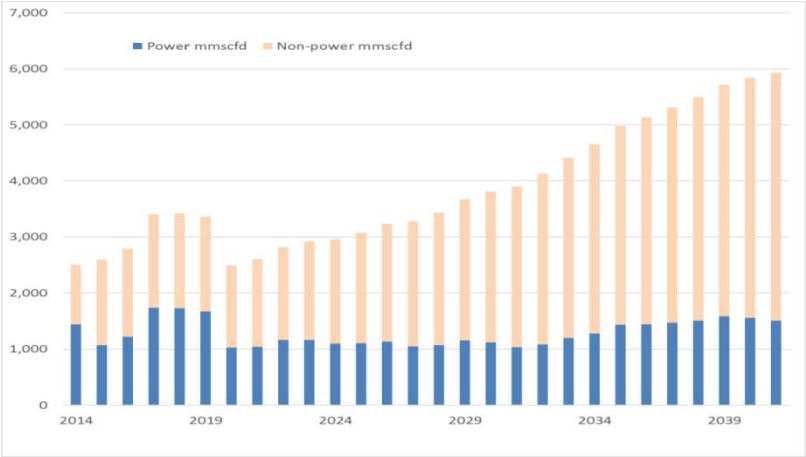
Storage of LNG should be adequately planned considering the influence of bad weather, accidents, etc.

The following table shows the proposed development scenario for LNG receiving terminals.

Table 11-26 Development scenario for LNG terminals

	Demand	Supply	Shortage	LNG (Gas) Import						Balance
	Total	**Total**		FSRU		Onshore Terminal		Pipeline from India	Total of Imported LNG	LNG (Gas) Import Surplus
				Energy Div		Energy Div	Power Div	NWPGCL		
Source			**3 - 7**						9 to 13	8 + 14
FY	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd
2015	**2,594**	**2,464**	**-130**						0	-130
2016	**2,793**	**2,653**	**-140**						0	-140
2017	**3,409**	**2,716**	**-693**						0	-693
2018	**3,422**	**2,662**	**-760**	500	0	0	0	0	500	-260
2019	**3,368**	**2,563**	**-805**	500	0	0	0	0	500	-305
2020	**2,497**	**2,547**	**50**	500	0	0	0	200	700	750
2021	**2,602**	**2,188**	**-414**	500	0	0	0	200	700	286
2022	**2,818**	**2,075**	**-744**	500	500	0	0	200	1,200	456
2023	**2,917**	**1,851**	**-1066**	500	500	0	0	200	1,200	134
2024	**2,958**	**1,747**	**-1211**	500	500	0	0	200	1,200	-11
2025	**3,081**	**1,741**	**-1340**	500	500	0	0	200	1,200	-140
2026	**3,236**	**1,766**	**-1470**	500	500	0	0	200	1,200	-270
2027	**3,279**	**1,805**	**-1474**	500	500	0	500	200	1,700	226
2028	**3,438**	**1,740**	**-1697**	500	500	0	500	200	1,700	3
2029	**3,677**	**1,696**	**-1981**	500	500	500	500	200	2,200	219
2030	**3,810**	**1,671**	**-2139**	500	500	500	500	200	2,200	61
2031	**3,903**	**1,653**	**-2250**	500	500	500	500	200	2,200	-50
2032	**4,132**	**1,642**	**-2490**	500	500	1,000	500	200	2,700	210
2033	**4,414**	**1,633**	**-2780**	500	500	1,000	500	200	2,700	-80
2034	**4,658**	**2,137**	**-2521**	500	500	1,000	500	200	2,700	179
2035	**4,981**	**2,104**	**-2877**	500	500	1,500	500	200	3,200	323
2036	**5,139**	**1,996**	**-3143**	500	500	1,500	500	200	3,200	57
2037	**5,312**	**1,996**	**-3316**	500	500	2,000	500	200	3,700	384
2038	**5,494**	**1,996**	**-3498**	500	500	2,000	500	200	3,700	202
2039	**5,721**	**1,997**	**-3724**	500	500	2,000	500	200	3,700	-24
2040	**5,837**	**1,999**	**-3838**	500	500	2,500	500	200	4,200	362
2041	**5,933**	**1,999**	**-3933**	500	500	2,500	500	200	4,200	267

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-14 Gas Supply Scheme

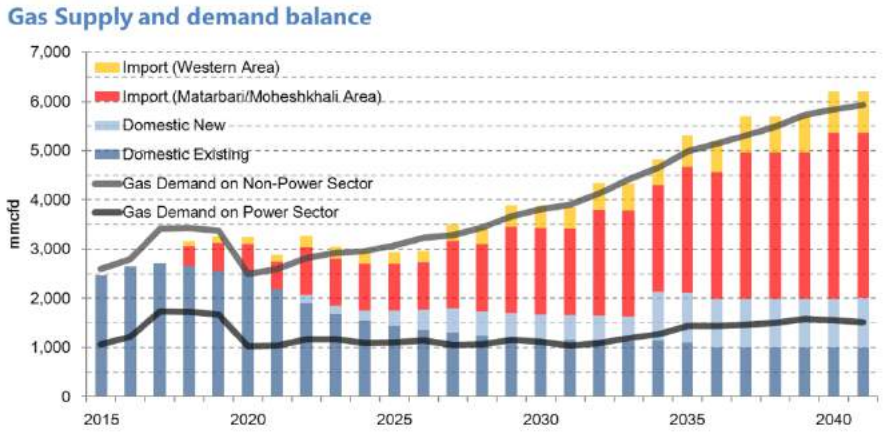
From the above table, it is found that the amount of 4,000 mmcfd (2 x 500 mmcfd from the FSRU + 2,500 mmcfd from the Energy Div.'s onshore terminals + 500 mmcfd from the Power Div.'s onshore terminal) among the total demand of about 5,855 mmcfd in FY2041 should be supplied from the new LNG terminals and, if these terminals are constructed in the Matarbari area, a large portion of the total gas demand has to rely on one supply base. This situation is not preferable from the viewpoint of energy security. There may be operational problems in the existing gas supply network as well. Considering these points, it has been arbitrarily judged that the maximum supply capacity in the Matarbari area should be limited to about 50% of the total demand in FY2041 and thus, the last two onshore terminals (2 x 500 mmcfd capacity) in FY2037 and 2040 should be constructed at different locations.

Consequently, the new LNG terminals to be developed in the Matarbari area are as summarized below:

Table 11-27 New LNG Terminals to be developed in the Matarbari Area

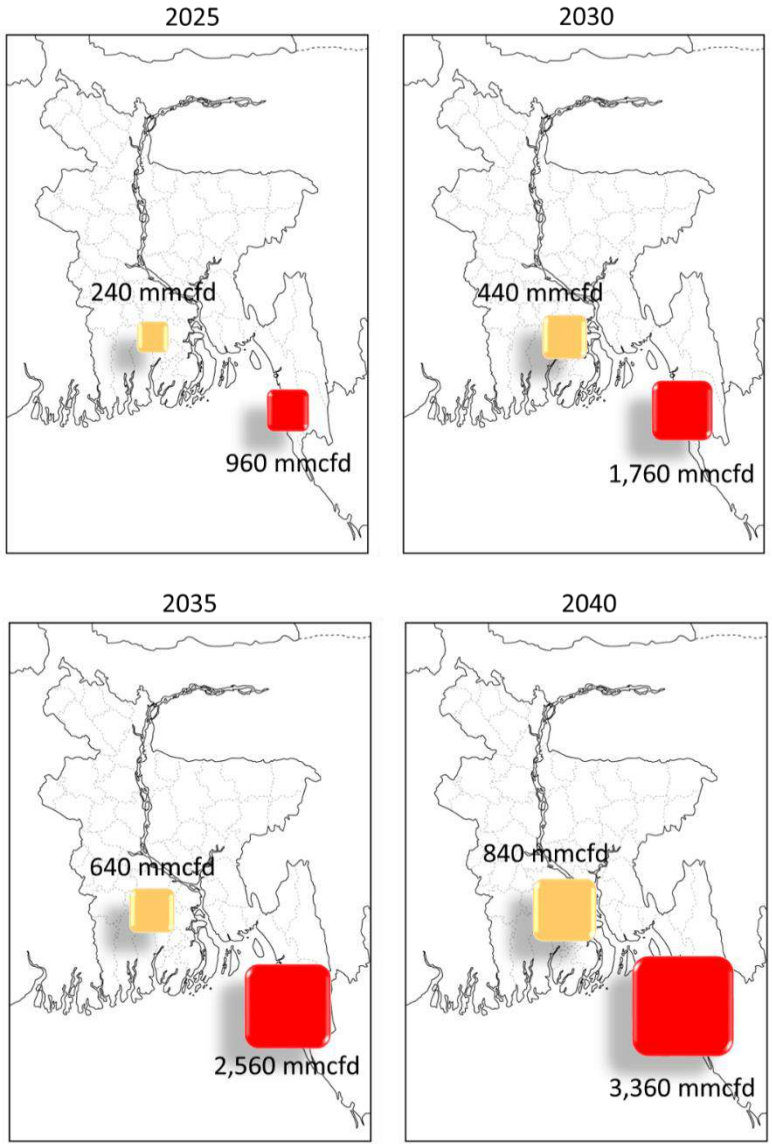
FY	Type of Terminal	Capacity (mmcfd)	Remarks
2018	FSRU	500	On-going project by Petrobangla
2022	FSRU	500	To be planned
2027	Onshore	500	To be planned
2029	Onshore	500	To be planned
2032	Onshore	500	To be planned
2035	Onshore	500	To be planned
Total Capacity		3,000	-

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-15 Scenario to Develop Imported Gas in Each Region



Source: JICA Survey Team

Figure 11-16 Scenario to Develop Imported Gas in Each Region (Unit: mmctd)

11.10.4 Coal development scenario

(1) Existing coal development

Domestic coal production in Bangladesh is only from the Barapukuria coal mine (underground mine), which produces at present approximately 1 million tonnes annually and supplies Barapukuria power station, etc., and will produce only approximately 1.5 million tonnes annually for Barapukuria power station, etc. even after the implementation of the expansion plan. Although Phulbari coal mine has a huge reserve, its development was cancelled by the current government because many people needed to be resettled for the development. As the production of domestic gas and coal will not increase against the surge in power demand in future, imported coal and LNG will be necessary.

(2) New coal terminal development scenario

As for coal transportation from coal production countries, such as Australia, Indonesia and South Africa to Bangladesh, using larger vessels is a cost-effective transportation method. A Panamax vessel (80,000DWT) can access near Matarbari #1 and 2, and Matarbari/Maheshkhali #1, 2 and 8-13 project sites, if a multi-purpose port at Maheshkhali Island is constructed. On the other hand, the vessel cannot access near Maowa, Khulna, Chittagong, Rampal, Payra or Matarbari/Maheshkhali #3-7 project sites, because of the very shallow bay around these project sites. These projects may use onshore coal terminals or offshore coal trans-shipment stations to reduce fuel transportation costs.

As per the discussion with the power companies, that is, BIFPCL, CPGCBL, NWPGC, and Orion Group, etc., the following information was supplied.

a) Ramapal Project

Rampal projects will use an offshore coal trans-shipment station. An 8,000DWT-10,000DWT barge from the station to project sites has been considered. However, these projects will use CTT, in the case that the COD of CTT is earlier than the COD of the Rampal projects, and the tariff for the terminal is cheaper than the operation costs for the offshore coal trans-shipment station.

b) PayraProject

A deep sea port will be constructed at Payra, which also has a coal terminal.

c) Maowa and Khulna Project

Maowa and Khulna projects will use imported coal using a 5,000DWT barge via Chittagong port, whose maximum draft is 9.1m. A Panamax vessel cannot access Chittagong port because of the shallow waterway.

d) Matarbari North Project

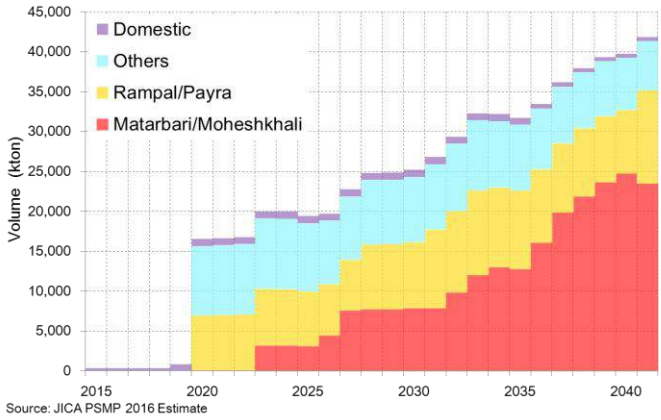
Matarbari North Projects will use CTT.

e) Brick manufacturers (Non-Power)

Brick manufacturers in the north of Dhaka use imported coal using 5,000DWT barges via Chittagong port. It is a possibility that the Rampal projects, Payra projects, Maowa, Khulna and Chittagong projects and brick manufacturers also use CTT, which a Panamax vessel can access, because of cheaper fuel transportation costs. The estimated annual trading volume of CTT depends on the development progress of the Payra deep sea port.

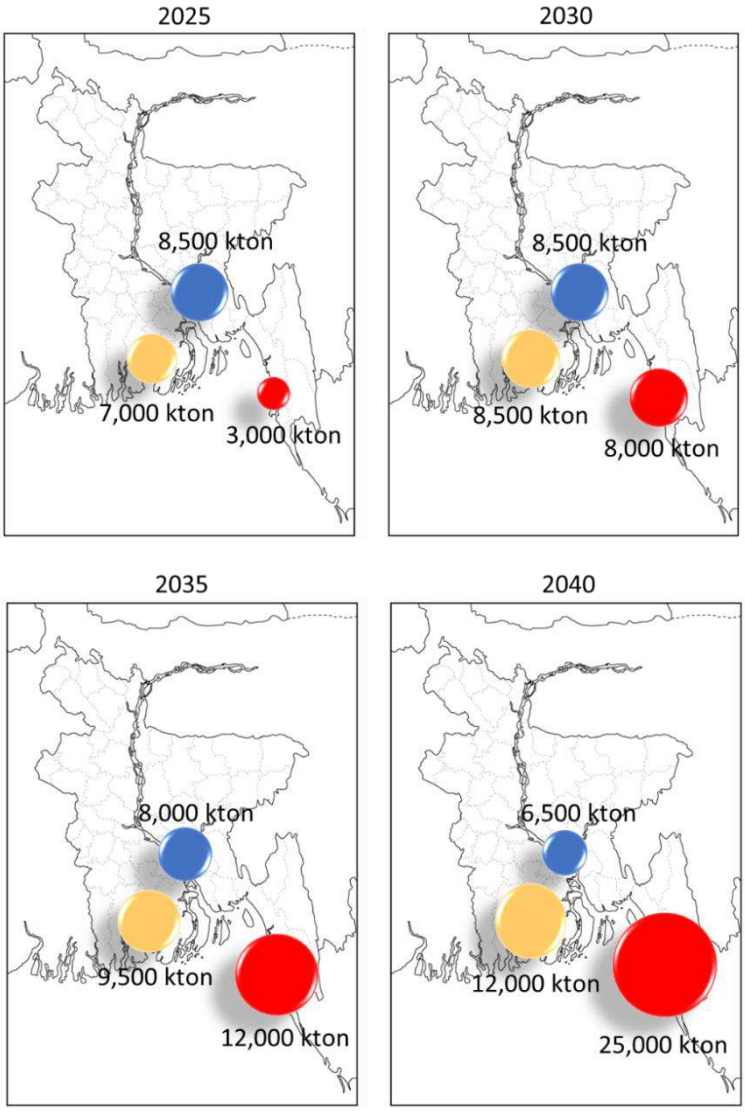
(3) Regional coal import scenario

The following figure shows the amount of coal supply by region. Imported coal is primarily used and coal is mainly imported to the Matarbari and Moheshkali regions (see Figure 11 18 (red)) as well as the Rampal and Payla regions (see Figure 11 18 (yellow)). Matarbari and Moheshkali expect to import 25,000 ktons of coal in 2040, while 11,000 ktons are supposed to be imported to Rampal and Payla. As shown in Figure 11 18, a total of 42,000 ktons of coal are estimated to be imported to Bangladesh in 2040.



Source: JICA Survey Team

Figure 11-17 Estimated Coal Demands for Power Supply (k tons)



Source: JICA Survey Team

Figure 11-18 Prospective imported coal amounts by 2041 (Unit: kTon)

11.11 Long and ultra-long term development plan (Candidate Plan)

A study on increasing the power sources by changing the ratios of the gas and coal power generation in accordance with the progress in the infrastructure and port development planned in JICA's Southern Chittagong MP Survey is to be conducted for the formulation of the candidate plan.
In this section, a scenario that sets the composition ratios of the gas and coal power generation in 2041 at 35% is to be used as the basic power development plan.

11.11.1 Gas based

The list of candidate gas-fired power plants is as follows.

Table 11-28 Candidate gas-fired power plants (Candidate)

No.	Gas Plant (Candidate)	Type	COD	Retirement	Output (MW)
	CC800				
1	Mohesikali	Gas	2032	-	800
2	Mohesikali	Gas	2033	-	800
3	Mohesikali	Gas	2034	-	800
4	Pyra	Gas	2034	-	800
5	Pyra	Gas	2035	-	800
6	Pyra	Gas	2035	-	800
7	Pyra	Gas	2035	-	800
8	Gas800 after 2035	Gas	2036	-	800
9	Gas800 after 2035	Gas	2037	-	800
10	Gas800 after 2035	Gas	2038	-	800
11	Gas800 after 2035	Gas	2039	-	800
12	Gas800 after 2035	Gas	2039	-	800
13	Gas800 after 2035	Gas	2040	-	800
14	Gas800 after 2035	Gas	2041	-	800
	CC500			-	
15	Mohesikali	Gas	2028	-	500
16	Mohesikali	Gas	2029	-	500
	CC250			-	
17	Anowara	Gas	2026	-	250
18	Anowara	Gas	2029	-	250
19	Anowara	Gas	2031	-	250
20	Pyra	Gas	2032	-	250
21	Pyra	Gas	2033	-	250
22	Pyra	Gas	2034	-	250
23	Pyra	Gas	2035	-	250
24	Gas250 after 2035	Gas	2036	-	250
25	Gas250 after 2035	Gas	2036	-	250
26	Gas250 after 2035	Gas	2037	-	250
27	Gas250 after 2035	Gas	2037	-	250
28	Gas250 after 2035	Gas	2038	-	250
29	Gas250 after 2035	Gas	2039	-	250
30	Gas250 after 2035	Gas	2041	-	250
	SGT100			-	
31	SGT100 -1	Gas	2027	-	100
32	SGT100 -2	Gas	2028	-	100
33	SGT100 -3	Gas	2028	-	100
34	SGT100 -4	Gas	2029	-	100
35	SGT100 -5	Gas	2029	-	100
36	SGT100 -6	Gas	2029	-	100
37	SGT100 -7	Gas	2029	-	100

Source: JICA Survey Team

11.11.2 Coal based

The list of candidate coal-fired power plants is as follows.

Table 11-29 Candidate coal-fired power plants (Candidate)

No.	Coal Plant (Candidate)	Type	COD	Retirement	Output (MW)
	CO600				
1	Matarbari/Maheshkhali #1	Imp. Coal	2026	-	600
2	Matarbari/Maheshkhali #2	Imp. Coal	2027	-	600
3	Matarbari/Maheshkhali #3	Imp. Coal	2027	-	600
4	payra West #1	Imp. Coal	2028	-	600
5	payra West #2	Imp. Coal	2031	-	600
6	Matarbari/Maheshkhali #4	Imp. Coal	2032	-	600
7	Matarbari/Maheshkhali #5	Imp. Coal	2033	-	600
8	Matarbari/Maheshkhali #6	Imp. Coal	2034	-	600
9	Matarbari/Maheshkhali #7	Imp. Coal	2036	-	600
	CO1000				
10	Matarbari/Maheshkhali #8	Imp. Coal	2036	-	1000
11	Matarbari/Maheshkhali #9	Imp. Coal	2037	-	1000
12	Matarbari/Maheshkhali #10	Imp. Coal	2037	-	1000
13	Matarbari/Maheshkhali #11	Imp. Coal	2038	-	1000
14	Matarbari/Maheshkhali #12	Imp. Coal	2039	-	1000
15	Matarbari/Maheshkhali #13	Imp. Coal	2040	-	1000
16	Payra West #3	Imp. Coal	2041	-	1000
17	payra West #4	Imp. Coal	2041	-	1000

Source: JICA Survey Team

11.11.3 Power Imports

The list of candidate power imports is as follows

Table 11-30 Candidate power import plans (Candidate)

No.	Power Import (Candidate)	Type	COD	Retirement	Output (MW)
1	Comilla - Tripura HVDC Phase 1-2 (100MW) (India)	P.I.	2020	-	100
2	Comilla - Tripura HVDC Phase 2 (300MW) (India)	P.I.	2021	-	300
3	Case 2 HVDC (Barapkuria S/S) Phase I-1 Bheramara - Baharampur Arunachal, India (East India)	P.I.	2028	-	500
4	Case 2 HVDC (Barapkuria S/S) Phase 1-2 Bheramara - Baharampur Arunachal, India (East India)	P.I.	2031	-	500
5	Case 2 HVDC (Barapkuria S/S) Phase Ⅱ	P.I.	2036	-	500
6	Case 2 HVDC (Barapkuria S/S) Phase Ⅲ	P.I.	2039	-	500
7	Case 3 HVDC (Barapkuria S/S) Phase I From India (Purnea - Barapukuria) (India)	P.I.	2021	-	500
8	Case 3 HVDC (Barapkuria S/S) Phase Ⅱ Phase I From India (Purnea - Barapukuria) (India)	P.I.	2024	-	500
9	Case 3 HVDC (Barapkuria S/S) Phase Ⅲ From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2027	-	500
10	Case 3 HVDC (Barapkuria S/S) Phase Ⅳ From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2029	-	500
11	Case 3 HVDC (Barapkuria S/S) Phase V From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2035	-	500
12	Case 3 HVDC (Barapkuria S/S) Phase Ⅵ From Nepal (Purnea - Barapukuria) (Nepal)	P.I.	2038	-	500
13	Bibiyana - Meghalaya (PSPP) (India)	P.I.	2030	-	1,000
14	Cox's Bazar - Myanmar	P.I.	2040	-	500
15	Rawta - Jamarpur HVDC PhaseⅠ Bongaigaon/Rangia - Jamarpur (Bhutan)	P.I.	2032	-	500
16	Rawta - Jamarpur HVDC PhaseⅡ Bongaigaon/Rangia - Jamarpur (Bhutan)	P.I.	2034	-	500

Source: JICA Survey Team

11.11.4 Nuclear power

The list of candidate nuclear power plants is as follows

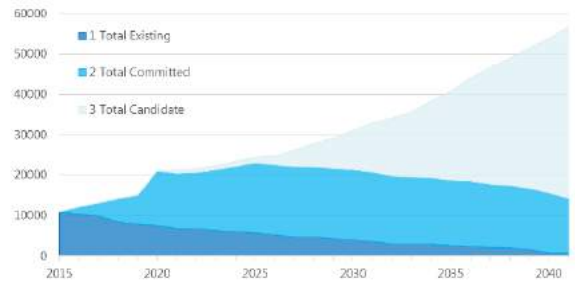
Table 11-31 Candidate nuclear power plants (Candidate)

No.	Nuclear Plant (Candidate)	Type	COD	Retirement	Output (MW)
1	Roopoor 3rd Unit	Nuclear	2030	-	1,200
2	Roopoor 4th Unit	Nuclear	2031	-	1,200
3	South West Nuc 5th Unit	Nuclear	2040	-	1,200
4	South West Nuc 6th Unit	Nuclear	2041	-	1,200

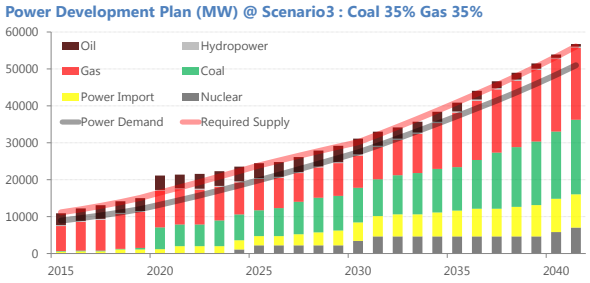
Source: JICA Survey Team

11.11.5 Summary of power development plan (Base case)

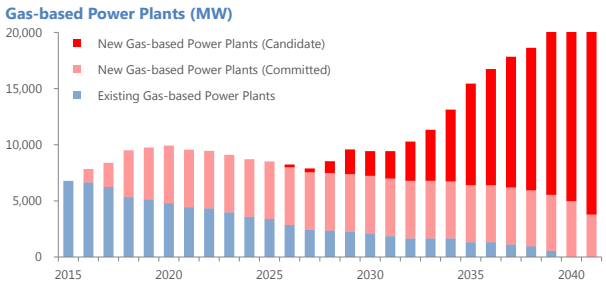
The figure below shows the power supply plan formulated by adding the capacity of the existing plants estimated with the retirement plan in the plan for the existing facilities taken into consideration (existing capacity), the capacity of the plants mentioned in the Committed Plan to be constructed by 2025, the capacity of the plants to be constructed later in the Candidate Plan that is subject to changes and the capacity required to ensure supply reliability during peak demand.



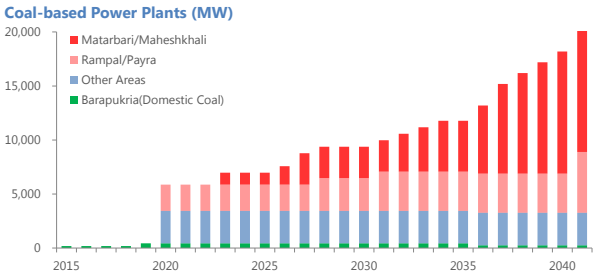
Power development plan（base case）



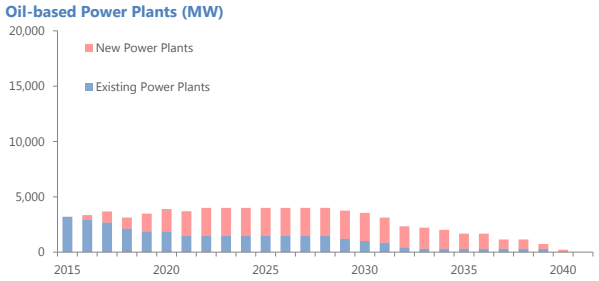
Power development plan of each power



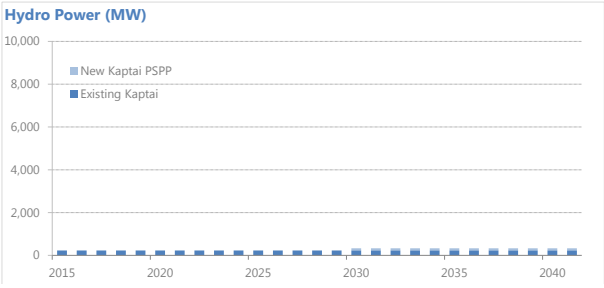
Gas



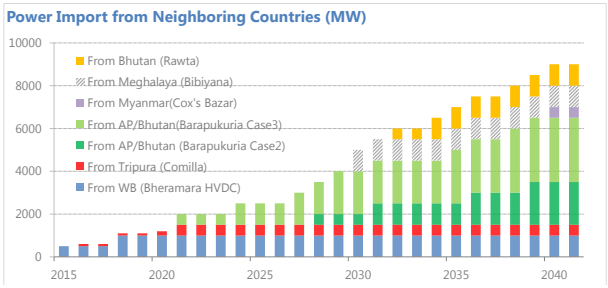
Coal



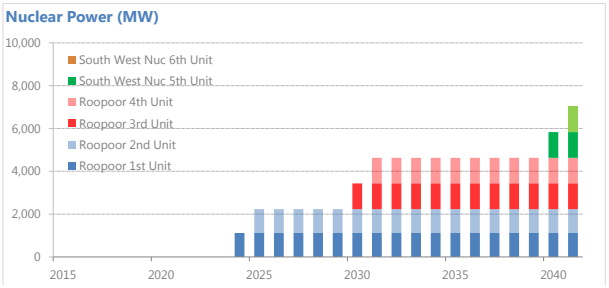
Oil



Hydro



Power Import



Nuclear

Source: JICA Survey Team

Figure 11-19 2015～2041 Power development plan（MW）

Table 11-32 List of power development plan

FY	Output (MW)	COD	Retirement	2015	2020	2025	2030	2035	2040	2041
1 Total Existing	Output (MW)			10,895	7,589	5,762	4,023	2,538	730	730
Coal				182	182	182	182	182	0	0
Barpapukuria 250MW (Unit 1&2)	182	2000	2036	182	182	182	182	182	0	0
Gas				6,781	4,802	3,390	2,106	1,321	0	0
Raojan (Chittagong) 2x210 MW	166	EX	2023	166	166	0	0	0	0	0
Raojan (Chittagong) 2x210 MW	166	EX	2023	166	166	0	0	0	0	0
SIKALBAHA (Chittagong) (60 MW)	39	EX	2016	39	0	0	0	0	0	0
Shikalbaha 150 MW PP	147	EX	2030	147	147	147	0	0	0	0
Ashuganj (B.Baria) 2x64 MW ST	89	EX	2017	89	0	0	0	0	0	0
Ashuganj (B.Baria) 3x150 MW ST	366	EX	2021	366	366	0	0	0	0	0
Ashuganj (B.Baria) 56 MW GT)	39	EX	2017	39	0	0	0	0	0	0
Ashugonj 50 MW Engine	44	EX	2031	44	44	44	44	0	0	0
Ashugonj 225 CCPP	218	EX	2040	218	218	218	218	218	0	0
Chandpur 150 MW CCPP	158	EX	2038	158	158	158	158	158	0	0
Ghorasal (Polash, Norshindi) 2x55 MW ST 1&2	78	EX	2019	78	0	0	0	0	0	0
Ghorasal (Polash, Norshindi) 210 MW ST 3,4,5&6	672	EX	2018	672	168	168	0	0	0	0
SIDDHIRGANJ (210 MW)	138	EX	2035	138	138	138	138	0	0	0
SIDDHIRGANJ 2x120 MW)	206	EX	2032	206	206	206	206	0	0	0
HARIPUR (96 MW) (Narayangonj)	59	EX	2017	59	0	0	0	0	0	0
Haripur 412 MW CCPP (EGCB)	400	EX	2039	400	400	400	400	400	0	0
TONGI (105 MW) (Dhaka)	103	EX	2025	103	103	0	0	0	0	0
Shahjibazar (Hobigonj) 2x35 MW GT 8&9	65	EX	2019	65	0	0	0	0	0	0
Lump GT Publick Gas ~30MW (SYLHET (20 MW)	19	EX	2018	19	0	0	0	0	0	0
SYLHET (150 MW) PP	139	EX	2018	139	0	0	0	0	0	0
Fenchuganj 97 & 104 MW CC BPDB	165	EX	2020	165	0	0	0	0	0	0
Lump GT Publick Gas ~100MW (Baghabari (Sirajgonj) 71 MW GT	69	EX	2020	69	0	0	0	0	0	0
Baghabari (Sirajgonj) 100 MW GT	98	EX	2025	98	98	0	0	0	0	0
Sirajgonj 210 MW CCPP (1st Unit)	204	EX	2037	204	204	204	204	204	0	0
RPCL (Mymenshing) (210 MW)	202	EX	2031	202	202	202	202	0	0	0
Haripur Power Ltd. (360 MW)	360	EX	2026	360	360	360	0	0	0	0
Meghnaghat power Ltd. (450 MW)	450	EX	2027	450	450	450	0	0	0	0
Ghorasal 108 MW IPP (Regent Power))	108	EX	2029	108	108	108	0	0	0	0
Ashugonj 195 MW Modular PP	195	EX	2035	195	195	195	195	0	0	0
Bibiana-II 341 MW CCPP (Summit)	341	EX	2040	341	341	341	341	341	0	0
Bogra 15 Years RPP (GBB)	22	EX	2023	22	22	0	0	0	0	0
Kumargoan, Sylhet RPP (Energyprima)	50	EX	2018	50	0	0	0	0	0	0
Shahjibazar 15 Yrs RPP (Shahjibazar Power)	86	EX	2024	86	86	0	0	0	0	0
Shahjibazar RPP (Energyprima)	50	EX	2017	50	0	0	0	0	0	0
Tangail SIPP (Doreen)	22	EX	2024	22	22	0	0	0	0	0
Feni SIPP (Doreen)	22	EX	2024	22	22	0	0	0	0	0
Lump Gas Rental ~50 MW (Kumkargoan, Sylhet 15 Years RPP (Des	10	EX	2024	10	10	0	0	0	0	0
Barobkundo SIPP (Regent Power)	22	EX	2024	22	22	0	0	0	0	0
Bhola 3 Years RPP (Venture)	33	EX	2017	33	0	0	0	0	0	0
Jangalia, Comilla SIPP (Summit))	33	EX	2024	33	33	0	0	0	0	0
Fenchuganj 15 Years RPP (Barakatullah)	51	EX	2024	51	51	0	0	0	0	0
Ashugong 55 MW RPP (Precision Energy))	55	EX	2018	55	0	0	0	0	0	0
Fenchugonj RPP (Energy Prima)	44	EX	2017	44	0	0	0	0	0	0
Ghorasal 45 MW QRPP (Aggreko)	45	EX	2018	45	0	0	0	0	0	0
Ghorasal 100 MW QRPP (Aggreko)	100	EX	2018	100	0	0	0	0	0	0
B. Baria 70 MW QRPP (Aggreco)	85	EX	2017	85	0	0	0	0	0	0
Lump Gas Rental ~100 MW (Ghorasal 78 MW QRPP (Max Power)	78	EX	2020	78	0	0	0	0	0	0
Ashugonj 80 MW QRPP (Aggreko)	95	EX	2016	95	0	0	0	0	0	0
Ashugonj 53 MW QRPP (United Power)	53	EX	2019	53	0	0	0	0	0	0
Shajahanullah Power Com. Ltd.	25	EX	2020	25	0	0	0	0	0	0
Summit Power(REB)	105	EX	2022	105	105	0	0	0	0	0
Bogra RPP (Energy Prima)	20	EX	2024	20	20	0	0	0	0	0
Lump SIPP Gas (Hobiganj SIPP (REB) (Confi-Energypac)	11	EX	2024	11	11	0	0	0	0	0
Ullapara SIPP (REB) (Summit)	11	EX	2024	11	11	0	0	0	0	0
Narsindi SIPP (REB) (Doreen)	22	EX	2024	22	22	0	0	0	0	0
Feni SIPP (REB) (Doreen)	11	EX	2024	11	11	0	0	0	0	0
Mouna, Gazipur SIPP (REB) (Summit)	33	EX	2024	33	33	0	0	0	0	0
Rupganj , Narayanganj SIPP (REB) (Summit)	33	EX	2024	33	33	0	0	0	0	0
Ashugonj 51 MW IPP (Midland)	51	EX	2028	51	51	51	0	0	0	0
Oil/HSD				922	305	305	305	305	0	0
Lump GT Public HSD ~20MW (BARISAL (40MW)	30	EX	2016	30	0	0	0	0	0	0
BHERAMARA (Kustia) (60 MW)	46	EX	2016	46	0	0	0	0	0	0
Khulna 150 MW PP (NWPGCL)	155	EX	2017	155	0	0	0	0	0	0
RANGPUR (20 MW)	19	EX	2016	19	0	0	0	0	0	0
SAIDPUR (20 MW) (Dinajpur)	19	EX	2016	19	0	0	0	0	0	0
Summit Meghnaghat Power Company Ltd. CCPP	305	EX	2040	305	305	305	305	305	0	0
Thakurgaon RPP (RZ Power)	40	EX	2018	40	0	0	0	0	0	0
Khulna 55 MW QRPP (Aggreko))	55	EX	2018	55	0	0	0	0	0	0
Lump HSD Rental ~50 MW (Pagla 50 MW QRPP (DPA)	50	EX	2018	50	0	0	0	0	0	0
Bheramara 110 MW RPP (Quantum Power))	105	EX	2018	105	0	0	0	0	0	0
Lump HSD Rental ~100 MW (Shiddirgonj 100 MW QRPP (Desh Ene	98	EX	2019	98	0	0	0	0	0	0
Oil/F.oil				2,281	1,570	1,155	700	0	0	0
Hathazari 100 MW Peaking PP	96	EX	2032	96	96	96	96	0	0	0
Sangu, Dohazari 100 MW Peaking PP	99	EX	2033	99	99	99	99	0	0	0
Lump HFO Public ~50 MW (Raojan 25 MW Peaking PP)	25	EX	2033	25	25	25	25	0	0	0
Gazipur 52 MW PP	51	EX	2032	51	51	51	51	0	0	0
Titas, Doudkandi 50 MW Peaking PP	51	EX	2031	51	51	51	51	0	0	0
KHULNA (110 MW)	50	EX	2016	50	0	0	0	0	0	0
Faridpur 50 MW Peaking PP)	52	EX	2031	52	52	52	52	0	0	0
Gopalgonj 100 MW Peaking PP)	107	EX	2032	107	107	107	107	0	0	0
BAGHABARI 50 MW Peaking PP	51	EX	2031	51	51	51	51	0	0	0
Lump HFO Public ~100 MW (BERA 70 MW Peaking PP	70	EX	2032	70	70	70	70	0	0	0
Santahar 50 MW Peaking PP	49	EX	2032	49	49	49	49	0	0	0
Katakhali 50 MW Peaking PP	49	EX	2032	49	49	49	49	0	0	0
KPCL BMPP 15 Years (Khulna) (Summit-United)	110	EX	2018	110	0	0	0	0	0	0
NEPC (110 MW) (Haripur BMPP)	110	EX	2019	110	0	0	0	0	0	0
Natore 52 MW IPP (Raj-Lanka)	52	EX	2029	52	52	52	0	0	0	0
Gognagar 102 MW PP (Summit)	102	EX	2029	102	102	102	0	0	0	0
Baraka-Potenga 50 MW IPP	50	EX	2029	50	50	50	0	0	0	0
Potiya, Chittagong 100 MW Power Plant	108	EX	2030	108	108	108	0	0	0	0
Jangalia, Comilla (Lakdanvhi)	52	EX	2030	52	52	52	0	0	0	0
Kathpotty, Munshigonj 53 MW PP (Sinha)	51	EX	2030	51	51	51	0	0	0	0
Lump Private Existing RE HFO ~50 (Shikal Baha RPP(Energis)	40	EX	2018	40	0	0	0	0	0	0
Lump Private Existing RE HFO ~100 (Madangonj 102 MW QRPP (Su	100	EX	2021	100	100	0	0	0	0	0
Khulna 115 MW QRPP (KPCL) (Summit-United)	115	EX	2021	115	115	0	0	0	0	0
Noapara 40 MW QRPP (Khan Jahan Ali)	40	EX	2029	40	40	40	0	0	0	0
Noapara 105 MW RPP (Quantum Power)	101	EX	2016	101	0	0	0	0	0	0
Meghnaghat 100 MW QRPP (IEL)	100	EX	2021	100	100	0	0	0	0	0
Siddirganj 100 MW QRPP (Dutch Bangla Power)	100	EX	2021	100	100	0	0	0	0	0
Amnura 50 MW QRPP (Sinha Power)	50	EX	2018	50	0	0	0	0	0	0
Keranigonj 100 MW QRPP (Power Pak)	100	EX	2017	100	0	0	0	0	0	0
Julda100 MW QRPP (Acron Infra Servicw)	100	EX	2018	100	0	0	0	0	0	0
Katakhali 50 MW QRPP (NPSL)	50	EX	2019	50	0	0	0	0	0	0
ImP				500	500	500	500	500	500	500
Bheramara-Bharampur HVDC Phase 1(from India)	500	2013	9999	500	500	500	500	500	500	500
Hyd				230	230	230	230	230	230	230
Kaptai Hydro Power Plant	230	2000	9999	230	230	230	230	230	230	230

FY	Output (MW)	COD	Retirement	2015	2020	2025	2030	2035	2040	2041
2 Total Comitted				0	13,441	17,297	17,397	16,170	14,925	13,504
Coal				0	5,691	6,795	6,795	6,795	6,795	6,795
Barapukuria 275MW (Unit 3)	252	2019	9999	0	252	252	252	252	252	252
Matarbari#1,2	1104	2023	9999	0	0	1,104	1,104	1,104	1,104	1,104
Rampal#1,2	1214	2020	9999	0	1,214	1,214	1,214	1,214	1,214	1,214
Payra#1,2	1214	2020	9999	0	1,214	1,214	1,214	1,214	1,214	1,214
Khulna	630	2020	9999	0	630	630	630	630	630	630
Maowa	522	2020	9999	0	522	522	522	522	522	522
Dhaka	635	2020	9999	0	635	635	635	635	635	635
Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-1	612	2020	9999	0	612	612	612	612	612	612
Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-2	612	2020	9999	0	612	612	612	612	612	612
Gas				0	5,126	5,126	5,126	5,076	4,978	3,777
Bhola 225 MW CCPP	189	2016	2041	0	189	189	189	189	189	0
Siddirganj 335 MW CCPP	328	2016	2041	0	328	328	328	328	328	0
Ashuganj (North) CCPP	370	2017	9999	0	370	370	370	370	370	370
Ashuganj (South) CCPP	361	2016	2041	0	361	361	361	361	361	0
Ghorasal 363 MW (7th Unit) CCPP	352	2017	9999	0	352	352	352	352	352	352
Shajibazar CCPP	322	2016	2041	0	322	322	322	322	322	0
Shikalbaha 225 MW CCPP	218	2017	9999	0	218	218	218	218	218	218
Bibiana South CCPP BPDB	372	2018	9999	0	372	372	372	372	372	372
Bibiana III CCPP BPDB	388	2019	9999	0	388	388	388	388	388	388
Bheramara 414 MW CCPP	402	2018	9999	0	402	402	402	402	402	402
Fenchugonj 50 MW Power Plant (NRB)	50	2019	2034	0	50	50	50	0	0	0
Sylhet 150 MW PP Conversion	221	2018	9999	0	221	221	221	221	221	221
Ghorasal 3rd & 4th Unit Repowering (Capacity Addition)	776	2018	9999	0	776	776	776	776	776	776
Kushiara 163 MW CCPP	163	2018	9999	0	163	163	163	163	163	163
Bagabari 71MW PP Conversion	102	2020	2042	0	102	102	102	102	102	102
Sirajganj 414 MW CCPP (4th unit)	414	2020	9999	0	414	414	414	414	414	414
Shahajibazar 100 MW	98	2018	2038	0	98	98	98	98	0	0
Oil/HSD				0	995	1,215	1,215	1,068	220	0
Kodda, Gazipur 150 MW Power Plant	147	2016	2035	0	147	147	147	0	0	0
Upgradation of Khulna 150 MW to 225 MW	221	2017	2037	0	221	221	221	221	0	0
Khulna 200-300 MW CCPP	196	2019	2039	0	196	196	196	196	0	0
Sirajgonj 225 MW CCPP (2nd Unit)	216	2019	2039	0	216	216	216	216	0	0
Sirajgonj 225 MW CCPP (3rd Unit)	216	2020	2040	0	216	216	216	216	0	0
Bhola 220 MW CCPP Dual Fuel BOO power plant	220	2021	2041	0	0	220	220	220	220	0
Oil/F.oil				0	1,030	1,330	1,330	300	0	0
Chapai Nababganj 104 MW PP	102	2017	2032	0	102	102	102	0	0	0
Keranigonj 100 MW PP (Re from Khulna))	100	2019	2034	0	100	100	100	0	0	0
Bosila, Keranigonj 108 MW PP (CLC Power)	108	2017	2032	0	108	108	108	0	0	0
Jamalpur 100 MW Power Plant	95	2017	2032	0	95	95	95	0	0	0
Barisal 100 MW PP (Re. from Syedpur)	110	2016	2031	0	110	110	110	0	0	0
Lump HFO Private New ~50 MW (Madangonj 50 MW Peaking Plant (	55	2016	2031	0	55	55	55	0	0	0
Manikgonj 55 MW PP	50	2016	2031	0	50	50	50	0	0	0
Kamalaghat 50 MW PP)	55	2017	2032	0	55	55	55	0	0	0
Nababgonj 55 MW PP	55	2016	2031	0	55	55	55	0	0	0
Satkhira 50 MW PP	50	2019	2034	0	50	50	50	0	0	0
Bhairab 50 MW PP	50	2019	2034	0	50	50	50	0	0	0
Patiya 100 Mw BOO FO power plant	100	2020	2035	0	100	100	100	0	0	0
Anwara 300 MW HFO plant	300	2022	2037	0	0	300	300	300	0	0
Julda 100 Mw BOO FO power plant	100	2020	2035	0	100	100	100	0	0	0
ImP				0	600	600	600	600	600	600
Comilla - Tripura HVDC Phase 1-1 (100MW) (India)	100	2016	9999	0	100	100	100	100	100	100
Bheramara-Bharampur HVDC Phase 2 Bheramara - Baharampur (	500	2018	9999	0	500	500	500	500	500	500
Nuc				0	0	2,232	2,232	2,232	2,232	2,232
Roopoor 1st Unit	1,116	2024	9999	0	0	1,116	1,116	1,116	1,116	1,116
Roopoor 2nd Unit	1,116	2025	9999	0	0	1,116	1,116	1,116	1,116	1,116
Hyd				0	0	0	100	100	100	100
New Kaptai Pumped Strage	100	2030	9999	0	0	0	100	100	100	100

FY	Output (MW)	COD	Retirement	2015	2020	2025	2030	2035	2040	2041
3 Total Candidate				0	100	1,400	9,700	22,150	38,250	42,500
CO600				0	0	0	2400	4800	5400	5400
Matarbari/Maheshkhali #1	600	2026	9999	0	0	0	600	600	600	600
Matarbari/Maheshkhali #2	600	2027	9999	0	0	0	600	600	600	600
Matarbari/Maheshkhali #3	600	2027	9999	0	0	0	600	600	600	600
payra West #1	600	2028	9999	0	0	0	600	600	600	600
payra West #2	600	2031	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #4	600	2032	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #5	600	2033	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #6	600	2034	9999	0	0	0	0	600	600	600
Matarbari/Maheshkhali #7	600	2036	9999	0	0	0	0	0	600	600
CO1000				0	0	0	0	0	6000	8000
Matarbari/Maheshkhali #8	1000	2036	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #9	1000	2037	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #10	1000	2037	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #11	1000	2038	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #12	1000	2039	9999	0	0	0	0	0	1,000	1,000
Matarbari/Maheshkhali #13	1000	2040	9999	0	0	0	0	0	1,000	1,000
Payra West #3	1000	2041	9999	0	0	0	0	0	0	1,000
payra West #4	1000	2041	9999	0	0	0	0	0	0	1,000
CC800				0	0	0	0	5,600	10,400	11,200
Mohesikali	800	2032	9999	0	0	0	0	800	800	800
Mohesikali	800	2033	9999	0	0	0	0	800	800	800
Mohesikali	800	2034	9999	0	0	0	0	800	800	800
Pyra	800	2034	9999	0	0	0	0	800	800	800
Pyra	800	2035	9999	0	0	0	0	800	800	800
Pyra	800	2035	9999	0	0	0	0	800	800	800
Pyra	800	2035	9999	0	0	0	0	800	800	800
Gas800 after 2035	800	2036	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2037	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2038	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2039	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2039	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2040	9999	0	0	0	0	0	800	800
Gas800 after 2035	800	2041	9999	0	0	0	0	0	0	800
CC500				0	0	0	1,000	1,000	1,000	1,000
Mohesikali	500	2028	9999	0	0	0	500	500	500	500
Mohesikali	500	2029	9999	0	0	0	500	500	500	500
CC250				0	0	0	500	1,750	3,250	3,500
Anowara	250	2026	9999	0	0	0	250	250	250	250
Anowara	250	2029	9999	0	0	0	250	250	250	250
Anowara	250	2031	9999	0	0	0	0	250	250	250
Pyra	250	2032	9999	0	0	0	0	250	250	250
Pyra	250	2033	9999	0	0	0	0	250	250	250
Pyra	250	2034	9999	0	0	0	0	250	250	250
Pyra	250	2035	9999	0	0	0	0	250	250	250
Gas250 after 2035	250	2036	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2036	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2037	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2037	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2038	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2039	9999	0	0	0	0	0	250	250
Gas250 after 2035	250	2041	9999	0	0	0	0	0	0	250
SGT100				0	0	0	700	700	700	700
SGT100 -1	100	2027	9999	0	0	0	100	100	100	100
SGT100 -2	100	2028	9999	0	0	0	100	100	100	100
SGT100 -3	100	2028	9999	0	0	0	100	100	100	100
SGT100 -4	100	2029	9999	0	0	0	100	100	100	100
SGT100 -5	100	2029	9999	0	0	0	100	100	100	100
SGT100 -6	100	2029	9999	0	0	0	100	100	100	100
SGT100 -7	100	2029	9999	0	0	0	100	100	100	100
ImP				0	100	1,400	3,900	5,900	7,900	7,900
Comilla - Tripura HVDC Phase 1-2 (100MW) (India)	100	2020	9999	0	100	100	100	100	100	100
Comilla - Tripura HVDC Phase 2 (300MW) (India)	300	2021	9999	0	0	300	300	300	300	300
Case 2 HVDC (Barapkuria S/S) Phase I-1 Bheramara - Baharampur	500	2028	9999	0	0	0	500	500	500	500
Case 2 HVDC (Barapkuria S/S) Phase 1-2 Bheramara - Baharampu	500	2031	9999	0	0	0	0	500	500	500
Case 2 HVDC (Barapkuria S/S) Phase II	500	2036	9999	0	0	0	0	0	500	500
Case 2 HVDC (Barapkuria S/S) Phase III	500	2039	9999	0	0	0	0	0	500	500
Case 3 HVDC (Barapkuria S/S) Phase I From India (Purnea - Barap	500	2021	9999	0	0	500	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase II Phase I From India (Purn	500	2024	9999	0	0	500	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase III From Nepal (Purnea - Bar	500	2027	9999	0	0	0	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase IV From Nepal (Purnea - Ba	500	2029	9999	0	0	0	500	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase V From Nepal (Purnea - Bar	500	2035	9999	0	0	0	0	500	500	500
Case 3 HVDC (Barapkuria S/S) Phase VI From Nepal (Purnea - Ba	500	2038	9999	0	0	0	0	0	500	500
Bibiyana - Meghalaya (PSPP) (India)	1,000	2030	9999	0	0	0	1,000	1,000	1,000	1,000
Cox's Bazar - Myanmar	500	2040	9999	0	0	0	0	0	500	500
Rawta - Jamarpur HVDC PhaseI Bongaigaon/Rangia - Jamarpur (Bh	500	2032	9999	0	0	0	0	500	500	500
Rawta - Jamarpur HVDC PhaseII Bongaigaon/Rangia - Jamarpur (BH	500	2034	9999	0	0	0	0	500	500	500
Nuc				0	0	0	1,200	2,400	3,600	4,800
Roopoor 3rd Unit	1,200	2030	9999	0	0	0	1,200	1,200	1,200	1,200
Roopoor 4th Unit	1,200	2031	9999	0	0	0	0	1,200	1,200	1,200
South West Nuc 5th Unit	1,200	2040	9999	0	0	0	0	0	1,200	1,200
South West Nuc 6th Unit	1,200	2041	9999	0	0	0	0	0	0	1,200
Hyd				0	0	0	0	0	0	0

11.12 Preconditions for the estimation of the economic and environmental values

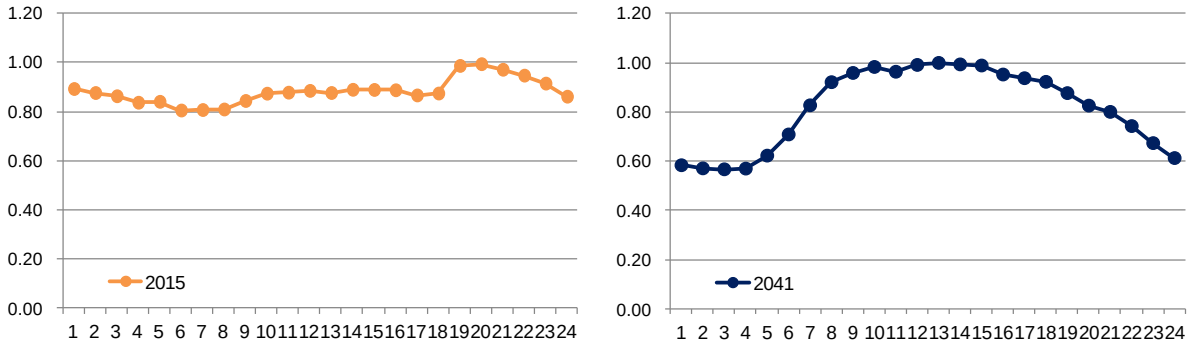
11.12.1 Daily load curve

(1) Estimating the daily load curve

The following estimates the daily load curve in Bangladesh during the 2015-2041 period. The performance records of the daily load curve in Bangladesh in 2015 are represented by a curve having a power demand peak in the evening, as illustrated below. In the meantime, by 2041, the economic growth rate in Bangladesh is estimated to reach the daily load curve of advanced countries, where the peak is found in the daytime and evening, if the growth of the electrification rate is taken into account.

In the fiscal 2015 daily load curve, consideration is given to the performance value for power consumption on a time-of-day basis in Bangladesh.

- From the fiscal 2015 power consumption (performance value) on a time-of-day basis in Bangladesh, the monthly Max/Average/Min data on a time-of-day basis will be created, where "Max" indicates the average value for highest three days for power consumption for each month, "Min" denotes the average value for lowest eight days for power consumption and "Average" represents the average value for the remaining days.
- According to the above-mentioned data, power consumption reaches the highest level in April. Thus, April is assumed as a "High" month. December is assumed as a "Low" month since power consumption reaches the lowest level in this month.
- The Max/Average/Min data will be standardized so that the Max value in April will be 1.0. This is assumed as the 2015 daily load curve for Bangladesh.



Source: JICA Survey Team

Figure 11-20 Daily load curve in Bangladesh (Performance record for 2015 on the left, and estimated value for 2041 on the right)

(2) Estimation method of load daily curve from 2015 to 2041

In the 2015-2041 daily load curve, there will be a gradual shift to the daily load curve of advanced countries by 2041.

i) The fiscal 2015 power consumption performance value on a time-of-day basis in Japan will be used as the data for advanced countries. Using the same procedure given in (1), Max/Average/Min data on a time-of-day basis for each month is created, and Max/Average/Min data is standardized so that the maximum value for August representing the maximum power consumption will be 1.0.

ii) "High" month in Bangladesh falls in April. Accordingly, the standardized Japan data for August created in (2)-i) will be applied to Bangladesh's April data for 2041. Similarly, "Low" month in Bangladesh falls in December. Accordingly, the standardized Japan data for May created in (2)-i) will be applied to Bangladesh's December data for 2041.

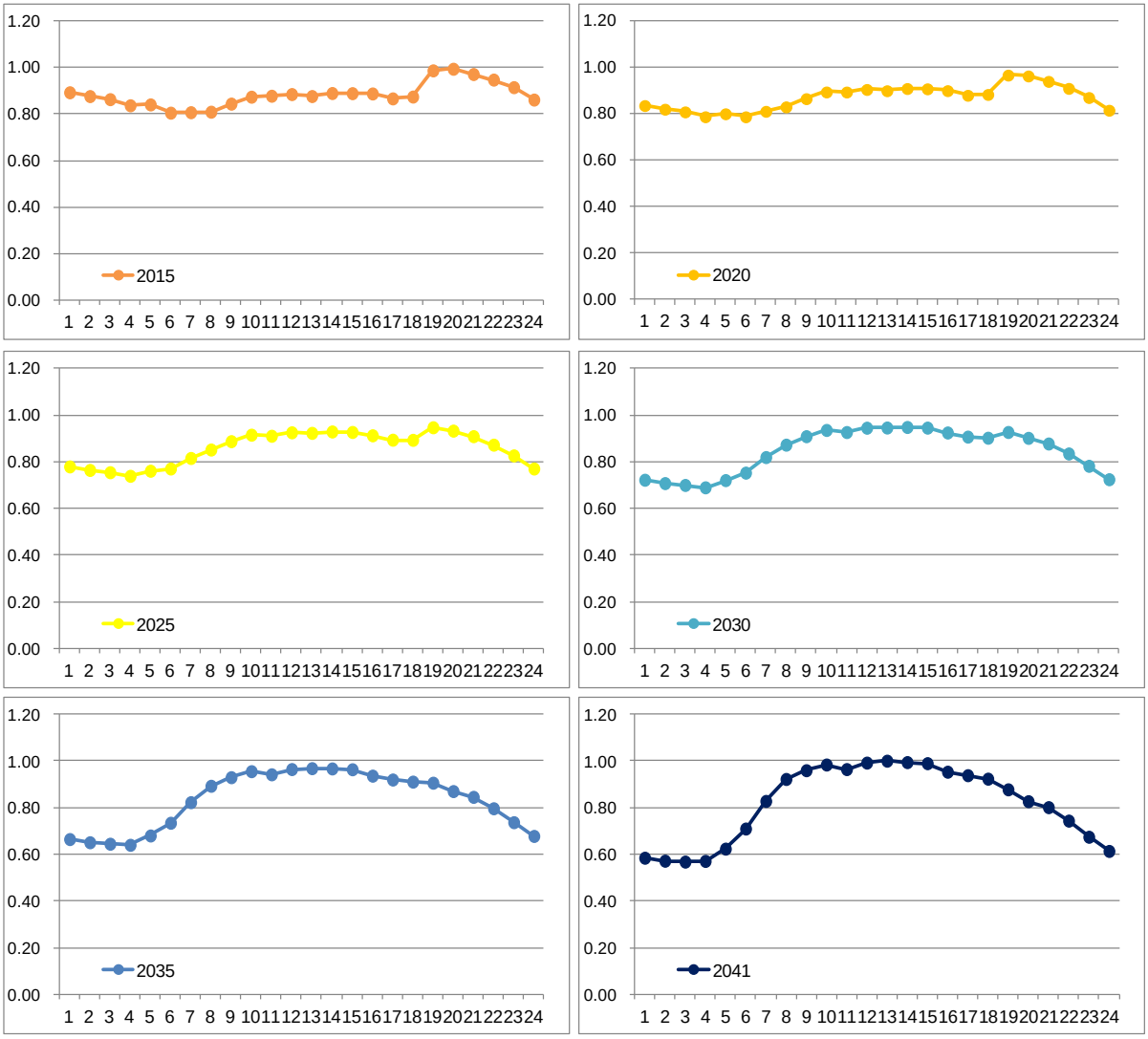
iii) For months other than December and May, there is a proportionate increase in power consumption from January to April, and a proportionate decrease in power consumption from June to November. This is assumed as an estimated daily load curve for 2041 in Bangladesh.

iv) From 2015 to 2040, there is assumed to be a proportionate increase or decrease in power consumption on a time-of-day basis. This is considered to be an estimated daily load curve for the 2015-2040 period in Bangladesh.

$$H_{i,t} = H_{i-1,t} + (H_{2041,t} - H_{2015,t}) / (2041-2015+1)$$

※ i: year, t: time of the day

The estimated result is illustrated below. Observing the transition of the daily load curve at intervals of five years from 2015, the evening peak curve as a 2015 performance value represents the yearly change in the daytime peak curve of advanced countries.



Source: JICA Survey Team

Figure 11-21 Estimated daily load curve for 2015-2041 period in Bangladesh

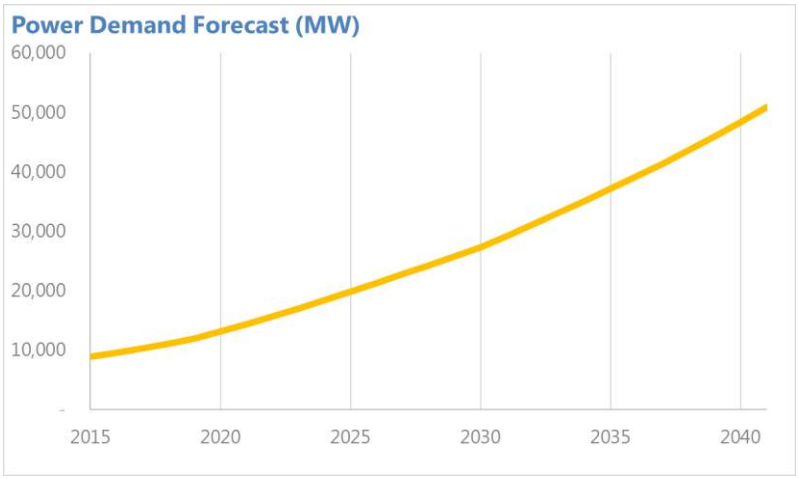
(3) Estimating the long-term power demand considering the future change in daily load curve

To estimate the long-term power demand considering the future change in daily load curve, the daily load curve up to 2041 estimated in (2) is superimposed on the maximum power demand with consideration given to the potential demand up to 2041 estimated in (1). The maximum power demand up to 2041 is estimated in another chapter. The value is shown in the Table and Figure.

Table 11-33 Maximum power demand from 2015 to 2041 (Unit: MW)

Power Demand	2015	2021	2026	2031	2036	2041
MW	8,921	14,460	21,328	29,250	39,315	50,979

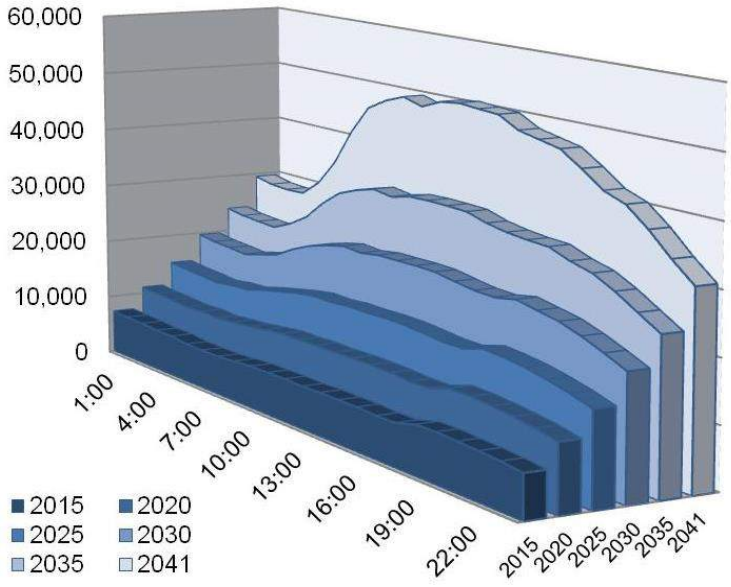
Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-22 Maximum power demand from 2015 to 2041 (Unit: MW)

The results of the estimation are illustrated below. The transition of the power demand at intervals of five years from 2015 suggests that there is a rise in power demand during the 2015-2041 period, and a change from the evening peak daily power demand to the daytime peak daily power demand in conformity with the changes in daily load curve.



Source: JICA Survey Team

Figure 11-23 Transition of power demand in 2015-2041 in Bangladesh (Unit: MW)

11.12.2 Supply Reliability

(1) Power supply reliability

Power supply reliability of electric power systems is generally evaluated based on the LOLE (loss of load expectation) value, which represents the number of hours (expected value) of power supply failure events out of 8760 annual operating hours.

i) Demand shape

The demand shape will decide the probability of the approximate level rising to the recorded maximum demand. The more frequently the demand approximately reaches the maximum demand, the higher the probability of power supply failures will be.

ii) Errors in the demand forecast

Errors in the demand forecast are divided into two types—short-term errors in daily operational forecasts and long-term errors in annual development forecasts.

A short-term error is a deviation in actual daily demand from the demand that is forecasted for the daily operation planning of the following day. An example is the unpredicted demand change caused by a weather forecasting error. Since short-term deviations cannot be covered by the sudden development of extra supply capacity, reserve capacity must be prepared for such deviations.

On the other hand, errors resulting from a long-term (e.g. 10-year term) demand forecast can be absorbed to a certain extent in the rolling development plans prepared each year. Thus, the supply reserve margin does not have to cover all of the long-term deviation. However, the annual rolling plan cannot alter power facility development plans with a long lead-time, a fact that necessitates a certain level of reserve margin to cover for the long-term deviation.

iii) Forced outage rate

Power outages are divided into two types—forced outages from accidents or other reasons and planned outages for regular inspections. Of the two, forced outages resulting, for example, from sudden accidents are a particularly important factor in determining the supply reliability. Thus, planned outages will not be considered normally.

Here, the outage rate is defined as the ratio of the number of outage hours to the total number of operating hours.

iv) Unit capacity and system scale

If the power system contains generators of large unit capacities, the probability of suddenly losing a large-scale supply capability will increase. The loss of a large supply capability not only causes a severe transitional impact on the system but also makes it quite difficult to recover the lost capability, and thus, increases the probability of power supply failure.

v) Water inflow fluctuations and reliance on hydropower (ratio against the whole capacity)

If hydropower makes up a large portion of the whole supply capacity, the influence on power supply capacity that comes from the fluctuations in annual precipitation, and the resulting river flow, is large. In Bangladesh, the capacity of hydropower is very small so these effects can be ignored.

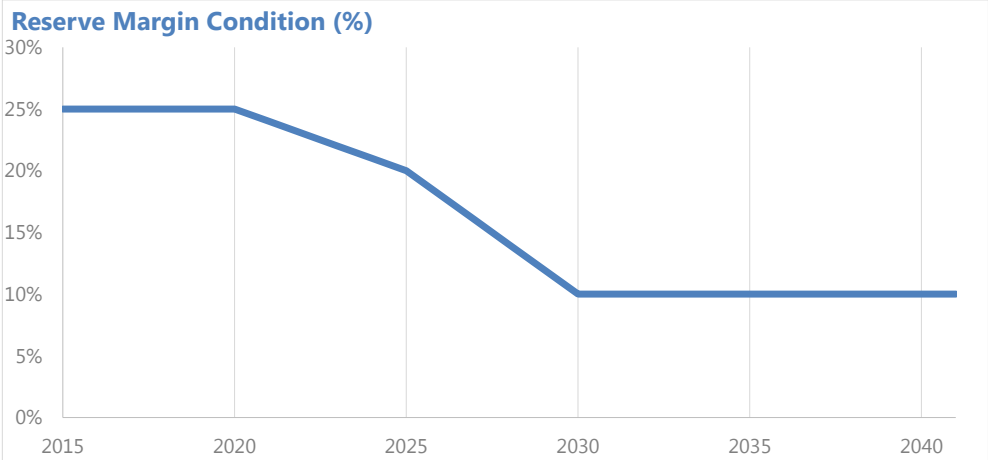
vi) Connection with Other Systems

Connecting two power supply systems has the advantage of improving the reliability of the power supply in both systems because the connection enables mutual power interchange between them. It is considered possible to utilize this advantage fully if the international connection between Bangladesh and neighboring countries is extended in future. However, this advantage, which is an uncertain factor at present, is not considered in the formulation of the power development plan from a conservative viewpoint.

(2) Relationship between Reliability of Supply and Required Capacity

An analysis was conducted on the relationship between the reliability of power supply and the required capacity based on the power demand forecast (Base Case) and PDP. The relationship between

the reserve margin and LOLE changes from year to year. If the value of LOLE is set at the standard value for developing countries of 1.0 to 1.5%, the reserve margin theoretically appropriate for the current state is approximately 25%. If international linkage and nuclear power generation are to be introduced *ca.* 2025, the reliability of the power supply shall have to be improved, as mentioned in detail in the chapter on power quality. A margin of between 8% and 15% will be required in order to achieve the target of LOLE = 0.3%, which is acknowledged to be a very challenging target. Therefore, it was assumed that the reserve margin shall be reduced from 25% in 2020 to the target of 10% by 2030 and shall be maintained at this level thereafter.



Source: JICA Survey Team

Figure 11-24 Reserve Margin

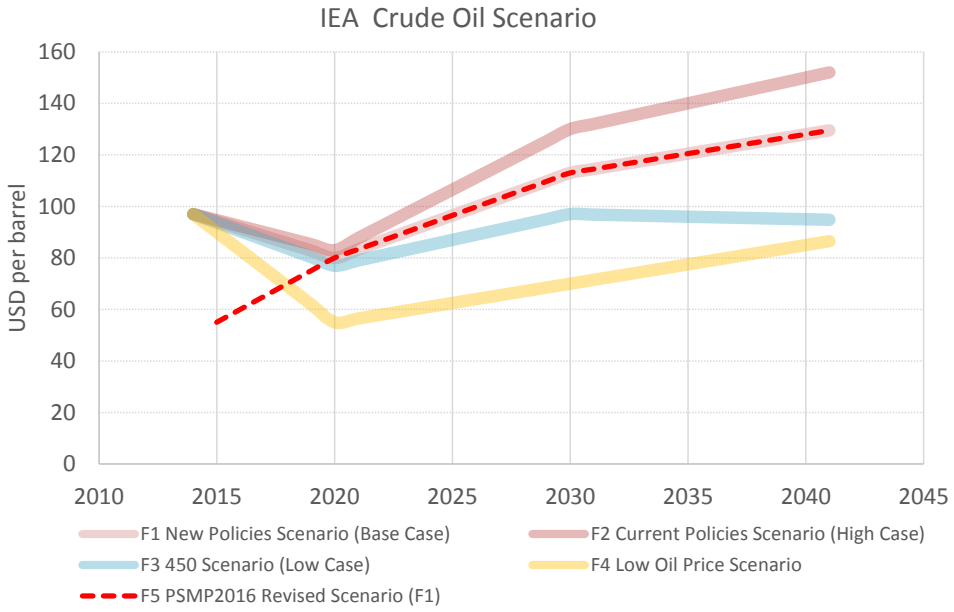
11.12.3 Fuel Price Scenarios

(1) IEA crude oil scenario

The differences between the prices of fuels in Bangladesh, including the price of domestically produced gas in particular, and the prices in the international market are large and fuel in Bangladesh is provided at prices significantly lower than those in the international market. As the future economic growth will inevitably make it impossible to satisfy the power demand with domestically produced resources, the proportion of imported fuel in the fuel supply is expected to increase rapidly and the prices of fuel are expected to increase to close to those in the international market.

In the discussion with the Government of Bangladesh and the IEA, the international organization on energy, it was decided to use the IEA Scenario for the price of crude oil that projected the price on the basis of a very long-term projection of the supply/demand balance in this analysis.

However, there is a difference between the market price of crude oil in the IEA scenario and the actual price in the market in Bangladesh at present. Therefore, an original scenario for this analysis (F5) has been formulated as the basic scenario for the price of crude oil. In this scenario, the reference price is set at the average price of crude oil in the domestic market in 2015 and the price is projected to follow the New Policies Scenario of the IEA (F1) from 2020 onward.



Source: JICA Survey Team

Figure 11-25 IEACrude Oil Scenario

(2) Long-term scenarios of the prices of fuel other than crude oil
The conversion factors shown in the table blow were used for the formulation of long-term scenarios of the prices of fuel other than crude oil based on the price of crude oil.

Table 11-34 Ratio of crude oil price

Items	Ratio to crude oil price/Ratio
Fuel oil price as % of Crude	0.80
Low Sulfur Diesel as % of crude	1.20
High Sulfur Diesel as % of crude	1.15
Natural gas price as % of fuel oil price	0.75
Domestic coal as % of imported coal	80%

Source: JICA Survey Team

Table 11-35 Long-term scenarios of the fuel prices

Fuel	Unit	2015	2020	2025	2030	2035	2040	2041
Crude Oil Price (IEA)	$/BBL	55.0	80.0	96.5	113.0	120.5	128.0	129.5
LNG@Bangladesh	$/MMBTU	9.2	13.3	16.0	16.0	16.0	16.0	16.0
Domestic Gas	$/GJ	6.3	9.1	11.0	12.9	13.8	14.6	14.8
Furnace Oil	$/GJ	8.4	12.2	14.7	17.2	18.3	19.5	19.7
High Sulfur Diesel	$/GJ	12.0	17.5	21.1	24.7	26.4	28.0	28.3
Import Coal	$/GJ	2.4	3.0	3.6	4.2	4.8	5.5	5.6
Domestic coal	$/GJ	1.9	2.4	2.9	3.4	3.9	4.4	4.5
LNG@Bangladesh	Cents/Mcal	3.6	5.3	6.3	6.3	6.3	6.3	6.3
Domestic Gas	Cents/Mcal	2.6	3.8	4.6	5.4	5.8	6.1	6.2
Heavy Fuel Oil	Cents/Mcal	3.5	5.1	6.1	7.2	7.7	8.1	8.2
High Sulfur Diesel	Cents/Mcal	5.0	7.3	8.8	10.3	11.0	11.7	11.8

Fuel	Unit	2015	2020	2025	2030	2035	2040	2041
Imported Coal	Cents/Mcal	1.0	1.3	1.5	1.8	2.0	2.3	2.3
Domestic coal	Cents/Mcal	0.8	1.0	1.2	1.4	1.6	1.8	1.9

Source: JICA Survey Team

A fuel unit price scenario was estimated for each type of fuel for the analysis of the economic value of the power development plan. The fuel market in Bangladesh is characterized by stable supply of fuel, that of the domestically produced natural gas in particular, at prices that are significantly lower than in the international market. However, because the economic growth was expected to make the significant increase in the demand for the primary energy sources and the reliance on the imported primary energy sources inevitable, it was decided to use the price scenario based on the very-long-term projection of the supply/demand balance of IEA.

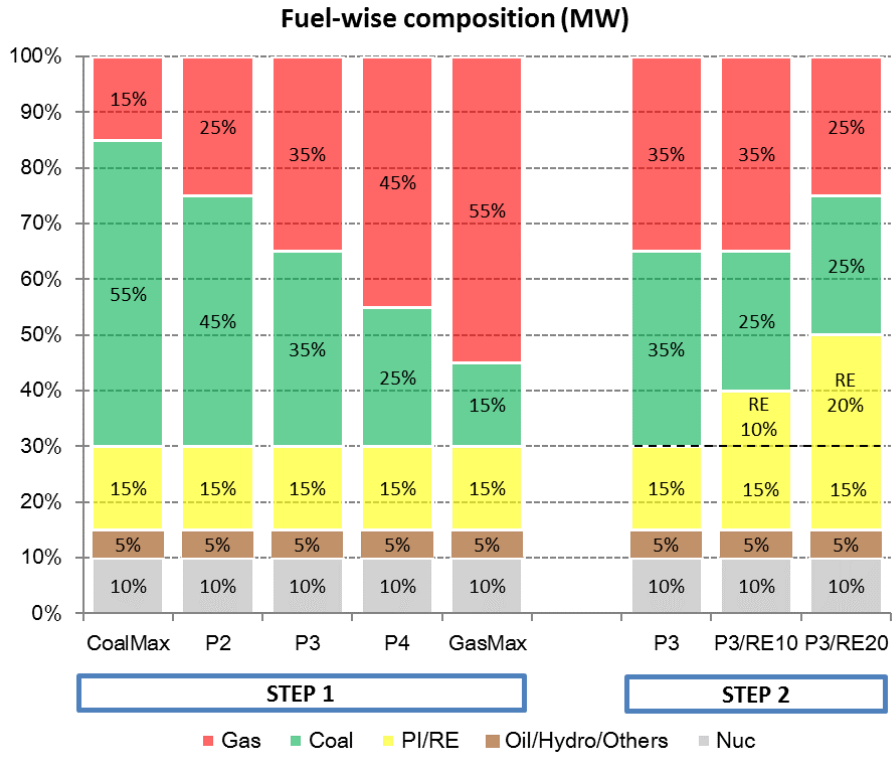
A revised fuel price scenario (F5) was formulated in order to reflect the current prices of fuel in the domestic market in the forecast for the period between 2015 and 2020. In this scenario formulated in consultation with IEA, the average fuel price in the domestic market in the period was forecast with the actual price in 2015 used as the baseline and the forecast price in 2020 of the New Policies Scenario (F1) of IEA as the goal.

The scenarios for the changes in the prices of various types of fuel were formulated in the discussion with the Government of Bangladesh and the IEA based on the IEA's crude oil scenario and the price conversion table (Table 11-34). Table 11-35 shows the fuel price scenarios used in this analysis.

11.13 Examination of economic and environmental value via power development planning simulation

The scenarios with the fixed and variable factors set as shown in the figure below were used in the simulation of the supply/demand operation. The scenario of "the basic power development plan (with the variable factors of the compositions of gas and coal set at 35%)" discussed earlier in this chapter was used as the Basic Scenario (P3).

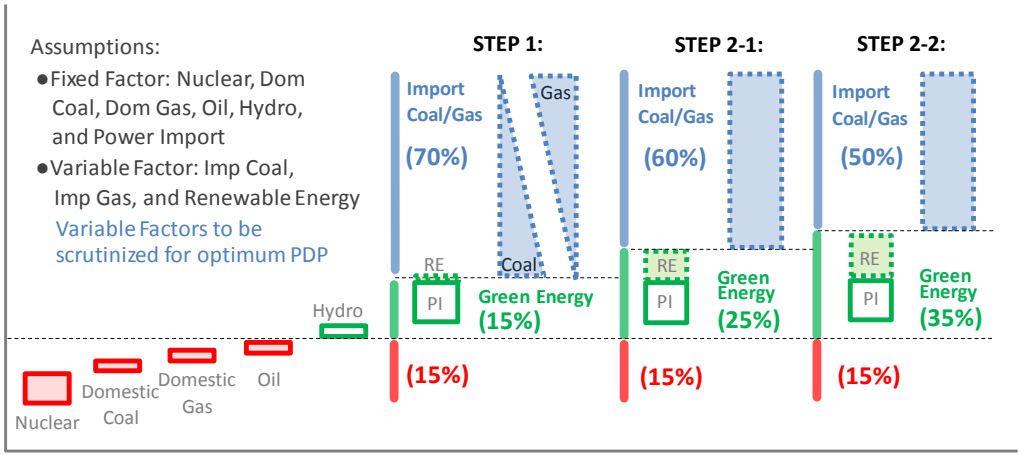
The capacities of the nuclear power plants, international connections, hydroelectric power plants, existing coal, gas and petroleum power plants and new coal, gas and petroleum power plants the construction of which was in progress were considered as fixed conditions. The five composition ratio scenarios, P1 – P5 in Fig. 11-27, with different compositions of coal and gas power generation in 2041 as variable conditions were studied in order to find the optimum power source composition, on the assumption that the coal and gas power generation accounts for 70% of the total power generation, which is considered appropriate for the formulation of a power development plan. The power source composition ratios of other power sources including petroleum were fixed in each of the five scenarios in the study. The power source composition ratios of each type of fuel between 2015 and 2041 are shown in the following table.



Source: JICA Survey Team

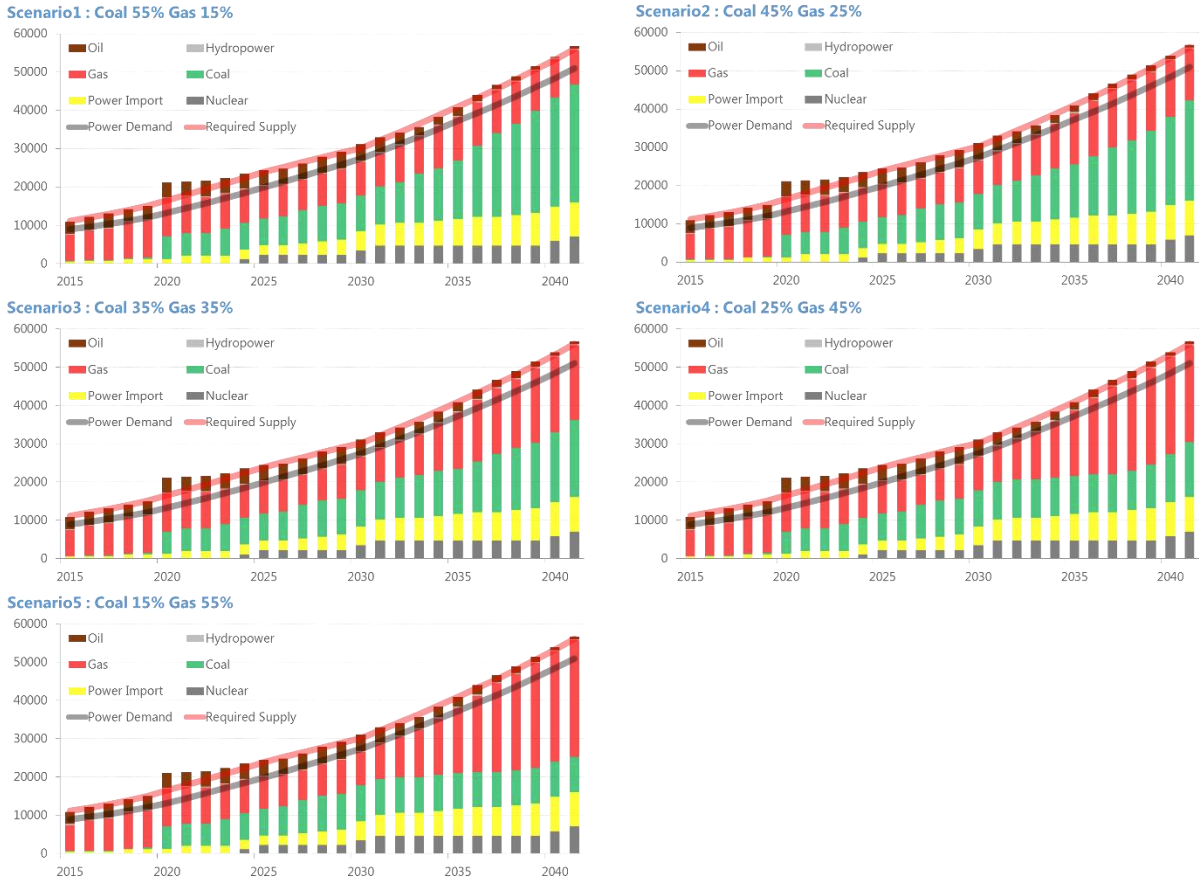
Figure 11-26 Fuel-wise composition of power development plan

After determining the optimum share of gas and coal in the energy mix, for Step 2, changing the share of fuels other than thermal power and nuclear power in the energy mix should be considered.



Source: JICA Survey Team

Figure 11-27 Methodology for demand and supply simulation



Source: JICA Survey Team

Figure 11-28 Fuel-wise composition of power development plan（MW）

11.14 Economic value

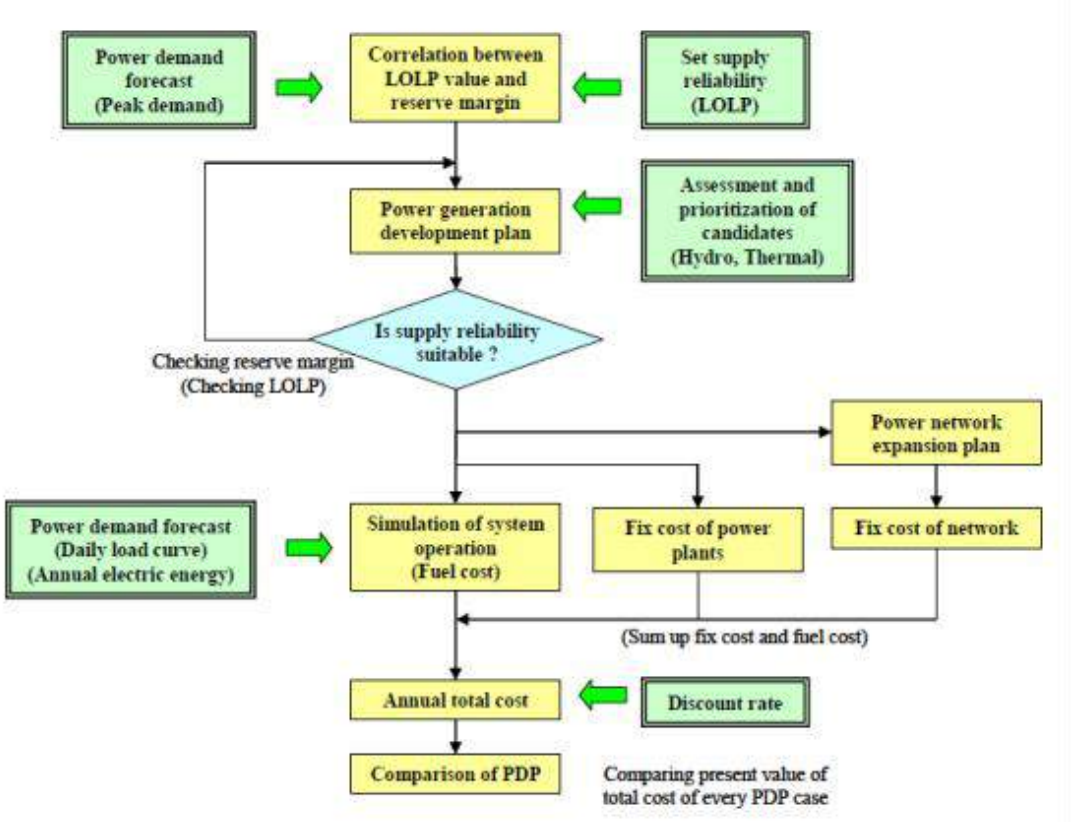
11.14.1 Economic value index

In long-term, Bangladesh will not owe much its economy on domestic energy mining industry nor plant manufacture industry. This means that lower power supply cost will bring lower burden to Bangladeshi economy as whole.
Thus, this study simply employed power generation cost (cost per unit electricity generated) to evaluate economic value of each power development scenario. Power generation cost consists of fixed price and fuel price. Fuel price projection in 2014 is shown in the previous clouse.

11.14.2 Concept of simulation for demand and supply planning

The estimation with the least cost method was used in the quantitative evaluation of the optimum power development plan. A good balance of the economic, environmental and energy security values based on the primary energy supply/demand balance, PDP, power system analysis and power system operation was taken into account in the evaluation. The results of the evaluation were reflected in PDP. PDPAT II and WASP IV were used as the tools for the simulation of supply/demand operation in the formulation of PDP, which was implemented in accordance with the flowchart shown in the figure below.

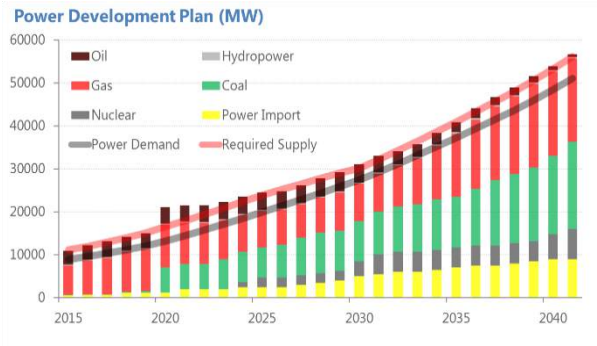
The annual fuel cost for a certain year was estimated by finding the most cost-effective operation of the given power generation facilities to satisfy a given demand of the year concerned in the simulation of the supply/demand operation. At the same time, a comparison of the fuel cost was conducted, the annual expenses were estimated as a total of the fixed cost, fuel cost and inter-connected cost, the least cost operation, the most cost-effective operation of the total power system, was identified in the simulation and the economic value of the power development plan was evaluated. The optimum development plan was selected by comparing the estimated annual expenses with those of other development plans.



Source: JICA Survey Team

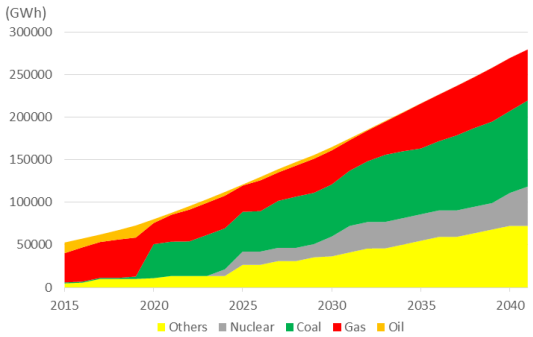
Figure 11-29 simulation of the supply/demand operation

The conditions mentioned above were used for the estimation of the consumption, unit power generation cost and CO2 emission by type of fuel in each scenario and the results of the estimation were used for the evaluation of the economic value of each scenario. The figure below shows the projection of the total power generation (GWh) in F5-P3 Scenario with its breakdown by fuel type.



Source: JICA Survey Team

Figure 11-30 Power development plan(MW)



Source: JICA Survey Team

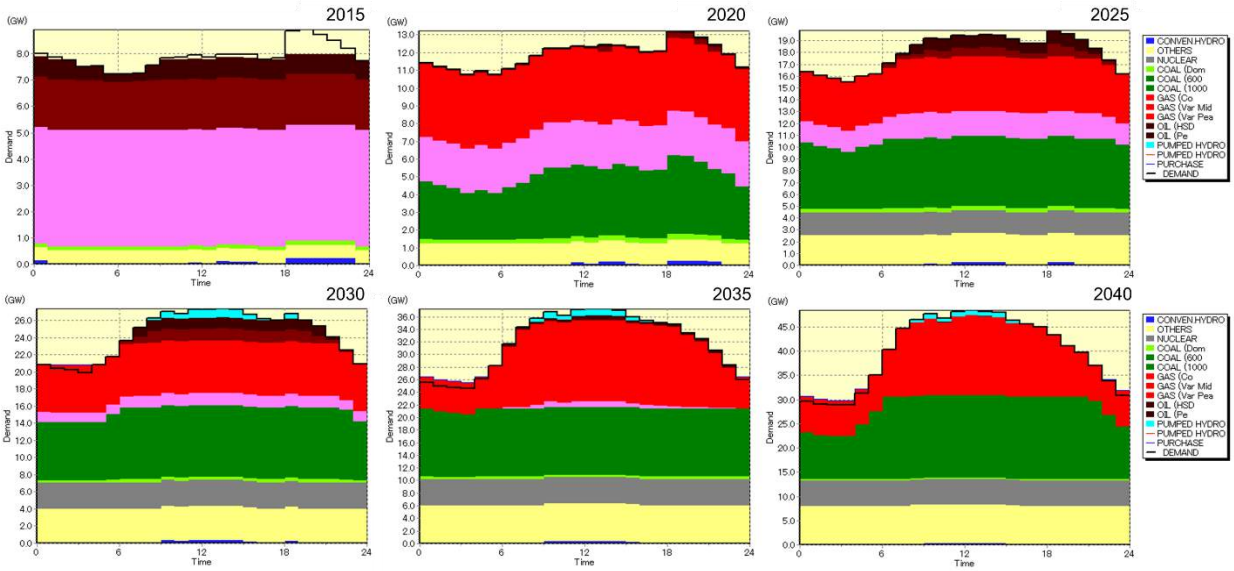
Figure 11-31 Total power generation (GWh)

11.14.3 Optimum operation pattern

The figure below shows the change in the optimum operation pattern estimated in the simulation of the supply/demand operation. At present, the base load and part of the intermediate load are supplied by power plants using the inexpensive domestically-produced fuel and part of the intermediate load and the peak load are supplied by the petroleum power plants. The base power source is expected to shift from gas to the international connection and coal gradually from 2020 onward with the commencement of operation of the large-scale coal power plants planned by the government.

The power demand in Bangladesh peaks in the evening as is seen in many developing countries where the demand for lighting accounts for a large proportion. Rolling blackouts have been used in the peak hours in the summer when the demand exceeds the supply capacity. As mentioned in detail in the previous section, the peak hours of power demand are expected to shift from the evening to the daytime between 2030 and 2035 as the economic growth is expected to increase power consumption from industrial and commercial activities.

When the international pumped storage power generation commences in 2030, the petroleum power generation that has been used as the source of the power supply in the peak hours will be replaced by the pumped storage power generation. Therefore, the role of the pumped storage power generation in the exit strategy for the use of petroleum in power generation is extremely important. The optimum operation pattern is expected to be realized in the period between 2035 and 2040 with partial replacement of the expensive gas power generation by low-cost coal power generation, which has been the main power source for the base load, as the source of the intermediate load.

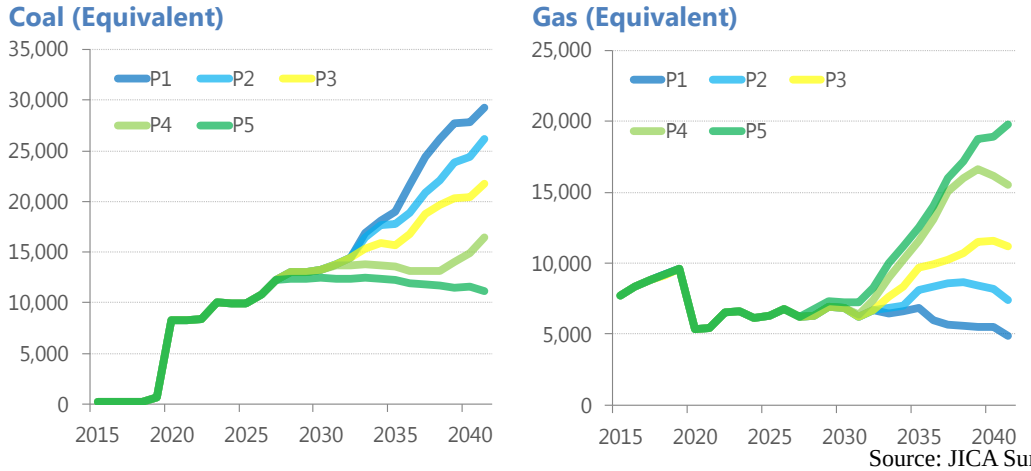


Source: JICA Survey Team

Figure 11-32 Transition of daily load curve

11.14.4 Transition of fuel consumption

The figure below shows the fuel consumption in different scenarios. The coal consumption is the highest in Scenario P1 and the lowest in Scenario P5. Conversely, the gas consumption is the highest in Scenario P5 and the lowest in Scenario P1.

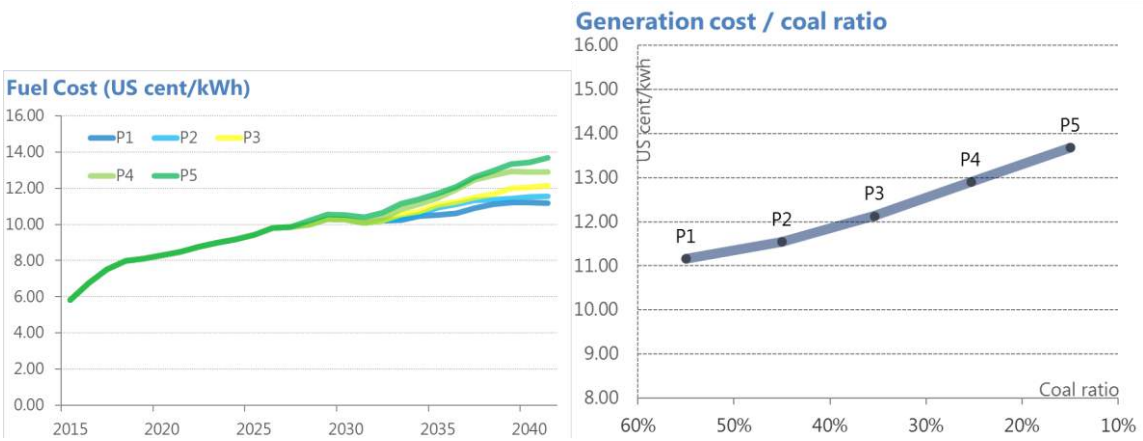


Source: JICA Survey Team

Figure 11-33 Scenario-wise gas and coal consumption (Unit / kTon of oil equivalent)

11.14.5 Transition of generation cost

The following figure shows the trends of five scenarios for generation cost. As the use of coal spreads in stages, the fuel expense will be slashed, helping curve increases in power generation costs. Thus, the power generation cost is estimated at 9 to 12 US cents/kWh for 2040. In addition, comparison of the power generation cost between the five scenarios for energy source ratio (P1 to P5) shows that the power generation cost becomes higher as the ratio of coal to all the energy sources becomes smaller.



Source: JICA Survey Team

Figure 11-34 Power generation cost under each scenario and Ratio of coal

11.15 Environmental Value

11.15.1 CO2 emission value

Environmental value of CO2 emissions has been examined by adopting the following equation. Each value is indicated in the following table based on the IPCC report.

CO2 emission [kg-CO2/Mcal]
= carboncontent per calorific value [t-CO2/TJ] / calorific consumption per calorific value [kcal/MJ]

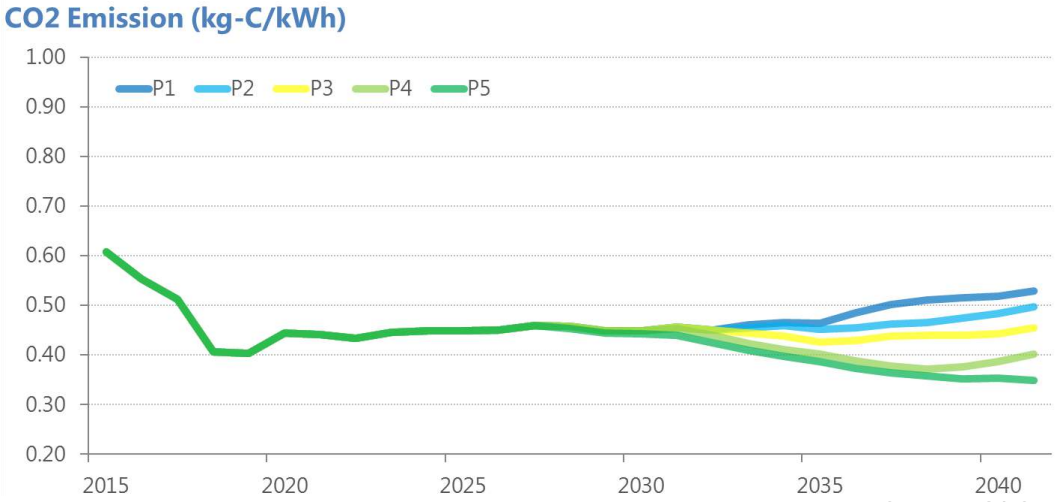
Table 11-36 Fuel-wise CO2 emission value

Item	CO2 emission (kg-CO2/Mcal)
COAL (Domestic)	0.39615
COAL (Import)	0.40229
HSD	0.30095
OIL	0.30709
GAS	0.23492

Source: JICA Survey Team based on IPCC report

11.15.2 Transition of CO2 emission

CO2 emissions in different scenarios are shown in the figure below. The CO2 emissions in 2041 are the highest (0.82 CO2 kg-C/kWh) in Scenario P1, with a high share of coal in the energy mix, and the lowest (0.55 CO2 kg-C/kWh) in Scenario P5, with a low share of coal in the energy mix.



Source: JICA Survey Team

Figure 11-35 Scenario-wise CO2 Emissions

11.15.3 Quantitative evaluation of environment value

As discussed in Chapter 5, which analyzes the environmental policy, climate change is one of the most critical issues among the environmental impacts of power supply. Bangladesh also submitted INDC to UNFCCC in 2015 and projected greenhouse gas emission reductions in the power sector by 2030.
Thus, the environmental value of each power development scenario should be evaluated focusing on CO2 emissions. This study employed CO2 cost per unit of electricity generated to evaluate the environmental value of each power development scenario. CO2 cost is calculated by multiplying CO2 emissions and CO2 price. In this study, 125 USD/tCO2 is used for the CO2 price, referring to the assumption in the 450 scenario of IEA World Energy Outlook 2015.

Table 11-37 CO2 emiaaion value by IEA World Enwegy Outlook 2015

	Region	Sectors	2020	2030	2040
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry	10	75	125

(USD2014 per ton)
Source: IEA World Energy Outlook 2015

11.16 Energy Security Evaluation

Energy security covers many concepts and there are no common approaches to evaluate it unlike previous two values. Here we presented the overview of energy security evaluation and reviewed past studies and then explained the methodology we employed.

11.16.1 Quantitative evaluation

Risk assessment is a theory of decision-making that was established in the field of engineering study. Risks consist of two factors, i.e. the probability of risk realization and the impact of the consequence.
It needs to be noted that studying on the risks concerning energy security covers a broad range of issues. According to International Energy Agency (IEA), energy security is defined as "the uninterrupted availability of energy sources at an affordable price".
An example of energy supply interruption was the case that European countries were faced with in 2006. At that time the natural gas supply from Russia was reduced because of soured relationship between Russia and Ukraine. In addition to the political incidents like that, economical incident and accidental event can bring about a problem of energy supply shortage. We also experienced a turbulent change in energy price recently when oil price rose to 150 USD per barrel in 2007 due to the turbulence in the Middle East, which then dropped to 40 USD per barrel after the Global Financial Crisis. Such high volatility is considered to be caused by the influx of speculative money in the energy market.
On a longer-term basis, the effect of continuous growth of energy demand and the depletion of fossil fuel needs to be taken into account. Uncertainty about the international policy on climate change can be also considered a kind of risk. The measurement for energy security may also change depending on the targeted period.
Furthermore, in discussing the availability of energy resources, it needs to be clarified who is the beneficiary as the precondition of the discussion. Energy availability can be discussed either as the availability at nation-level or as the availability for end-consumers. When we discuss the availability for the end-consumers, the channels of energy supply to them such as the conditions of domestic energy markets and energy supply network also need to be considered. Sometimes the accessibility to energy supply is regarded as one of the performance indicators of energy security.
Table 11-38 is one example to classify the risks concerning energy security from the aspect of different types of impact. Any kinds of risk related to energy security can be evaluated using risk assessment theory if they can be plotted with the axes of probability and impact.
A realistic approach to quantify the risks is the empirical approach. For example, it is empirically understood that, if we diversify the sources of energy supply, the possibility that all of them are suspended at once can be reduced. So the degree of diversification of energy sources can be an empirical index to measure energy security. In fact, most of the trials to quantify energy security were made based on the empirical approaches like that. Specific examples are discussed in the following section.

Table 11-38 An Example of Classifying Risks of Energy Security

Impact to what	Price (hike, volatility) Quantity (shortage)
Impact of when	Short-term Long-term
Impact to whom	Nation (consumers are also affected in the end) Consumers (risks in the course of energy distribution)

Source: JICA Survey Team

11.16.2 Past Studies on the Quantitative Evaluation of Energy Security

A standard methodology to evaluate the degree of diversification is to use "Herfindahl-Hirschman Index" (HHI). HHI was originally established to measure the status of market competition, and is formulated as the sum of the square of each business entity's market share. When this index is applied to energy supply, this can be used as a measure to evaluate the diversification of energy supply. That is, the smaller the index is, the more diversified the status of energy supply is.

Table 11-39 is the list of past studies to address the quantitative evaluation of energy security. HHI is applied in some of these studies such as IEA (2007), METI (2010) and IMF (2011), to evaluate the degree of diversification of energy suppler countries and/or primary energy sources. These studies concluded that HHI is too simple as a tool to express energy security, so they modified HHI by adding weights to parameters. For example, country risks of energy supplier countries are employed to weigh the suppliers' market share. Hence the index becomes smaller when the energy sources for a country rely on the supplier countries with lower country risk. This weighted HHI is utilized as an index to measure the risks for national-level energy supply on a short-term basis.
However, these studies did not provide clear explanation how the weight is determined quantitatively. Another drawback is that the proximity among supplier countries is not taken into account. That is, if a country relies on the energy import from two adjacent countries, this situation is considered to be riskier than importing from two distant countries.

The study of METI (2015) tried to address these issues. This METI study adopted a portfolio theory to evaluate the diversification of supplier countries and primary energy sources. The theory originally derives from the field of finance for deciding the portfolio of assets to gain expected return while minimizing risk. If this is applied to energy supply, return from each asset corresponds to energy import from a supplier country. Actually, weighted HHI can be interpreted as one specific situation of composite risks under the portfolio theory.

American Chamber of Commerce (ACC) takes a different approach to express various aspects of energy security. They employed no less than 37 indices that are considered to be related to energy security. Making use of empirically formulated weights, these indices are integrated into a single index called Index of U.S. Energy Security Index (see Figure 11-36). ACC also provides evaluations of the energy security of other countries (though Bangladesh is not covered), which is called International Energy Security Risk Index, where 29 indices are used. A previous study of METI (2010) also devised several indices for evaluating the entire supply chain of energy, besides the evaluation using HHI (see Figure 11-37).

A study of IEA (2011) ranked countries using a performance indicator combining various statistic data such as energy import ratio, number of energy-import ports and oil storage, on a highly empirical basis. A remarkable point of this study is that it distinguishes between risk and resilience in evaluating energy security (see Figure 11-38). Evaluating not only the extent of remaining risks but also the intensity of resilience can contribute to the effective evaluation of energy security.

Table 11-39 Past Studies on Quantitative Evaluation of Energy Security

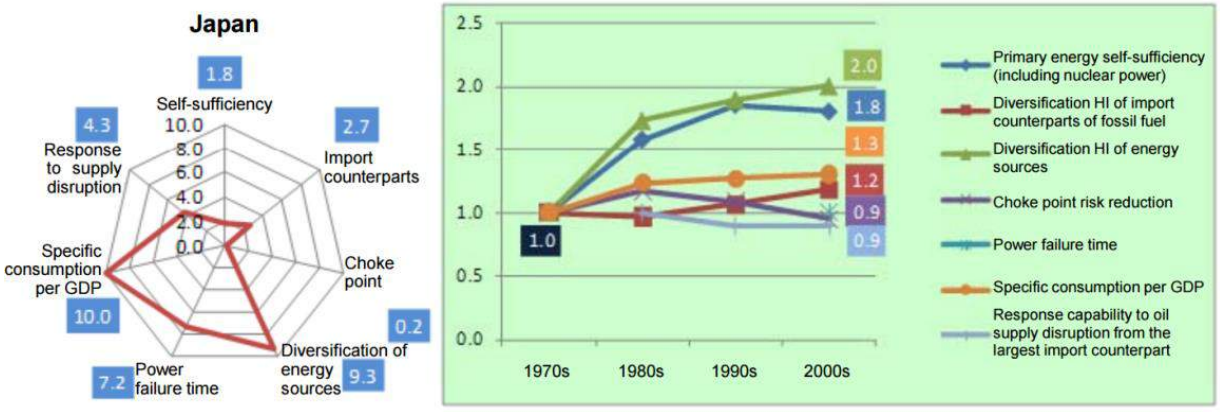
Literature	Approach
IEA "Energy Security and Climate Policy" , 2007	An index of market concentration is formulated considering the diversification of supply sources. The adopted index, which is a sort of weighted Herfindahl-Hirschman Index. Here the extent of concentration of each energy source is defined as the square sum of each supplier country's share in the energy supply, weighted by the country risk. Then the weighted average of each energy source's index is formulated considering the share of each energy source in the total primary energy supply.
METI (Japan), "2010 Annual Report on Energy (Energy white paper 2010)", 2010	Here energy security is defined as being able to secure energy in the "quantity" necessary for people's live, economic and social activities, and national defense etc. at affordable "price". National energy security is evaluated using 8 indices across energy supply chain, including primary energy self-sufficiency, diversification of countries from which energy is imported, diversification of energy source and reduction of dependency on choke points. Herfindahl-Hirschman Index is employed to evaluate the diversification.
IMF working paper, "Measuring Energy Security :Trends in the Diversification of Oil and Natural Gas Supplies ", 2011	Diversification of primary energy supplier is evaluated using the squared sum of the shares of energy suppliers, which are weighted with country risk of each supplier, proxy to each supplier, and the share of energy import of evaluated country (smaller import share means more flexibility in supply).
METI (Japan), "Toward the Stable Assurance of Fuel Resources ~ Energy Risk Index (Security Index) ~", 2015	The stability of energy supply is evaluated by focusing on the supply chain from supplier countries to Japan. Suppliers' country risk, sea-lane risk, and the effect of diversification of suppliers and sources are considered in an integrated way.
American Chamber of Commerce (ACC), "Index of US Energy Security Risk", annually updated	US's national energy security is evaluated using 37 different indices including geopolitical factor (ex. production of fossil fuel, import of US), economic factor (ex. energy price, energy consumption per GDP), reliability factor (ex. Electricity reserve rate), environmental factor (CO2 emission, R&D investment to renewable energy) etc.
IEA "Measuring Short-term Energy Security" , 2011	Energy security on each energy source is evaluated, taking into account the "risk"-related data and the "resilience"-related data. Countries are experientially ranked using these statistics data. The extent of energy source mix is not considered.

Source: JICA Survey Team



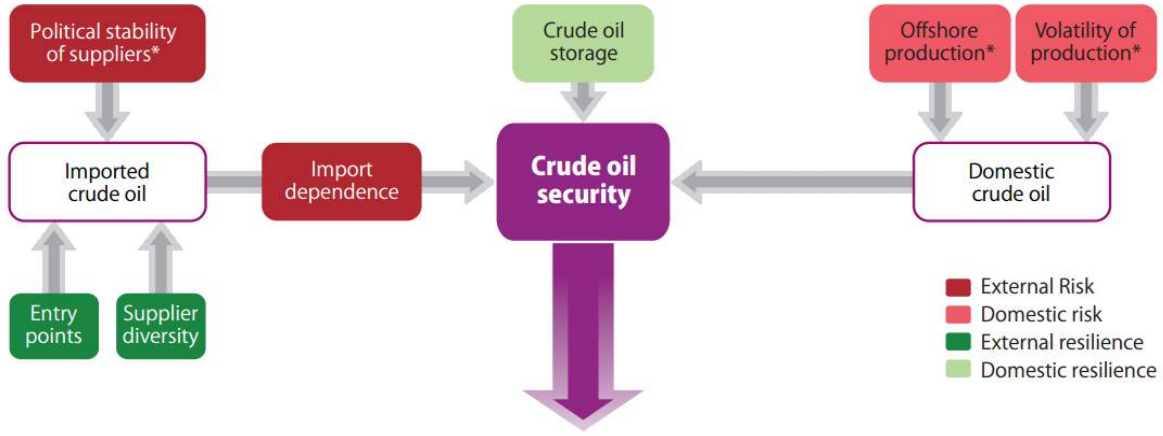
Source) American Chamber of Commerce (ACC), "Index of US Energy Security Risk 2014", 2014

Figure 11-36 Diagram of Indices that Form ACC's "Index of US Energy Security Risk"



Source: METI (Japan), "2010 Annual Report on Energy (Energy white paper 2010)", 2010

Figure 11-37 METI's Evaluation on the Status of Energy Security in Japan



Source: IEA "Measuring Short-term Energy Security", 2011

Figure 11-38 IEA's Schematic Diagram for Analyzing the Energy Security of Crude Oil

11.16.3 Key Issues in Considering the Energy Security in Bangladesh

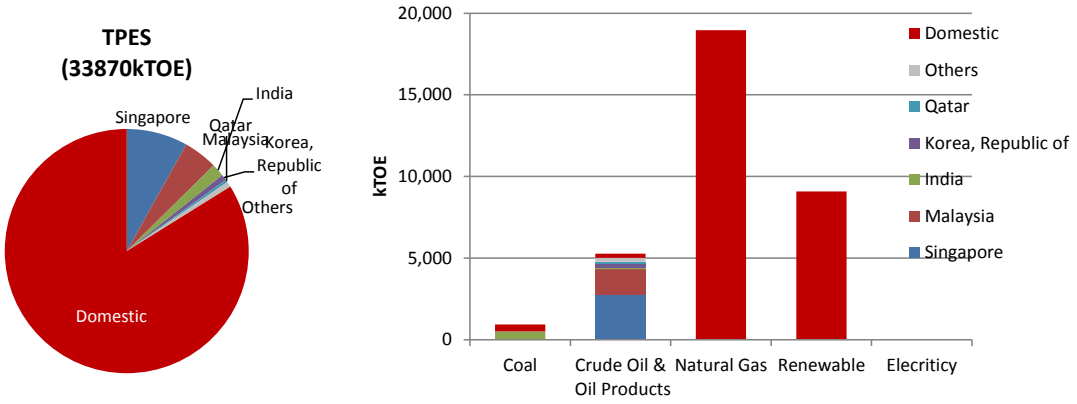
Because there is no agreed or standardize approach to evaluate energy security, this study recommends that a methodology of quantitative evaluation of energy security in Bangladesh should be devised by considering the characteristics of Bangladesh's energy supply and demand besides referring to the aforementioned approaches.
There are several studies on energy security in Bangladesh as shown in Table 11-40. These studies focus on relatively nation-side long-term energy supply. They commonly mention the importance stable expansion of energy supply capacity to achieve the economic growth target.

Figure 11-39 illustrates current energy supplier to Bangladesh. In 2013, around 80% of Bangladeshi energy was supplied by itself. India supplies coal by land. Southeast Asian countries supply oil products by sea, much of which is originally from Middle East. In the future, increase of energy import of Bangladesh is inevitable along with economic development. Which energy sources and from which countries Bangladesh can import are the key concerns in Bangladesh.
To evaluate energy security in this 3E evaluation, we focused on risk of sudden shortage in energy supply quantity, which would directly damage Bangladesh economic activities. The difference ratio of coal and gas among power development scenarios brings different dependence on supplier countries and delivery routes, and thus different shortage risks. This energy shortage risk can be quantified in monetary value as potential loss value of economic production.
There are of course other approaches to evaluate energy security. Energy price stability and predictability are other important aspects for energy security. We considered such aspects regrading price in "Economic viability" among 3E. Feasibility of these scenarios can be another aspect to ensure long-term energy security. We judged that these scenarios have similar feasibility and need equally intense policies, so considering this aspect will not be information for making a decision.

Table 11-40 Past Studies on Energy Security in Bangladesh

Literature	Approach
Unnayan Onneshan, "Energy Security: Trends and Challenges - Bangladesh Economic Update", 2014	It discusses current energy security situation using related data like below: ・ Power ➢ Availability (Consumption per capita, electricity access, load shedding) ➢ Reliability (Ownership, use of fuel) ➢ Affordability (Tariff and subsidy, system loss, cost) ・ Other energy ➢ Reserve, production, import ➢ Price, import cost
T. Ishtiaque (Bangladesh University) et al., "Energy Sector Development and Energy Security in Bangladesh", 2013	Energy sector development to 2050 is discussed. It points out that long-term energy policy is crucial to sustainable development of Bangladesh. As for energy security, it mentions the importance of cooperation with other countries to ensure energy supply, especially hydropower from Bhutan and Nepal.
ANM Obaidullah, Energy Security & Climate Change: Challenge for Bangladesh, Energy & Power	Uninterrupted energy supply is essential for stable economic growth in Bangladesh. It focuses on primary energy mix to ensure such energy supply. It consists coal is the most stable commodity in Bangladesh in spite of high CO2 emission. LNG, nuclear and renewables are other prospective commodities.

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-39 Current energy suppliers to Bangladesh in 2013

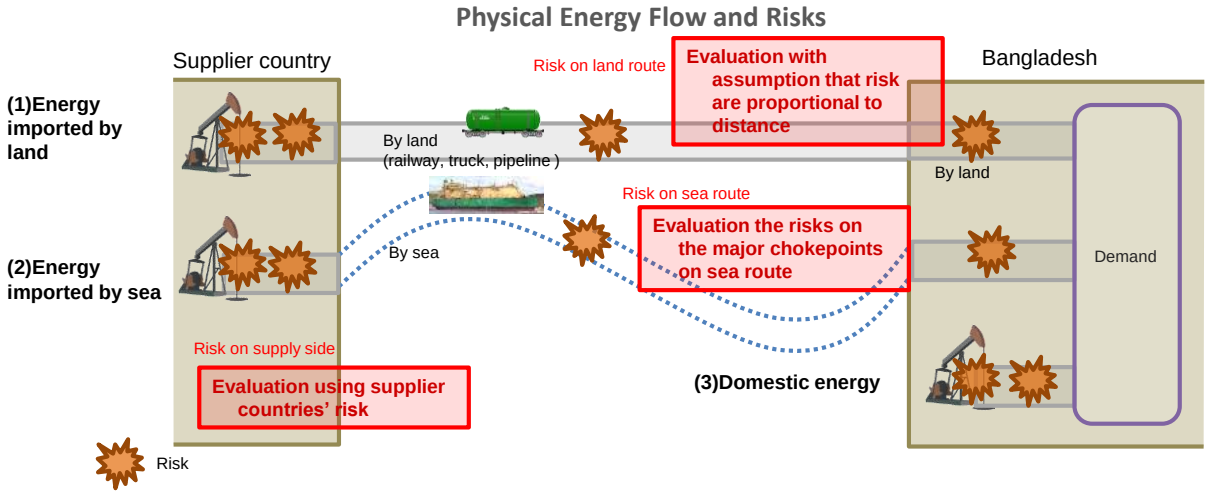
11.16.4 Methodologies of Evaluaion

As discussed above, we focused on risk of sudden shortage in energy supply to evaluate energy security. Proposed index is calculated using the formula below.

Energy Security Index [USD / kWh] = GDP [USD] x Possible non-delivery rate [%] / Primary Energy Supply [toe] / Generation Efficiency [kWh/toe]

To calculate "possible non-delivery rate", we modeled physical energy delivery routes to Bangladesh and assumed the blockage probability of each point on the routes.
The following figure illustrates the model concept. Among many kinds of risk on the energy delivery routes, we focused on three risks: export suspension risk, blockage risk on land route, and blockage

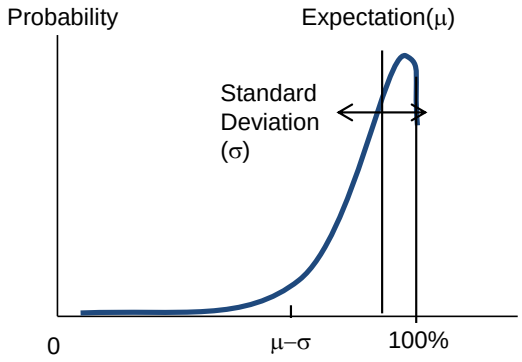
risk on sea route. We ignored the risks to deliver domestic energy.



Source: JICA Survey Team

Figure 11-40 Physical Energy Delivery Routes and Risks

With the model, energy delivery rate to Bangladesh can be expressed in the form of probability density function as shown in Figure 11-41, considering many different combinations of risk realization. This curve itself reflects the risk situation of the physical energy delivery of the country. Using the parameter of the expectation (μ) and the standard deviation (σ) of this distribution curve, we can calculate a value of (μ– σ) which shows minimum delivery rate with 84% confident interval mathematically. In the other word, 1– (μ– σ) shows maximum non-delivery rate. This number is that we call "Possible non-delivery rate" here.



Source: JICA Survey Team

Figure 11-41 An Example of Probability Density of Energy Delivery

In order to calculate these values, this study defined a portfolio of energy sources (share of domestic production and import as well as the source country of import) and the blockage probability of transport routes for each scenario.

Based on the analysis of natural gas, LNG, coal and oil supply in the previous chapters, and also referring to the current status of other Asian countries' fossil fuel import, the maximum volume of supply from domestic production, the volume of export from abroad, and the source countries are assumed, as summarized in Table 11-41.

As for natural gas, this study assumed that, even when LNG import is suspended, at maximum 10,000 ktoe of domestic gas production per year (about 1,300 mmcfd) can be appropriated for power generation, which is almost equivalent to the current level of natural gas supply for power generation on the grid and for captive power' own consumption in total, and that the gas supply exceeding this needs to be imported from Qatar for estimating the blockage risk of import. For the scenarios where the annual gas consumption for power generation in 2041 is less than 10,000 ktoe per year, gas supply will be managed anyhow by providing domestic gas for power generation with priority even when

LNG import is suspended.
As for coal, this study assumed that the maximum consumption of domestic coal for power generation is 600 ktoe per year (the maximum possible coal consumption of power stations that can use domestic coal only) and that remaining coal supply needs to be the import from abroad, which is the mix of 70% from Indonesia (low-grade coal) and 30% from Australia (high-grade coal) for estimating the blockage risk of import.
Whereas it is relatively easy for a gas-fired power station that usually uses imported LNG to switch to domestic natural gas as far as it's connected to a domestic gas pipeline, it is far difficult for a coal-fired power station, which is designed to use imported coal, to switch to domestic coal in a short period because of the difference in combustion characteristics among fuels and the difficulty with securing fuel transport etc. Therefore, this study does not consider the expanded use of domestic coal in the case of blockage of coal import. In general, the blockage risk of coal import is considered to be lower than that of LNG import because of the diversity of source countries, but the difference in flexibility in fuel switching between them leads to an implication that too much dependence on coal use in Bangladesh may become riskier than the balanced energy mix of coal and gas.
Regarding crude oil and oil products for power generation, this study assumed that all will be the import from the Middle East, for instance 50% each from UAE and Saudi Arabia.
Though there may be a possibility that a route of importing natural gas and coal via surface transport from India may be established, this study considers that its probability is negligibly low at this moment, thus this assumption was disregarded.

Table 11-41 Assumption of Supplier Countries and Volume of Fossil Fuel Supply for Power Generation (as of 2041)

Fuel supply	Natural gas	Coal	Crude oil and oil products
Domestic production	Max. 10,000 ktoe	Max. 600 ktoe	—
Import (maritime transport)	Qatar: all of the remaining	Out of the remaining: Indonesia: 70% Australia: 30%	UAE:50% Saudi Arabia: 50%
Imported (surface transport)	—	—	—

Source: JICA Survey Team

Though accurate quantization of routes' blockage probabilities is hardly possible, this study provisionally set parameters of risks as shown in Table 11-42 for quantitative evaluation of 3E.
In setting the export suspension risk, this study referred to the country risk classification of OECD and assumed the probability of blockage in accordance with the grades of risk classification.
Blockage probability of maritime transport was calculated as the product of the number of major chokepoints on the route and the constant factors. Blockage risk of import from the Middle East was set higher considering the transport via the Strait of Hormuz. Surface transport from India was not considered in this study, but just for reference, blockage probability was also calculated as the product of the travelling distance and the constant factors.

Table 11-42 Assumption of Export Suspension Risk

Fuel;	Supplier	Classification by OECD	Assumed export suspension risk	Assumed transport blockage risk
Coal	India	3	5%	0.5%
	Indonesia	3	5%	2%
	Australia	(High Income OECD Country not reviewed or classified)	0.1%	2%
Oil	UAE	2	1%	4%
	Saudi Arabia	2	1%	4%
Natural Gas	India	3	5%	1.5%
	Qatar	3	5%	4%

Note) Classifying countries into 7 grades (from 1(best) to 7(worst))
Source) OECD Country Risk Classification

11.17 3E Evaluation

Power supply is closely related with economic activities and environmental issues. For a certain pattern of energy supply to be sustainable, it has to satisfy the conditions called "3E," consisting of the economic value, environmental value and energy security value. The Basic Energy Plan of Japan states that the energy policy of Japan shall satisfy the "3E" conditions.
A quantitative evaluation of the 3E values in 2041 of each of the power development scenarios proposed in the previous section conducted for the selection of the most recommendable scenario is described in this chapter.

11.17.1 Selection of the Optimum Scenario of Energy Mix Based on 3E Evaluation

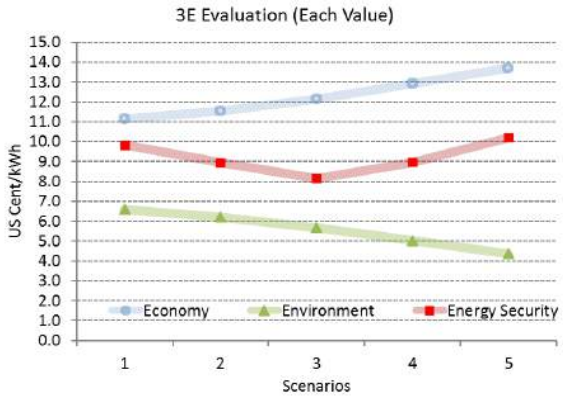
Based on the aforementioned methodologies, five scenarios of power development were evaluated using 3E indicators, as shown in the following table. All indicators are expressed in monetary values and they indicate better performance when the number is small. The sum of these three indicators is the total score for the 3E evaluation.
The economic indicator becomes favorable when the share of coal generation in the total power supply is high. Conversely, the environmental indicator becomes favorable when the share of coal in the total power supply is low. The energy security indicator becomes optimized when the shares of coal and natural gas are balanced.

Table 11-43 Results of 3E Evaluation for Each Power Development Scenario

[US cent/kWh]

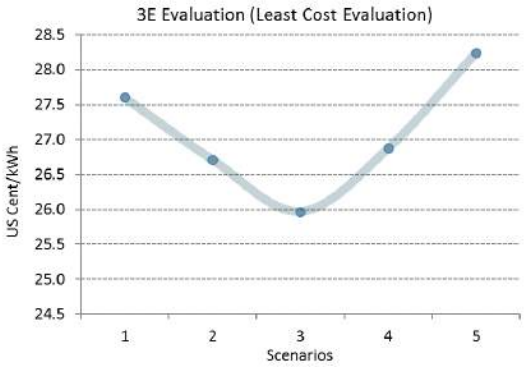
Scenario	Shares in generation capacity (in MW)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
1	Gas 15%, coal 55%	11.2	6.6	9.8	27.6
2	Gas 25%, coal 45%	11.6	6.2	8.9	26.7
3	Gas 35%, coal 35%	12.1	5.7	8.2	26.0
4	Gas 45%, coal 25%	12.9	5.0	9.0	26.9
5	Gas 55%, coal 15%	13.7	4.4	10.2	28.2

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-42 3E value (each value)

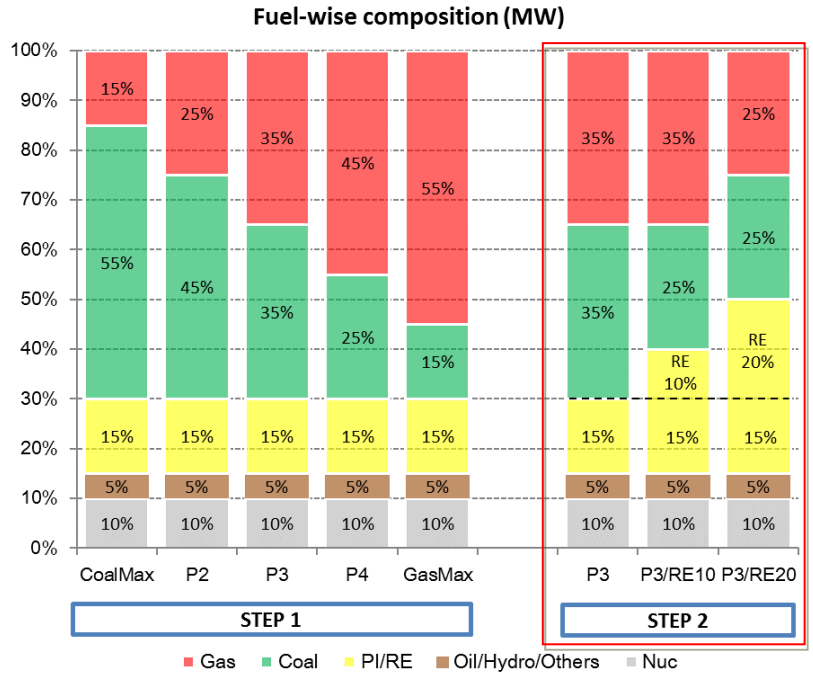


Source: JICA Survey Team

Figure 11-43 3E value (total value)

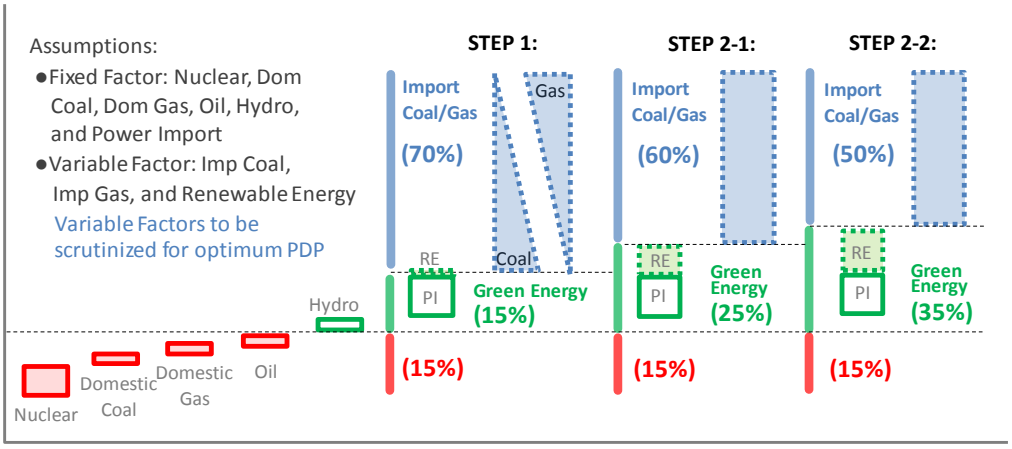
11.17.2 Challenging for renewable energy expansion

As mentioned above, the possibility of increasing the use of renewable energy was studied by changing the composition ratios of power sources other than the thermal and nuclear power generation in Step 2 after the optimum composition ratios of the gas and coal power generation had been decided. The scenarios in which the ratio of renewable energy was increased by 10% (RE10 Scenario) and 20% (RE20 Scenario) were used in this study. The composition ratios of gas and coal in each scenario are shown in the following fugure.



Source: JICA Survey Team

Figure 11-44 Simulation pattern



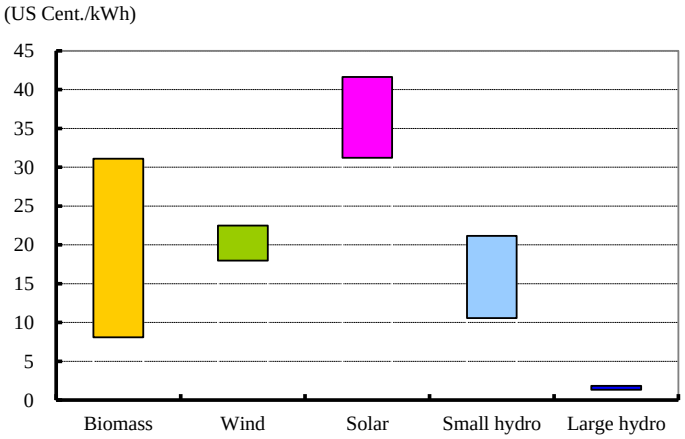
Source: JICA Survey Team

Figure 11-45 Power Source Composition in FY 2041 (as shown above)

(1) Matters to be Considered regarding the Introduction of Renewable Energy

The output of renewable energy power plants such as photovoltaic (PV) and wind power plants is significantly affected by weather conditions. Thus, unstable, actual supplies from these plants are much smaller than their installed capacities. In fact, the maximum supply is estimated at approximately 30% of the expected plant capacity. Therefore, installed capacity of approximately three times' the required supplies will be required if 10% and 20% of the total power supply is to be generated by renewable energy power plants as assumed in RE 10 Scenario and RE 20 Scenario, respectively.

The capacity factor of renewable energy power plants was assumed as 30%, and the construction of renewable power plants of the total installed capacity of three times' the power required to be supplied by those plants to achieve RE 10 and RE 20 Scenarios in the plan was assumed in this analysis in order to consider the conditions mentioned above. The table below shows the standard specifications of the renewable energy used in the estimation.



Source: JICA Survey Team

Figure 11-46 Renewable energy typical generation cost

(2) 3E evaluation including the possibility of the use of renewable energy

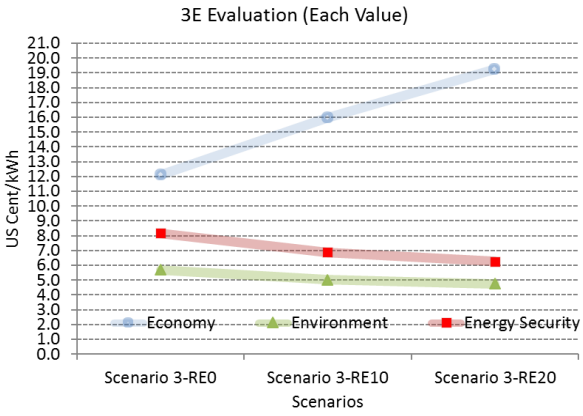
Figs. 11-47 and -48 show the 3E values of the scenarios estimated with the "3E" Evaluation Indicator Estimation Method mentioned above. The introduction of power generation with renewable energy in RE Scenarios 10 and 20 will lead to a significant increase in the unit power generation cost because of the increase in the cost for its introduction.

Table 11-44 3E evaluation of each scenario with renewable energy

[US cent/kWh]

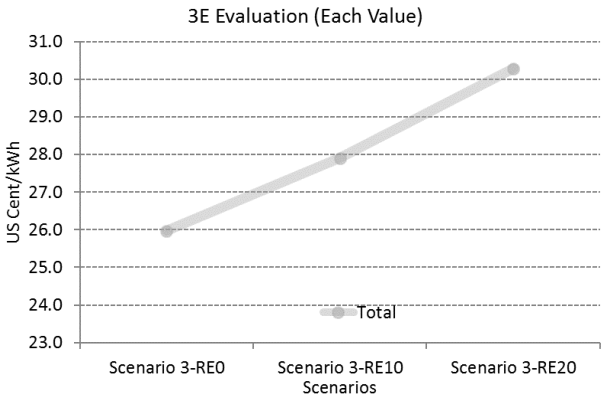
Scenario	Shares in generation capacity (in MW)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
3-Base	Gas 35%, coal 35%	12.1	5.7	8.2	26.0
3-RE10	Gas 35%, coal 25%	16.0	5.0	6.9	27.9
3-RE20	Gas 25%, coal 25%	19.2	4.7	6.2	30.2

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11-47 3E value (each value)



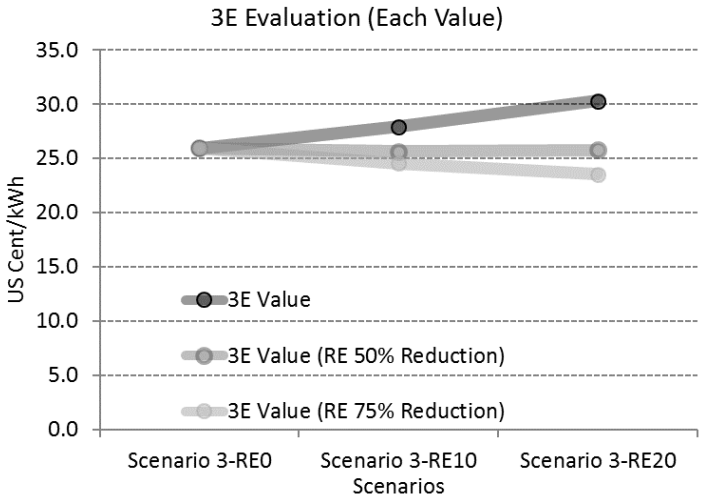
Source: JICA Survey Team

Figure 11-48 3E value (total value)

(3) Sensitivity Analysis on the Cost of Introducing Power Generation with Renewable Energy

Because the power generation cost is an economic indicator that has a great impact on the 3E evaluation, a sensitivity analysis was conducted with different costs for the introduction of renewable energy power generation. Fig. 12-48 shows the result of the comparison of cases in which the introduction cost is assumed to have been reduced by 50% and 75% with the case of introduction at the current price.

The 3E evaluation values of the scenarios with the introduction of renewable energy power generation are lower than those of the scenario without the introduction when the cost of the introduction has been reduced by at least 50%. Therefore, it is advisable to decide the proportion of the power supply generated with renewable energy in the total supply with the reduction in the cost of the introduction to be realized by technical innovation taken into account.



Source: JICA Survey Team

Figure 11-49 3E value (total value)

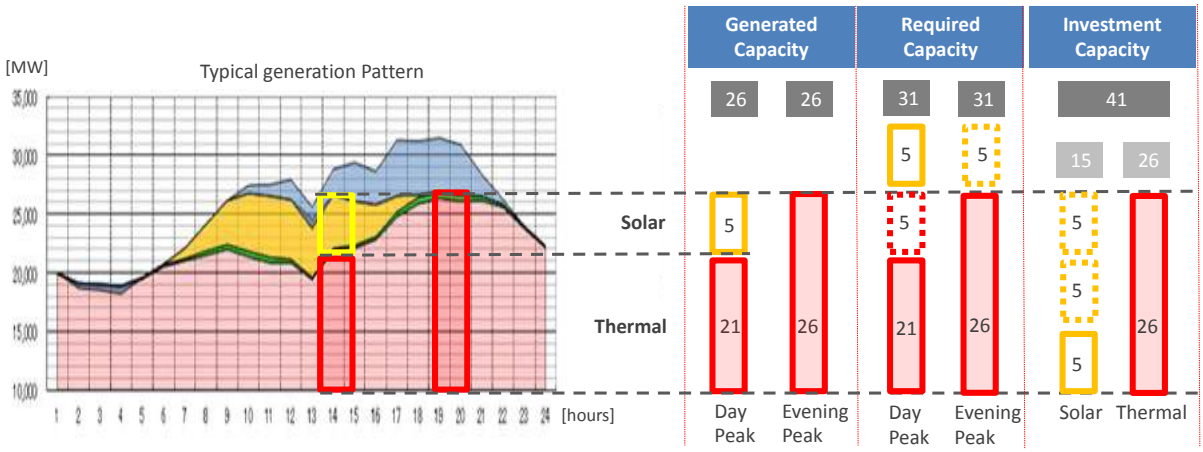
(4) Challenge and issued of expansion of renewable energy

An illustration of the patterns of operation of thermal and PV power plants on a fine day in the peak-demand period in the summer is shown in the figure below. The figure shows that the output of the PV power generation begins to increase gradually at around 7 a.m. until it reaches the maximum output of 5,000 MW at around 10:00. This maximum output is maintained until around 14:00. The output of the thermal power plants operated with an installed capacity of 26,000 MW is reduced in

tandem with the increase in the output of the PV power generation system between 7 a.m. and 10 a.m. and the output is maintained at 21,000 MW in the peak hours between 10:00 and 14:00. After 14:00, the output of the PV power generation gradually decreases until it reaches zero in the evening, while the output of the thermal power plants is increased. When the output of the thermal plants has returned to 26,000 MW, preparations for the evening peak shall be made.

During the daytime peak hours, 5,000 MW of the thermal generation capacity remains unused because of the use of PV power plants with an installed capacity of 5,000 MW. Therefore, a total installed capacity of 31,000 MW, consisting of 26,000 MW of thermal power generation and 5,000 MW of PV power generation, is required to satisfy both the daytime and evening peak demands. In addition, it is very difficult to forecast the output of a PV power plant accurately because it changes depending on weather conditions. The kW equivalent of the output of renewable energy power plants was estimated with the (expected) contribution of power generation with renewable energy to a peak demand empirically set at approximately 30%. If 5 MW of the net power supply is to be realized from power generation with renewable energy, investment in the development of renewable energy power plants with a total capacity of approximately 15 MW will be required, as 5 MW ÷ 0.3 (expected proportion of the contribution) ≃ 15 MW. Therefore, it should be fully noted that, when the target output of power generation with renewable energy is set on the MW base, facilities with a total capacity of three times' the target output will be required to supply the target output stably throughout the year.

As mentioned in the description of the demand forecast, the peak demand that is currently found in the evening is expected to shift to the daytime sometime between 2030 and 2035 as a result of the economic development in Bangladesh. The optimum power source composition in a PDP is generally formulated against the annual peak demand. Although it is not impossible to use the power generated by PV power plants (from renewable energy) and stored in storage batteries for the evening peak hours if the cost and the operational difficulty of such a system can be ignored, it is advisable to introduce this system after economic development has moved the peak demand to the daytime, with the unpredictability of the output of power generation with renewable energy taken into account. Therefore, it is recommended that investment be made in the development of ordinary power sources to make the supply meet the demand at the moment.



Source: JICA Survey Team

Figure 11-50 Operation pattern in case of renewable energy installation

11.18 General strategy for finding the optimum energy mix

11.18.1 Outline

(1) Short term (up to 2020)

- Capacity building for MP revision
  - ✓ Collaboration between organizations for power and energy master plan
  - ✓ Periodic rolling revisions for milestone mater plan
  - ✓ Comprehensive statistical work function
  - ✓ Introduction of KPI management
- Improvement in the investment climate
  - ✓ Improvement of PPA
  - ✓ Reinforcing tax exemption for FDI
  - ✓ Prompt procedure
  - ✓ Financial credit approval by international organization
- Eliminating rolling blackouts
- Reform of O&M of power plants and revision of electricity charges

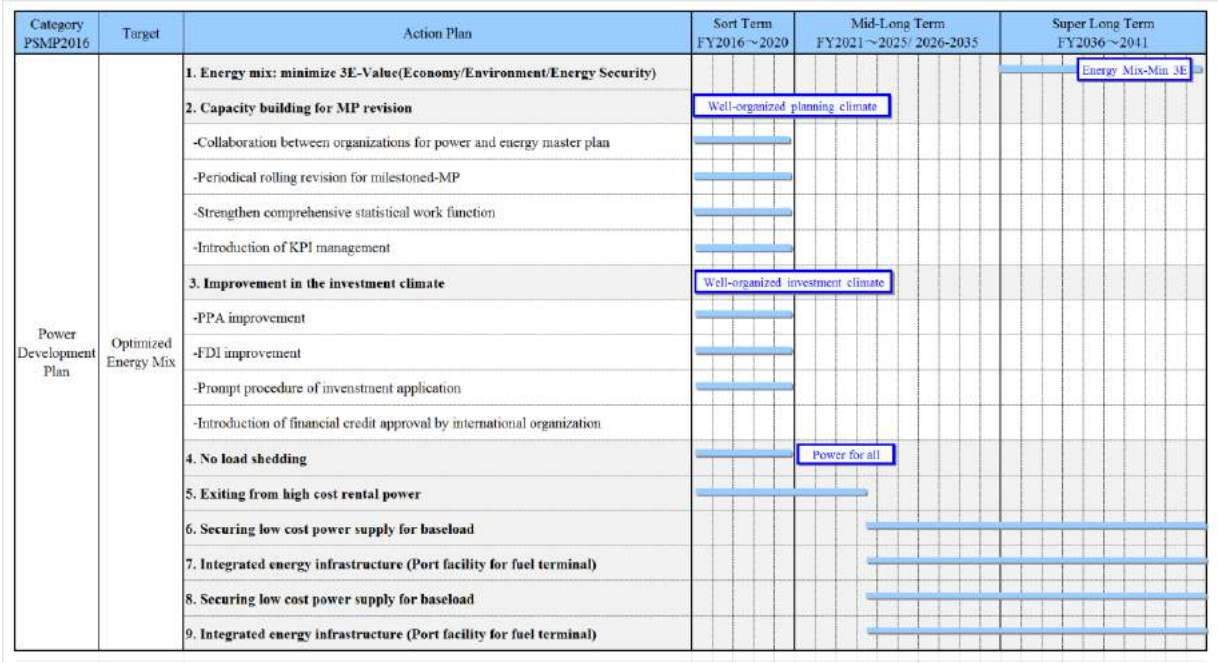
(2) Short- to medium-term (up to 2025)

- Breaking away from the dependence on costly petroleum and rental power generation
- Promotion of PPP investment in power generation projects
- Reform of O&M of power plants and revision of electricity rates

(3) Medium- to very long-term (up to 2041)

- Establishment of reliable large-scale base power sources
  Promotion of PPP investment in power generation projects
  Reform of O&M of power plants and revision of electricity rates
  Realization of the best mix of power sources with high 3E values

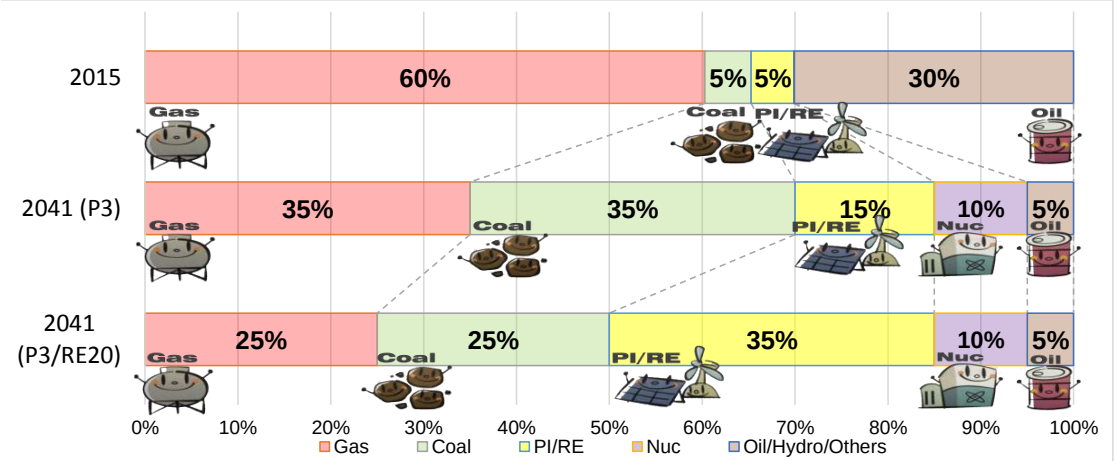
Table 11-45Road map of power development plan



Source: JICA Survey Team

11.18.2 Acchieve to best energy mix

In order to maximize the 3E value (the total of the economic, environmental and energy security values) of the power source composition of the energy mix, a portfolio consisting of well-balanced proportions of gas, coal and other power sources shall be realized. This shall be done by halving the proportion of gas power generation to depart from the current heavy reliance on gas, and with the systematic expansion of relatively inexpensive large-scale coal power generation and international connection with the neighboring countries as an exit strategy from the reliance on expensive oil-based rental power.
In addition, the investment cost for the use of renewable energy, which is larger than that for the use of conventional energy sources, is expected to reduce in future with technological advancements and the extension of its use in society. When this condition has been met, a shift to the active use of renewable energy and a reduction in the consumption of fossil fuel shall have to be realized, following the global trend, with the aim of increasing the use of zero-emission power sources.



Source: JICA Survey Team

Figure 11-51 Best mix including expansion of renewable enegy

11.18.3 Recommendations on the implementation & monitoring of the master plan

(1) Capacity building for master plan revision

(a) Collaboration and cooperation between organizations involved in the formulation of mp

In Bangladesh, the Power Division under the Ministry of Power, Energy and Mineral Resources (MoPEMR) is responsible for developing power development plan, and the practical works are done by the Bangladesh Power Development Board (BPDB). In the meanwhile, the Energy and Mineral Resource Division under MoPEMR is responsible for the energy supply plan other than electricity and the practical works are done by Petrobangla, Bangladesh Petroleum Corporation (BPC) and so on.
This study observed that, because of the separated administration between electricity and other energy sources, there is no organizational structure that supervises the overall energy supply and demand in Bangladesh comprehensively. As the domestic production of natural gas in Bangladesh is expected to deplete whereas the energy demand will continue to increase rapidly, the country will need to depend more on imported energy sources.
Considering this situation, the importance of developing an energy supply plan from a comprehensive viewpoint is expected to gain importance for determining how to appropriate the limited domestic energy production among various sectors and which energy sources to import for supplying to which sector and how much.
In developing the aforementioned power development plan and energy supply plan, a systematic relation among stakeholders is needed so that the responsibility of various data necessary for making future projection such as the actual operational data and facility development plan is identified and that these data are administrated in unity. Current status is that, as observed by the JICA Study Team, relations among the organizations responsible for administrating these data are not sufficiently established.
These power development plan and energy supply plan need to be updated regularly by reflecting the conditional changes. Therefore, establishing an institutional framework is necessary to develop and implement both plans comprehensively by involving all the relevant stakeholders for these plans to share information.

(b) Periodical rolling revision of the milestone plan

Although a PSMP has been formulated every five years as a milestone plan, its periodical revision based on a rolling plan has not been conducted appropriately. In principle, a power supply plan in a power development plan is formulated on the basis of demand projection and appropriate standards for ensuring the reliability of supply. However, as the proportions of the projects mentioned in power development plans that have reached the operation stage have been small, a list of prospective projects for investment tends to be included in a power development plan as it is. In principle, a power development plan has to be revised in accordance with power demand and the supply reliability standards as the planning and preparation for projects progress. It is also necessary to revise the power development plan and the energy supply plan formulated in this survey periodically, at least once a year, with changes in the situation including the state of the economy, supply/demand balance of energy sources including domestically-produced natural gas and power supply/demand balance taken into consideration.

(c) Strengthening of integrated statistical processing functions

BPDB has a record of electricity sales to its customers and those wholesaling to other distributing companies. The total sum of them is the total volume of electricity sold by BPDB, but is not identical with the total volume of electricity that is sold by distribution companies including BPDB and used by end consumers. For analyzing the trend of electricity consumption in Bangladesh more specifically, grasping the electricity sales of all distribution companies to end-consumers with sectorial breakdown, such as residential, commercial, industrial etc., is more important. Power Division and/or BPDB is suggested to take an initiative to develop a database of nationwide electricity consumption uniformly

as a routine.
The JICA Study Team also observed that there is no government agency responsible for grasping how each sector (residential, commercial, industrial, transport etc.) utilizes energy as the combination of various sources of energy supply such as electricity, natural gas, LPG, oil products, non-commercial fuel (bio fuel) etc. When the JICA Study Team interviewed with various organizations, there were some opinions that, in order to mitigate the increase of natural gas demand, new supply of natural gas to residential sector and transport sector should be restricted and these sectors should be induced to use LPG instead. However, if this idea is actually implemented without long-term perspective of energy supply and demand, it may result in the rapid increase of LPG procurement that is apt to be costlier than LNG, and the burden of nationwide energy cost may become heavier. In order to realize the long-term optimization of nationwide energy balances, GoB needs to strengthen the function to consider and coordinate the national energy policy comprehensively.
Although it should be the Government of Bangladesh that decides which organization is to be responsible for performing these integrated statistic processing functions, the Survey Team recommends the establishment of Integrated Statistics Bureau in MoPEMR for the centralized management of all the data from the organizations under the jurisdiction of the Power Division and the Energy Division with the need to revise the power and energy master plan periodically taken into consideration.

(d) Introduction of Key Performance Indicators

Furthermore, GoB is suggested to set appropriate KPIs (key performance indicators) in the process of planning and to set quantitative target based on this, in order to indicate clearly the directions of energy policy of Bangladesh. Above all, as the country's energy demand is expected to increase rapidly, target setting for rationalizing energy supply and demand (energy efficiency) is indispensable. In addition, strengthening the capacity to analyze the effect of conditional changes on these KPIs and, if necessary, to adjust the targets and plans flexibly to reflect the changes is also required.
Examples of KPIs that serve for target-setting for the power and energy sectors are as follows.

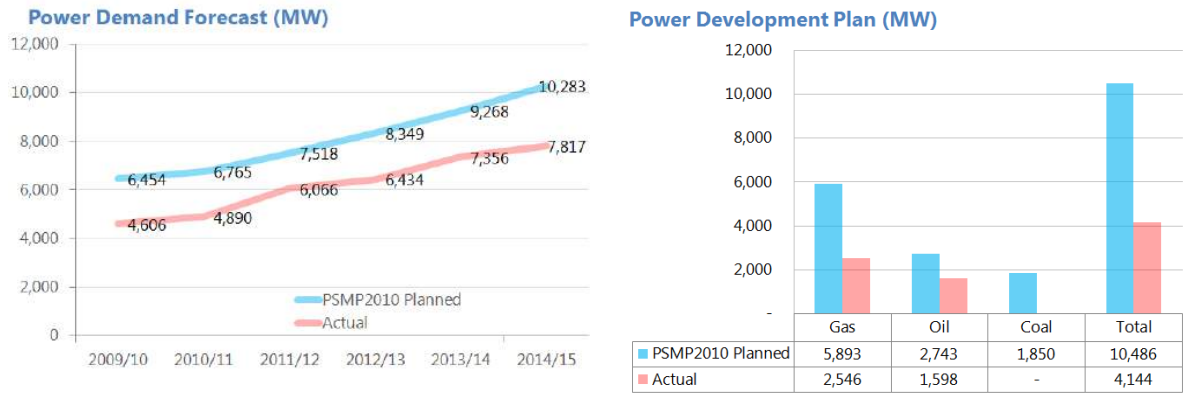
- Energy efficiency: energy intensity per GDP (toe/million BDT), GDP elasticity of energy consumption etc.;
- Economy: cost per unit of energy supply (BDT/kWh) etc.;
- Environmental consideration: emission factor of greenhouse gas etc.;
- Stable supply of energy: energy security index (dependence on energy import, diversification of energy sources), average frequency and duration of power interruption (SAIFI, SAIDI) etc.;
- Optimized supply of energy: balance of aforementioned 3E (integrated indicator), composition of energy source mix etc.;

Currently the main stakeholder agencies in Bangladesh do not have sufficient organizational and staff capacity to deal with these new challenges and international support for improving the capacity of planning, policy implementation and monitoring/evaluation is also needed. Japan has also provided various kinds of assistance such as the dispatch of policy advisors, training programmes and capacity development support programmes. These kinds of assistance will still be needed for Bangladesh.

(2) Measures to Facilitate Improvement of Investment Climate

(a) Outline

As a rapid economic growth is expected in Bangladesh, a power development plan has been formulated to reinforce power generation facilities to meet the increasing power demand. However, as the construction of power generation facilities has not been progressing as planned in reality, as mentioned in detail in the chapter of the power development plan, the demand has been suppressed due to the limited supply and, therefore, the difference between the actual demand and the demand projection including potential demand has been large. This fact may have undeniably had negative impact on the economic growth in Bangladesh.
It is obvious that the milestones in a power development plan, however theoretically the plan may have been formulated, will be just empty theories in the current state in which various factors impede the construction of power source facilities.
Therefore, a discussion conducted on the way to create a climate that makes investment in power development attractive with opinions of investors taken into account is described in the following.



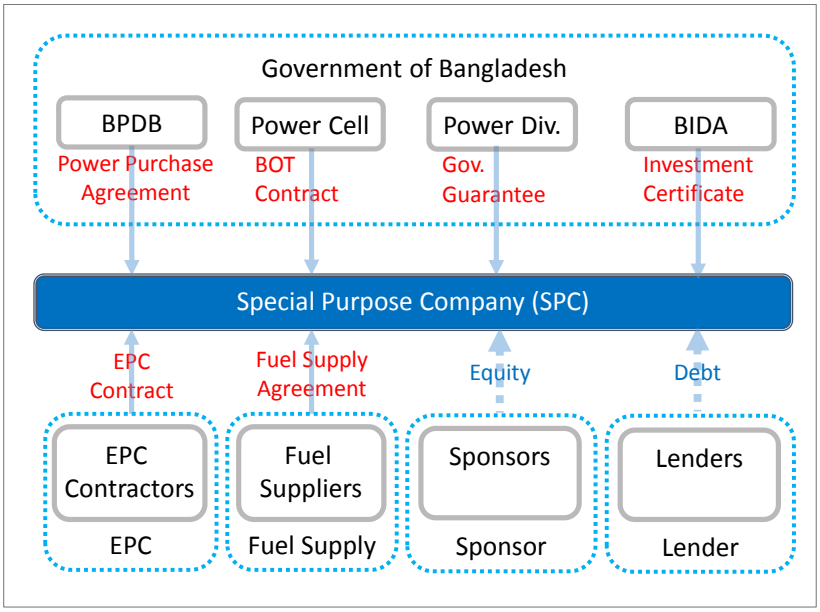
	Gas	Oil	Coal	Total
PSMP2010 Planned	5,893	2,743	1,850	10,486
Actual	2,546	1,598	-	4,144

Source : JICA Study Team

Figure 11-52 PSMP2010 Review (Demand and Power development plan)

(b) Project implementation structure

In addition to conventional loan projects implemented with public financing from international organizations, projects with PPP investment that utilize the technological capacity and capital of the private sector more than the loan projects are considered a promising means of power development in Bangladesh. The figure below shows a possible project implementation structure assumed for the implementation of IPP projects in Bangladesh.



Source: JICA Survey Team

Figure 11-53 Organaization of IPP

The sponsor of a project consisting of a contractor and an investor usually minimizes the project risk by establishing a special purpose company (SPC) and concluding contracts with various organizations to be involved in it through the SPC. The major project risks are summarized in the following.

- ■ Risks directly concerned with the Government
- ✓ Risks associated with power sales agreements and payment of electricity charges
- ✓ Foreign exchange and remittance risks
- ✓ Country and political risks
- ■ Risks to be controlled mainly by contractors
- ✓ Risks of delay and cost overrun
- ✓ Risks in fuel procurement
- ✓ O&M risks (including risks in the construction of power transmission, transforming and distribution facilities)

(c) Risks directly concerned with the Government

In Bangladesh, an SPC and BPDP conclude a power purchase agreement (PPA) and the SPC becomes the only off-taker of the power under the PPA. Because this agreement provides long-term security, in principle, investors consider it an important agreement that promises profitability of their investment in the project life. Investors prefer a large proportion of the payment for electric power to be made in foreign currencies, while the investee prefers a large proportion of it to be made in the local currency, as they collect electricity charges from users in the local currency. This proportion of the payment in foreign currency has significant influence on investors' decision on investment. If there is a restriction on foreign exchange applicable to a case in which a SPC exchanges the profit from a project after deducting the local costs that it has saved in the local currency in a foreign currency and remits it to the country of the investor, such a restriction will also be an obstacle to the investment.
Power Division applies for the licenses and permits for the establishment of SPCs and construction of facilities with a consent of Power Cell and applies for a government guarantee with a consent of the Ministry of Finance. All the permission and licensing for investment in foreign currencies used to be controlled by the Board of Investment, Bangladesh, (BOI). However, it is currently controlled by Bangladesh Investment Development Authority, which was established recently as a one-stop center for foreign investors. The government's efforts in reorganizing itself in accordance with the needs of investors such as the case mentioned above should be highly appreciated. A contractor for the

implementation of a project with foreign investment is required to be established as a joint venture (JV) of a foreign investor and a local partner, and a foreign investor is not allowed to participate in such a project as its sole investor in many countries, including Bangladesh, in order to facilitate the development of domestic and local industries.
Successful project implementation naturally requires strict compliance with agreed rules and provisions of the agreement, which requires minimization of the country and political risks as the major precondition. These are the risk factors in the agreement directly concerned with the Government.

(d) Risks to be controlled mainly by contractors

The risk of delay and cost overrun is a risk to be hedged by contractors. The conclusion of an EPC agreement between a SPC and an EPC contractor is a means to hedge such risk. The risk in fuel procurement, which may emerge in different forms in different projects, is considered a risk to be controlled by contractors. The O&M risk is also considered a risk to be controlled by contractors.
There is a risk that power may not be transmitted as planned when the power source facilities have been constructed and put in use as planned, if a project for constructing transmission lines and substations is delayed by various factors. If such a project is not in the scope of the investment in the power source development of an investor, it is considered extremely difficult for the investor to control the project concerned. Therefore, a mechanism that places the responsibility for the consequence of the delay of the project to its contractor has to be established.

(e) Recommendations for improvemen

■ PPA
A PPA will stipulate the standards of tariffs that sufficiently accommodate various risks associated with foreign exchange and international remittance. The privileges to receive electricity tariffs in US dollars and transfer the revenue in dollars received from the sale of electricity overseas without restriction will be granted to investors.

■ Tax exemption for FDI
The tax exemption to be granted will include exemption from the customs duties on all the imported materials and equipment required for the plant construction, exemption from the corporate and personal income taxes for a certain period of time and exemption from the import tax on vehicles and heavy and specialized equipment to be used by contractors.

■ Streamlining of procedures
It is not sufficient just to establish better rules. It is also necessary to reduce the time required for the issuance of licenses and permits.

■ Credit enhancement to local enterprises by international organizations
A tripartite relationship of the political system, bureaucracy and private sector led by a local large-scale company has been formed in many of the successfully implemented IPP projects in Bangladesh. A foreign investor must form a JV with a local investor if the foreign investor intends to implement such a project because there is a law that does not allow purchase of land solely with a foreign currency in Bangladesh. Therefore, such a project will be implemented as a long-term joint investment project with a local company to ensure steady cash flow into the project and the financial credibility of such a local company may have significant influence on the decision of a foreign investor. For example, an international organization will enhance credit limit of a local company as a guarantor of its credit in order to improve its credibility in the local industry sector in a scheme to implement large-scale IPP project as a “model PPP project.” In practice, a mechanism that guarantees the payment of fees by guarantor in the case of breech of a provision in a PPA and fully covers damage to a developer will be established.

Chapter 12 Hydropower

12.1 Outline of Hydropower Potential Study

12.1.1 Background

Bangladesh's climate is categorized as a subtropical zone monsoonal climate, and its characteristic is abundant rainfall. In the winter, from October to March, it is warm and dried by the Northeast monsoon. In summer, from March to June, it is hot and humid, and particularly from June to October, squalls and monsoons hit the country. Average annual rainfall is recorded as 1500 to 1800 mm in Western areas, 2000 mm in the area surrounding Dhaka, and more than 5000 mm in the Assam hilly terrain area in the Northeast. In the Chittagong hilly terrain area in the Southeast, annual rainfall is recorded as 2500 to 4000 mm on average. As such, Bangladesh has relatively high rainfall and abundant water resources, particularly in the Northeast and Southeast of the country.

On the other hand, as for the topography of Bangladesh, most of the national land is spread over the delta area, along the Bay of Bengal on the Indian subcontinent. There are lots of swamps and jungles. Most of the areas are lowland lower than 9 m above sea level. Even in the hilliest area of Chittagong, elevation of the area is from 300 m to 600 m. The highest point of Bangladesh is known as Mount Keokradong, at 1230 m above sea level. In this regard, Bangladesh has relatively limited hydropower potential even though it has abundant water resources.

Karnafuli Hydropower Plant, using the water of Kaptai Lake, is the only hydropower plant in Bangladesh, with a total installed capacity of 230 MW. Its No.1 and 2 units (2 units of 40 MW) and No.3 unit (50MW) were installed with assistance from the United States, and operation started in 1962 and 1982 respectively. No. 4 and 5 units were installed with assistance from Japan, and operation started in 1987. Further, No. 6 and 7 units were planned as Japanese Yen Loan Projects in order to strengthen the power supply for peak demand. However, since an Environmental Impact Assessment was not carried out and local consensus was not attained, a Japanese ODA loan was not provided for the project. The problem was caused by conflicts between indigenous people and immigrant Bengali people who were living around Kaptai Lake. Compensation issues during the construction of Kaptai Dam were also one of the causes. Even now, entry to the area is restricted because of order problems.

Despite of such a situation, the Government of Bangladesh expects hydropower development for reduction of CO2 emissions and power system stability as well. The JICA Survey Team carried out a hydropower potential study for Pumped Storage Power Plant (PSPP) and Small Scale Hydropower Plant (SSHP).

12.1.2 Objective of the study

The objective of the Study is to identify hydropower potential sites for the future development. Pumped Storage Power Plant (PSPP) and Ordinary Hydropower Plant (Ordinary HP) or Small Scale Hydropower Plant (SSHP) are targeted in this Study.

12.1.3 Study flow

The study flow for identification of potential sites for PSPP and SSHP is shown in Figure 12-1.

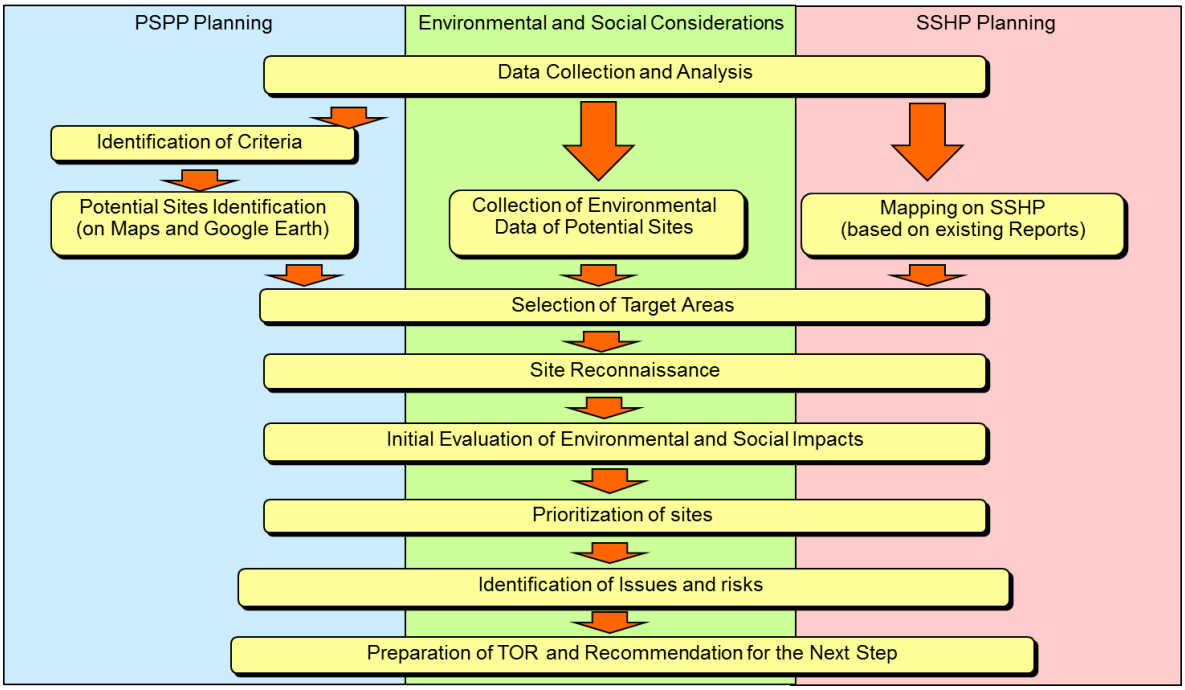
12.1.4 Limitation in the study

On the course of the study, the JICA Survey Team encountered the following difficulties:

- Limitation of maps available, and
- Limitation of access to the potential site areas due to security reasons.

Since topographic maps available for Chittagong hilly areas are only 1/50,000 scale maps with 100m counter lines, those maps could not be used for planning purpose and even for conceptual design of hydropower projects. Therefore, the JICA Survey Team identified and planned potential sites based on google earth with limited accuracy.

The JICA Survey Team also encountered the difficulty to access to the remote locations in Chittagong hilly areas due to security reasons. During the site reconnaissance, the Survey Team hired security guards. The Survey Team was, however, able to stay in the hilly areas for limited time only during day time, and to visit only the locations accessible by cars. And also, talking directly to local people was also restricted.



Source: JICA Survey Team

Figure 12-1 Flowchart of Hydropower Potential Study

12.2 Current Situation of Hydropower Development in Bangladesh

12.2.1 Outline of Karnafuli Hydropower Plant

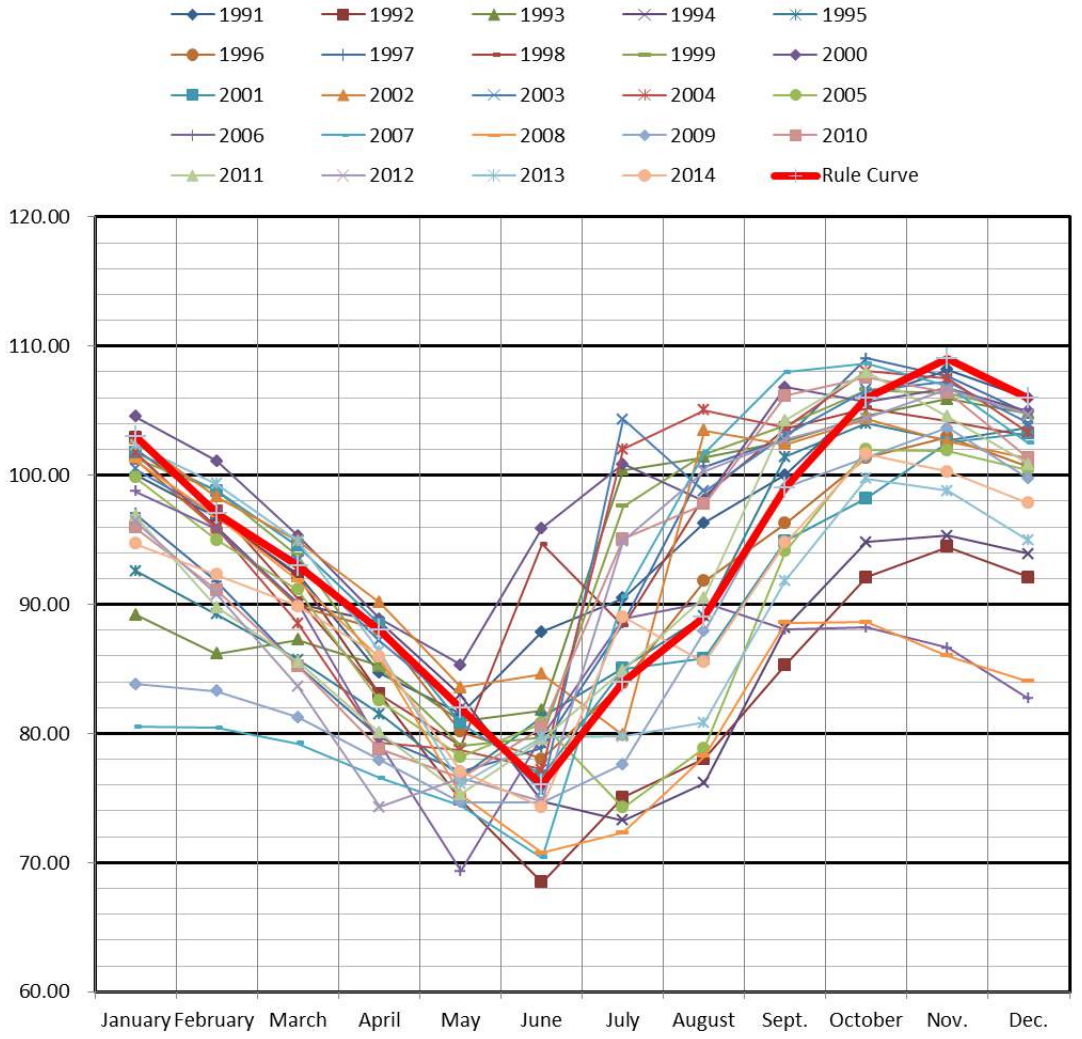
Kaptai Dam is on the Karnafuli River at Kaptai, 65 km (40 mile) upstream of Chittagong in Rangamati District, Bangladesh. It is an earth-fill embankment dam with a reservoir (known as Kaptai Lake) water storage capacity of 6,477 million m3 (5,251,000 acre·ft). The primary purpose of the dam and the reservoir was to generate hydroelectric power. Its construction was completed in 1962. The generators of the 230 MW (310,000 hp) Karnafuli Hydroelectric Power Station were commissioned between 1962 and 1988. It is the only hydropower plant in Bangladesh.

A brief reconnaissance occurred in 1906 when the Karnafuli Hydropower Plant was first contemplated. The second study was carried out in 1923. In 1946, E. A. Moore recommended the proposed project at Barkal about 65 km upstream of the present dam site at Kaptai. In 1950, the Marz Rendal Vatten Consulting Engineers suggested a site at Chilardak, about 45 km upstream of Kaptai. In 1951, the government engineers proposed Chitmoram, 11 km downstream of the present site. Under the guidance of then chief engineer (Irrigation) Khwaja Azimuddin, the construction site was finally chosen at the present site in 1951.

Utah International Inc. was selected as the construction contractor. The construction of the dam was started in 1957. When the first phase of the construction was completed in 1962, the dam, spillway, penstock and two units of 40 MW Kaplan turbines and generators were built in the power station. In August 1982, the third unit of 50 MW was commissioned. In October 1988, the fourth and fifth units of 50 MW turbines and generators were installed, and then the total generation capacity became 230 MW.

The Kaptai dam is an earth-fill type dam with 45.7m (150 ft) high, 670 m (2,200 ft) long, and it has a spillway with 16-radial gates whose each width is 11.5m on the left side. The construction of the dam submerged 655 km2 (253 sq mile) area that included 220 km2 (85 sq mile) of cultivable land, 40 percent of the cultivable land in the area. It also forced resettlement of 18,000 families and 100,000 tribal people of which 70% were Chakma. The dam flooded the original Rangamati town and other structures.

As per rule curve the water level of the reservoir is supposed to be 33.2m (109 ft) MSL of the highest water level in November and 23.2m (76 ft) MSL of the lowest level in June as shown in Figure 12-2. In reality actual reservoir operation was different from the rule curve due to difference in rainfall year to year.



Source: JICA Survey Team

Figure 12-2 Karnafuli Hydro Station Reservoir Operation Rule Curve and its Records

12.2.2 Hydropower potential and hydropower development plan in Bangladesh

There are only two studies on hydropower potential and/or hydropower development plan in Bangladesh at this moment. The first hydropower potential study in Bangladesh was carried out by National Rural Electric Cooperative Association (NRECA) under the assistance of US-AID in 1981. It covered small scale hydropower potential sites in the whole country except Chittagong Hilly areas. The second study on hydropower potential was carried out by Ministry of Power, Energy and Mineral Resources (MPEMR) in 2014 targeting Ordinary HP potential sites particularly in Chittagong Hilly areas.

Outline of the studies conducted in the past are briefly described below.

(1) Small hydropower potential sites in Bangladesh (except Chittagong Hilly areas)

Under the assistance of US-AID, National Rural Electric Cooperative Association (NRECA) carried out small hydropower potential study in 1981, and 20 sites were listed as shown in Table 12-1 and Figure 12-3.

Most of the potential sites are to utilize dams and/or canals for irrigation, and those capacities are relatively small from several ten to 200kW, which are a range of micro hydropower projects. Only some potential sites with capacity of several MW are also included in the list. In the study, Chittagong hilly areas where there is high possibility of high hydropower potential due to relatively large undulation are not included.

Table 12-1 SSHP Potential Sites List in the Country (excluding Chittagong Hilly Area)

Sites	Discharge (cfs)	Head (feet)	Available Operation Months (months)	Installed Capacity (kW)	Annual Generation (1000kWh)	Type
Chota Kumira	11	40	12	30	250	New Storgae Dam
Hinguli	12	15	12	12	100	New Storgae Dam
Soalock	70	35	12	170	1400	New Storgae Dam
Longi	15	10	12	10	90	New Storgae Dam
Dudia	6	25	12	10	90	New Storgae Dam
Nikhari Chara	17	40	12	50	400	New Dam
Monu Barrage	200	12	7	160	800	Existing Dam
Marisi	120	18	12	80	600	Storage Dam
Bhgai-Kangsa	280	18	12	190	1400	Storage Dam
Dahuk	140	12	12	75	500	Storage Dam
Chawai	200	12	12	100	700	Storage Dam
Talma	140	12	12	75	500	Storage Dam
Patraj	200	12	12	100	100	Storage Dam
Tangon	200	12	12	100	700	Storage Dam
Teesta Canal Mile23	7300	10	12	5000	36000	Canal Head
Rangpur Canal Mile7	2500	10	12	1700	12000	Canal Head
Rangpur Canal Mile19	1800	10	12	1250	9000	Canal Head
Rangpur Canal Mile33	1100	10	12	750	5000	Canal Head
Bogra Canal Mile7	4000	10	12	2700	20000	Canal Head
Teesta Barrage	2000	7	7	1200	5000	Dam

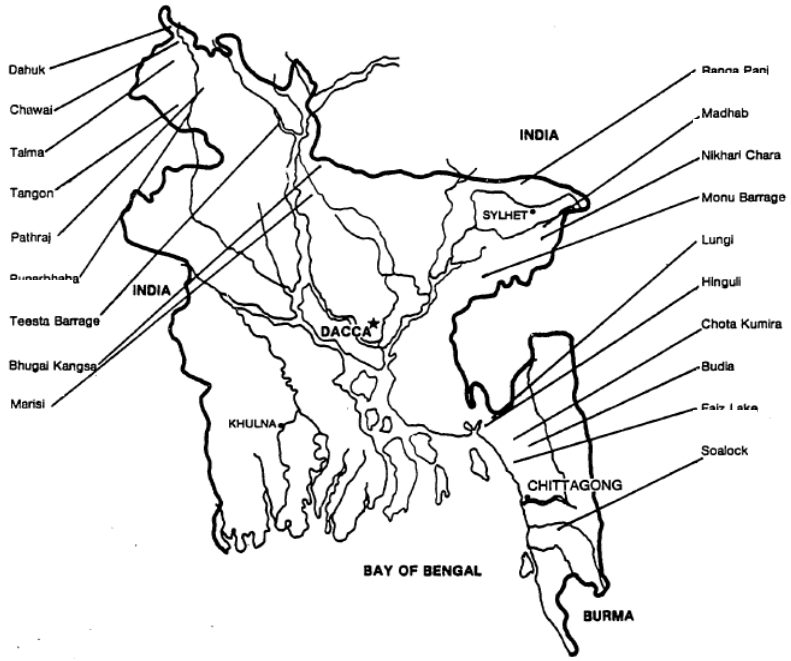
Source: Bangladesh An assessment of small hydropower potential, NRECA, November 1981

(2) Ordinary HP potential sites in Chittagong Hilly Area

Ministry of Power, Energy and Mineral Resources (MPEMR) requested Streams Tech, Inc. (STI), which is an American firm, to carry out a hydropower potential study on the three river basins (Sangu River, Matamuhuri River and Bakkhali River) in Chittagong Hilly Area in order to find potential sites

for hydropower development next to Kaptai hydropower plant.

As results of the potential study, 18 sites in total were found; 10 sites in the Sangu River, 5 sites in the Matamuhuri River, and three sites in the Bakkhali River as shown in Table 12-2 and Figure 12-4. Installed capacities of those potential sites would be varied from 0.1 MW to 201.7 MW.



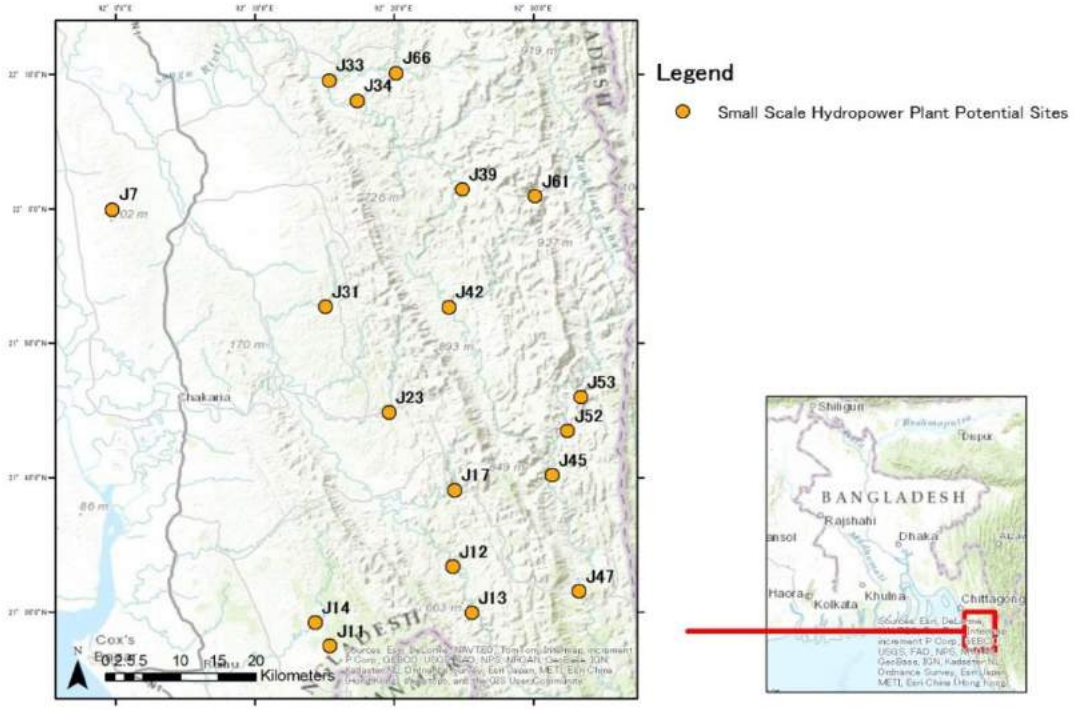
Source: Bangladesh An assessment of small hydropower potential, NRECA, November 1981

Figure 12-3 Location Map of SSHP Potential Sites in the Country

Table 12-2 Ordinary HP Potential Sites List in Chittagong Hilly Area

River	Location	Head	Flow (m^3/s)	Power (MW)	Max. Energy (MWh/year)	Percent of Time
Sangu	J33	12	268	23.5	37,648	18.3
Sangu	J34	20	217	31.8	50,877	18.3
Sangu	J39	70	200	102.7	144,000	16.0
Sangu	J42	60	156	68.6	96,676	16.1
Sangu	J45	20	101	14.8	21,035	16.2
Sangu	J47	40	47	13.9	16,126	13.3
Sangu	J52	20	30	4.4	5,733	15.0
Sangu	J53	30	25	5.5	7,106	14.7
Sangu	J61	40	9	2.6	3,296	14.6
Sangu	J66	20	31	4.6	6,426	16.0
Matamuhuri	J12	20	55	8.0	7,406	10.6
Matamuhuri	J13	15	41	4.5	4,430	11.3
Matamuhuri	J17	50	21	7.5	8,295	12.7
Matamuhuri	J23	50	16	5.9	6,535	12.7
Matamuhuri	J31	10	10	0.7	842	12.9
Bakkhali	J11	10	14	1.0	1,388	16.1
Bakkhali	J14	10	16	1.1	1,547	15.5
Banshkhali	J7	12	1	0.1	95	13.1

Source: Study on Prospective Hydropelectricity Generation in Southeast Bangladesh



Source: Study on Prospective Hydropelectricity Generation in Southeast Bangladesh

Figure 12-4 Location Map of Ordinary HP Potential Sites in Chittagong Hilly Area

(3) Hydropower projects under other donors' assistance

The JICA Survey Team conducted interview with MPEMR, Power Division, BPDP as well as donor agencies such as WB, ADB, US-Aid, to ask if they have any projects related to hydropower projects in Bangladesh. According to the their answers, there is no project conducted in the past and planned for the future even technical assistance related to hydropower development other than the two studies mentioned above.

12.3 Environmental Law and Regulations

Environmental laws and regulations related to hydropower development are as follows:

12.3.1 Environment Conservation Act

Bangladesh Environment Conservation Act (1995) covers environmental protection, pollution control, conservation area, environmental clearance, industrial discharge standards, environmental standards, solid waste discharge standards, and environmental guidelines. Bangladesh Environment Conservation Rules (1997) stipulate the following items including procedures of issuance of Environment Clearance Certificate (ECC).

- Declaration of ecologically critical area
- Vehicles emitting smoke injurious to health and otherwise harmful
- Application relating to pollution or degradation of environment
- Notice for collection of sample
- Procedure for issuing ECC
- Procedure for hearing of appeal
- Determination of environmental standards

- Information of special incident

12.3.2 Environmental Impact Assessment Regulations and Guidelines

Procedures of Environmental Impact Assessment (EIA) are stipulated in Bangladesh Environment Conservation Rules (1997), and EIA Guidelines for Industries (1997) are also provided by Department of Environment (DoE).

There are no rules and regulations which instruct Strategic Environmental Assessment for this study in such Master Plan stage in Bangladesh.

Procedures of EIA in Feasibility Study stage are provided in Bangladesh Environment Conservation Rules (1997). The rules classify project types in four (Green, Amber-A, Amber-B, Red) and different procedures for each category. A power plant project is categorized in Red which requires Initial Environmental Examination (IEE) followed by comprehensive EIA. The locations for the power plant are restricted under the following conditions:

- Industrial units shall not be located in any residential area
- Industrial units shall preferably be located in areas declared as industrial zones or in areas where there is concentration of industries or in vacant areas.
- Industrial units likely to produce sound, smoke, odor beyond permissible limit shall not be acceptable in commercial areas.

The projects catagorized in Red have to obtain both Site Clearance Certificate (SCC) and ECC based on the Bangladesh Environment Conservation Rules (1997). The SCC and ECC are normally applied at the same time. But they can be applied separately if the project such as manufacturing facility adds the pollution control facilities later. In case of the power plant, SCC and ECC should be applied at the same time and those procedures are described as follows:

1) Project proponent prepares IEE and Terms of Reference of EIA (TOR/EIA) and submits them to DoE.
2) DoE reviews the IEE and TOR/EIA and issues approval or rejection.
3) When Project Proponent gets approval of IEE and TOR/EIA, Project proponent can conduct EIA study and prepares EIA report.
4) Project proponent submits EIA application to DoE.
5) DoE reviews the application documents
6) When the EIA is approved, the project proponent applies ECC and SCC to DoE.
7) DoE grants ECC and SCC to the project proponent within thirty working days, or the application shall be rejected mentioning appropriate reasons.
8) The project proponent can start construction with ECC and SCC.

EIA Guidelines for Industries (1997) mentions that the public participation is important during EIA preparation and information disclosure and exchanging views with many stakeholders in various ways are required for effective public participations. Some sample methods for public participations introduced in the EIA Guidelines (1997) are:

- Radio and Television
- Newspaper
- Advertisement
- Lobbying activity
- Workshop
- Public explanatory meeting
- Public discussion meeting

- Civil advisory committee

12.3.3 Relevant ministries and agencies to Environmental Conservation

Ministry of Environment and Forest (MoEF) takes the main role for Environmental policies and regulations. Responding to the growing Environmental concern MoEF was established in 1989 substituting Ministry of Forest. MoEF has been a permanent member of the Executive Council of National Economic Commission. The Council is the main decision maker of the economic policy and responsible for approval of all the public investment projects. As a member of the Council MoEF supervises the activities of the following organizations:

- Department of Environment (DoE)
- Department of Forest (DoF)
- Forest Industries Development Corporation (FIDC)

In order to expand the scope of environmental management and strength the performance, the government stipulates the environment pollution control ordinance in 1977. Based on the ordinance Environmental Pollution Control Board was proposed for deciding policies and planning approaches. The Environmental Pollution Control Board was renamed to Department of Environmental Pollution Control (DEPC) in 1982 and six sub-departments are established in Dhaka, Chittagong, Khulna, Barisal, Sylhet, and Rajshahi. DEPC was changed to DoE and settled under the MoEF jurisdiction by Presidential order.

12.3.4 Laws and regulations on Land acquisition and Resettlement

Laws and regulations relevant to land acquisition and resettlement are the Land Acquisition Act (1894), The Acquisition and Requisition of the Immovable Property (Amendment) Act (1994), and The Acquisition and Requisition of Immovable Property Ordinance (1982) were revised in 2004. The main procedures are as follows:

1) Project owner applies for expropriation of land and immovable property to Deputy Commissioner
2) Deputy Commissioner gives public notice of the application and starts site survey
3) Deputy Commissioner gives public notice of the decision of the expropriation
4) Deputy Commissioner decides the compensation cost and pays compensation
5) Implement the expropriation

Preparation of the Resettlement Action Plan by the project proponent is not mandated but land owners have a right to take objections.

12.4 Selection of Hydropower Potential Sites for this Study

12.4.1 Identification of Pumped Storage Power Plant (PSPP) Sites

(1) Criteria for finding PSPP potential sites

In consideration of technical, economic, environmental and social aspects, criteria for finding PSPP potential sites were determined as shown in Table 12-3. However, in consideration of the limited data available, the criteria were used just for reference in order to identify potential sites as many as possible.

For comparison of the potential sites, those installed capacities were set as 500MW in consideration of scale of the potential sites.

Table 12-3 Criteria for Finding PSPP Potential Sites

Item		Consideration Point	Criteria	
Technical	Generation plan	・ Peak duration time ・ Installed capacity	・ 7hrs ・ About 500 MW	○ ○
	Limit of manufacturing of power facility	・ Design head ・ K Value (Hpmax / Hgmin) ・ Max. utilizing water depth of pond	・ Less than 750m of maximum head ・ Less than the limit (1.25-1.4) ・ Less than 30m (40m in case of full facing pond type)	○ ○ ○
	Location / Layout	・ Catchment area of Lower reservoir ・ Crest length of Lower Dam ・ Dam height ・ Length of water way ・ Length / Head (L/H) ・ Overburden of underground power cavern	・ More than 50km^2 ・ Less than 500m ・ Less than 200m ・ Less than 10km ・ Less than 10 ・ Less than 500m	○ ○ ○ ○ ○ ○
	Geological conditions	・ Active fault (Quaternary fault) ・ Fault and fractured zone ・ Landslide area ・ Permeability of peripheral rock of upper reservoir	・ Elongation from active faults >10km ・ Avoid large-scaled fault and fractured zone ・ Avoid large-scaled landslide area ・ Avoid lime stone / Quaternary volcanic rock	● ● ● ●
Topographical conditions		・ Demand center / pumping energy source ・ Existing and planned power network ・ Accessibility	・ Near demand center / pumping energy source ・ Near bulk power network (Substation) ・ Good accessibility to the site	○ ○ ●
Environmental	Natural	・ Protected Area (e.g. Natural Parks) ・ Endangered species	・ Avoid important Protected Areas (Natural Parks, Nature Parks, and Ramsar Sites) ・ Avoid the critical habitats of important fauna and flora	○ ●
	Social	・ Mining right ・ Historical and Cultural heritage ・ Houses to be resettled	・ Avoid the area of mining concession ・ Avoid being submerged ・ Less than 50	● ● ●

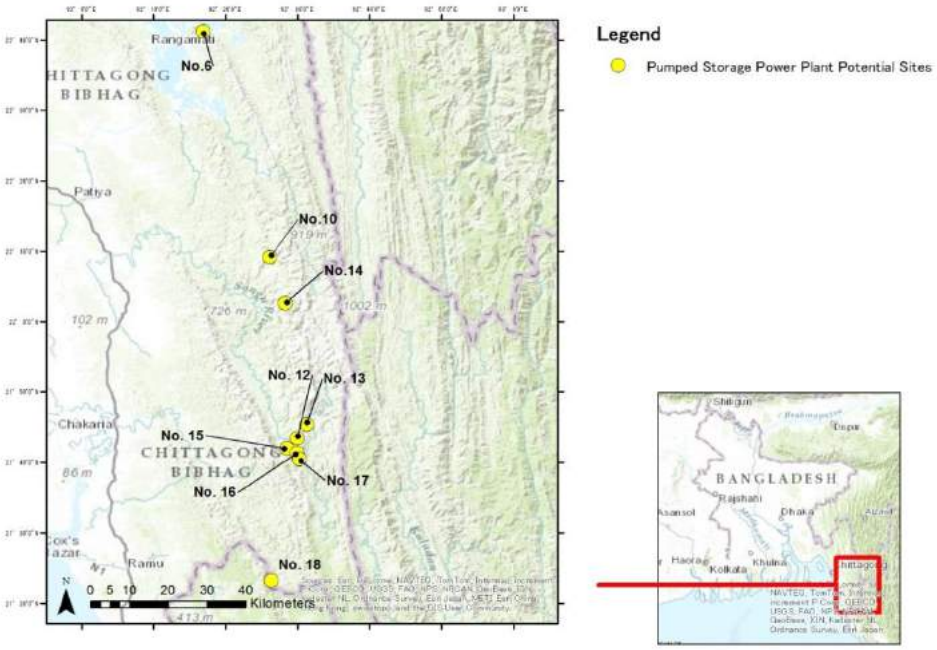
○ : considered in primary project finding ● : necessary to confirm the situation by site survey

Source: JICA Survey Team

(2) Finding of PSPP potential sites

In consideration of the criteria for finding of PSPP potential sites mentioned above, the JICA Survey Team carried out the finding PSPP potential sites with the Google Earth. In total, nine potential sites were found as shown in Figure 12-5.

No. 6 site is only potential site, which utilizes Kaptai Lake as a lower reservoir. The remaining eight sites found are located in the Sangu River basin, which require new construction of both upper reservoir and lower reservoir.

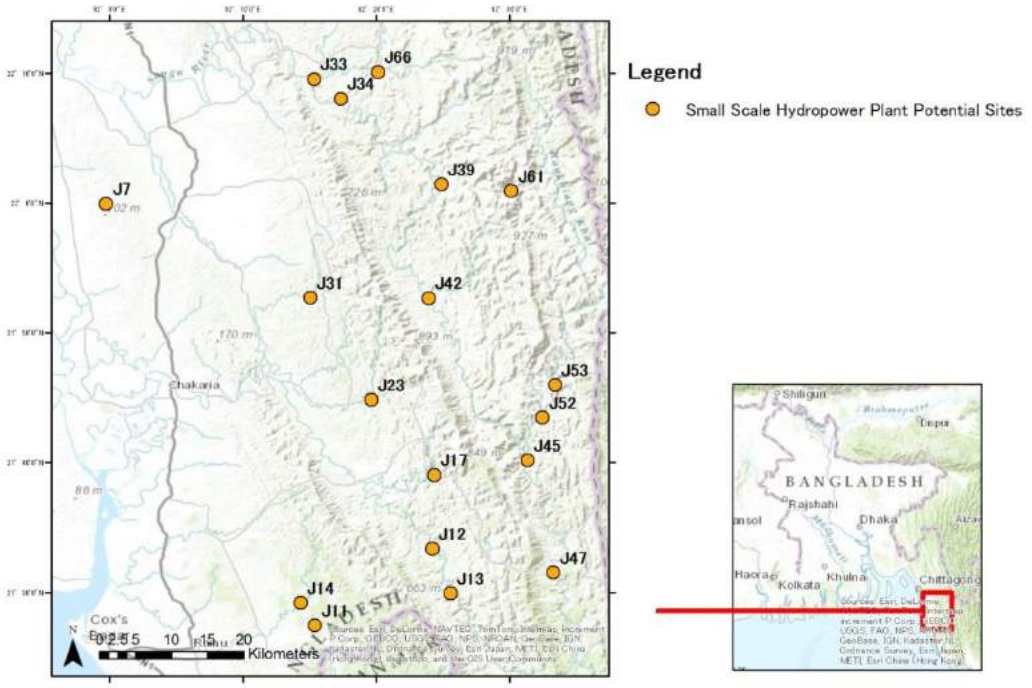


Source: JICA Survey Team

Figure 12-5 PSPP Potential Sites

12.4.2 Selection of ordinary HP /SSHP potential sites for this study

In consideration of attractive scale of hydropower development, the Ordinary HP potential sites in Chittagong hilly area were targeted in this Study.



Source: Study on Prospective Hydropelectricity Generation in Southeast Bangladesh

Figure 12-6 Ordinary HP Potential Sites in Chittagong Hilly Area

12.5 Selection of Target Areas and Site Reconnaissance

The JICA Survey Team selected Chittagong Hilly Area as a target area for site reconnaissance, since most of the potential sites are located in the area. However, accessible potential sites are limited due to peace and order situation, and limited access roads. Therefore, targeted sites for site reconnaissance were not selected in advance. Only accessible sites among all potential sites were surveyed during the site reconnaissance.

The JICA Survey Team together with an official of BPDB and local consultants carried out the site reconnaissance of the potential sites from June 8 to June 14, 2015. Results of the site reconnaissance are as follows:

12.6 Geology around the Potential Sites

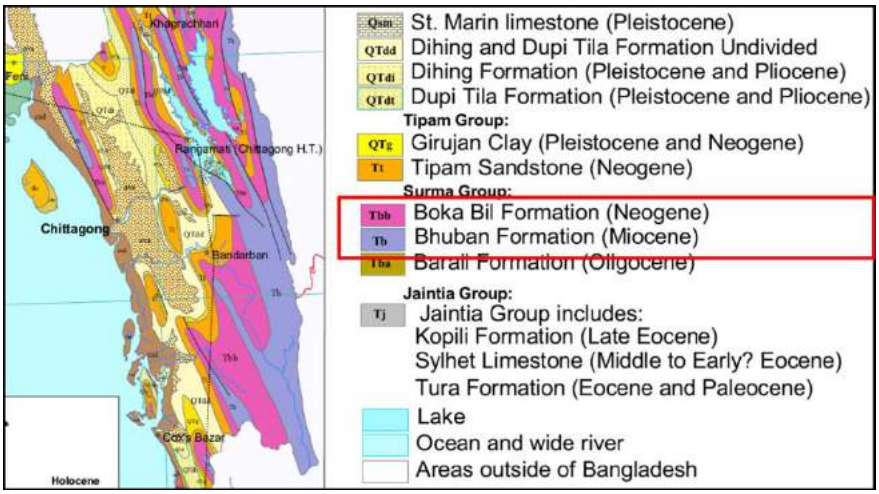
As one of the technical requirements for PSPP development, geology of the project site must be firm and impermeable, since dams and/reservoir are newly created, and a large scale cavern for a powerhouse is excavated in deep underground.

Figure 12-7 shows the geology of Chittagong Hilly Area where hydropower potential sites are located. Geology around the potential sites is Boka Bil Formation (Neogene) or Bhuban Formation (Miocene), which consists of sand stone, mad stone and those alternate layers. Though the rocks are relatively low concreteness, it is assumed possible to construct PSPP on such geology. Active faults near the potential sites are not recognized. Thus, from viewpoints of regional geology around the project sites, PSPP development in the area is possible.





Typical alternate layer of sand stone and mad stone and mad



Source: JICA Survey Team

Figure 12-7 Geological Map of Chittagong Hilly Area

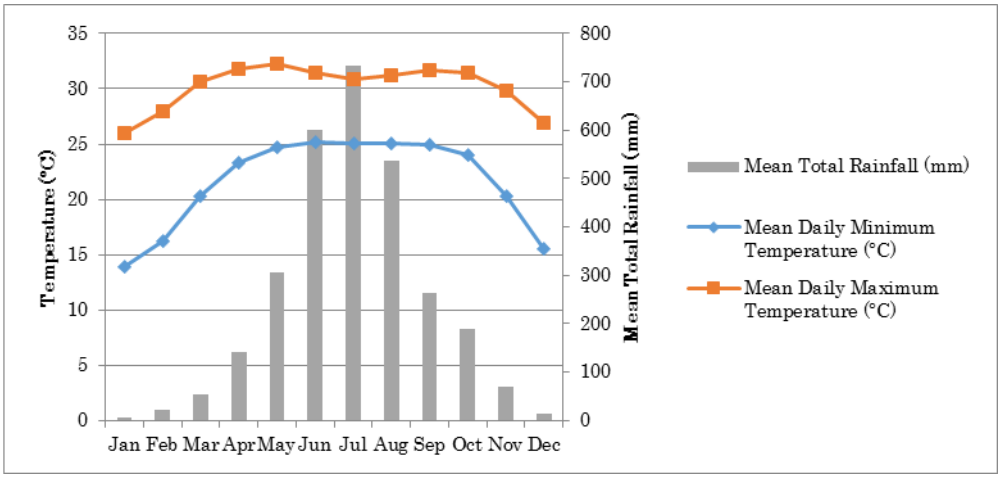
12.7 Environmental and Social Considerations

12.7.1 Baseline of environmental and social information in and around the potential sites

(1) Physical environment

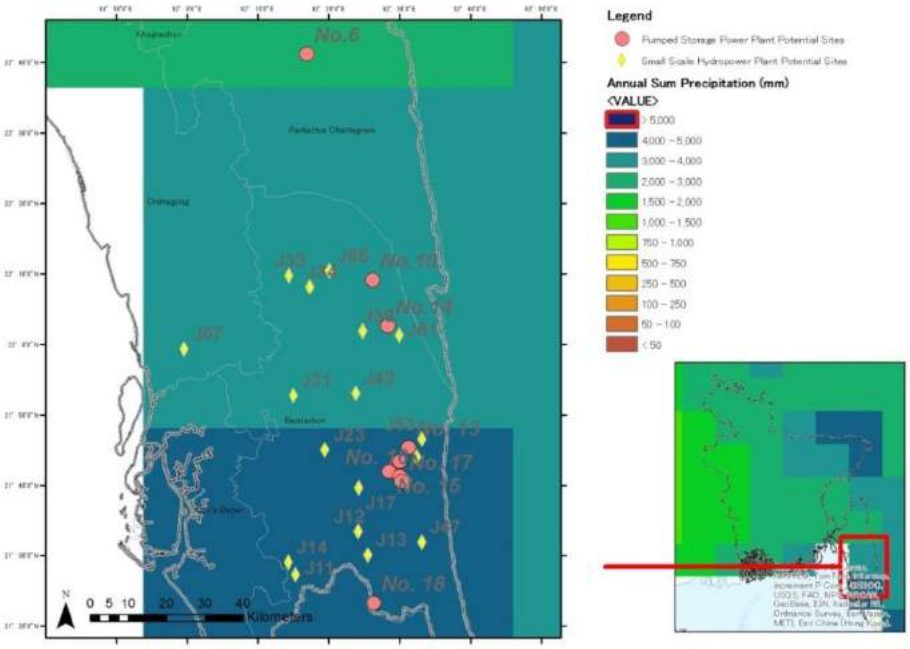
(a) Climate and weather

The climate of Chittagong and Chittagong high land fall in Tropical monsoon climate (Am) by Köppen climate classification. The light dry season is from December to March as shown in Figure 12-8. Amount of precipitation in southern part of Chittagong where many potential project sites are located is greater than northern part as shown in Figure 12-9.



Source: World Meteorological Organization

Figure 12-8 Temperature and Rainfall in Chittagong (average from 1971 to 2000)



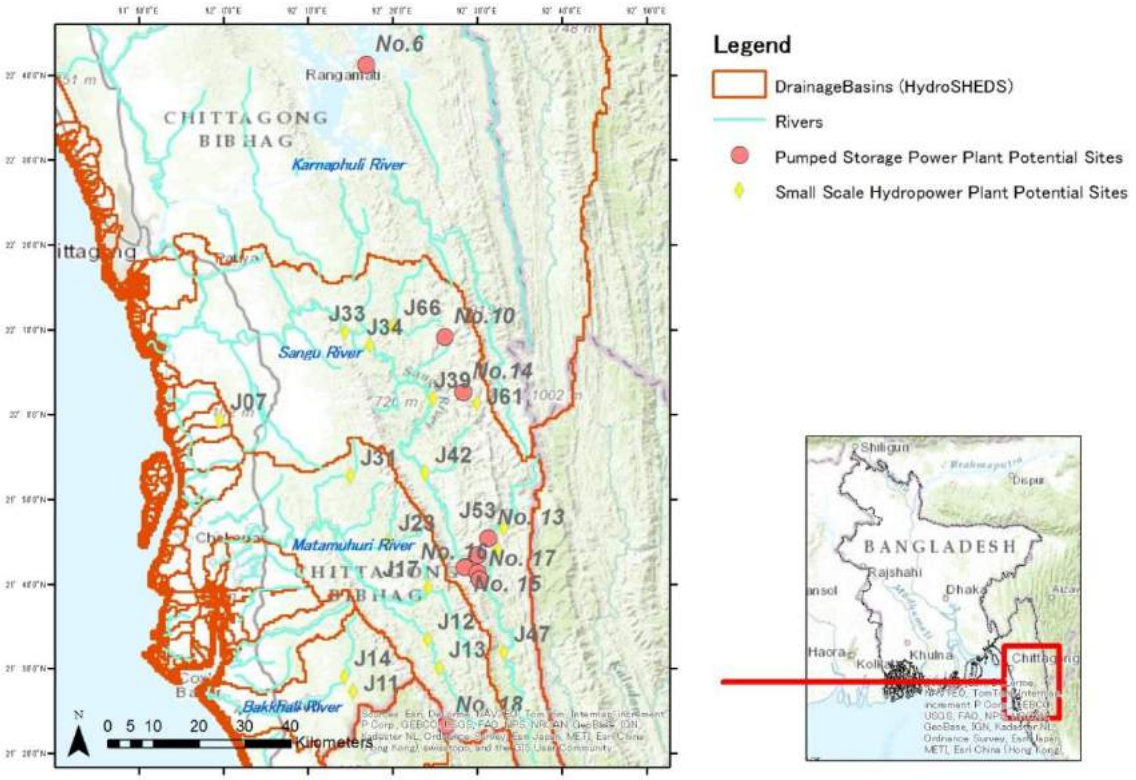
Source: WorldClim bio-climatic variable: BIO12

Figure 12-9 Annual Sum Rainfall around the Survey Area

(b) River system and water quality

River systems in Bangladesh are divided in two, the systems flowing down to sea from north to south including Padma River (Ganges river), Jamuna River (Brahmaputra River) and Meghna River, and systems flowing down from Chittagong high land to Bay of Bengal. Ganges River, Brahmaputra River, and Meghna River are international rivers from contiguous countries. Their total basin is 1.73 million km2 and including Bhutan, Nepal, a part of India and China. Main streams from Chittagong high land to Bay of Bengal are Karnaphuli river, Sangu river, Matamuhuri river, and Bakkhali river. Most of the potential sites are located in three southern systems as shown in Figure 12-10. 15 potential sites are in the Sangu river system and 6 potential sites are in the Matamuhuri river system as shown in See Table 12-4.

The surface river water quality in Bangladesh is not in good condition. Meghna River system in dry season is seriously polluted. Arsenic concentration of underground water in Bangladesh is also high especially in downstream area of Ganges/ Brahmaputra/ Meghna river system and causing health problems. On the other hand arsenic concentration is not confirmed in Chittagong high land other than sea side of northern Chittagong.



Source: Lehner, B., Verdin, K., Jarvis, A. (2006): HydroSHEDS Technical Documentation

Figure 12-10 Main Rivers on Chittagong Hill Tracts

Table 12-4 River System and Potential Sites

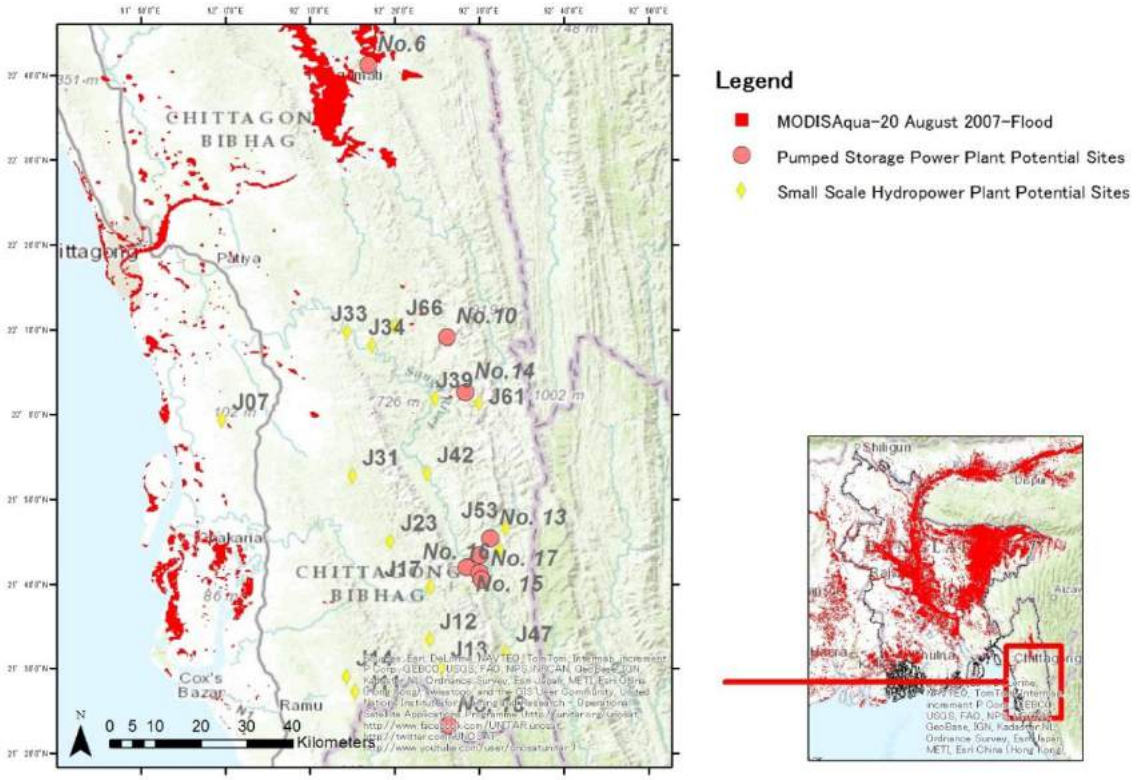
River system	PSPP		SSHP	
	Main Stream	Tributary	Main Stream	Tributary
Bakkhali	-	-	J14	J11
Banshkhali	-	-	-	J7
Kaptai lake	-	No.6	-	-
Matamuhuri	-	No.18	J12, J13	J17, J23, J31
Sangu	-	No.10, No.12, No.13, No.14, No.15, No.16, No.17	J33, J34, J39, J42, J45, J47	J52, J53, J61, J66

Source: JICA Survey Team

(c) Flood and salinity

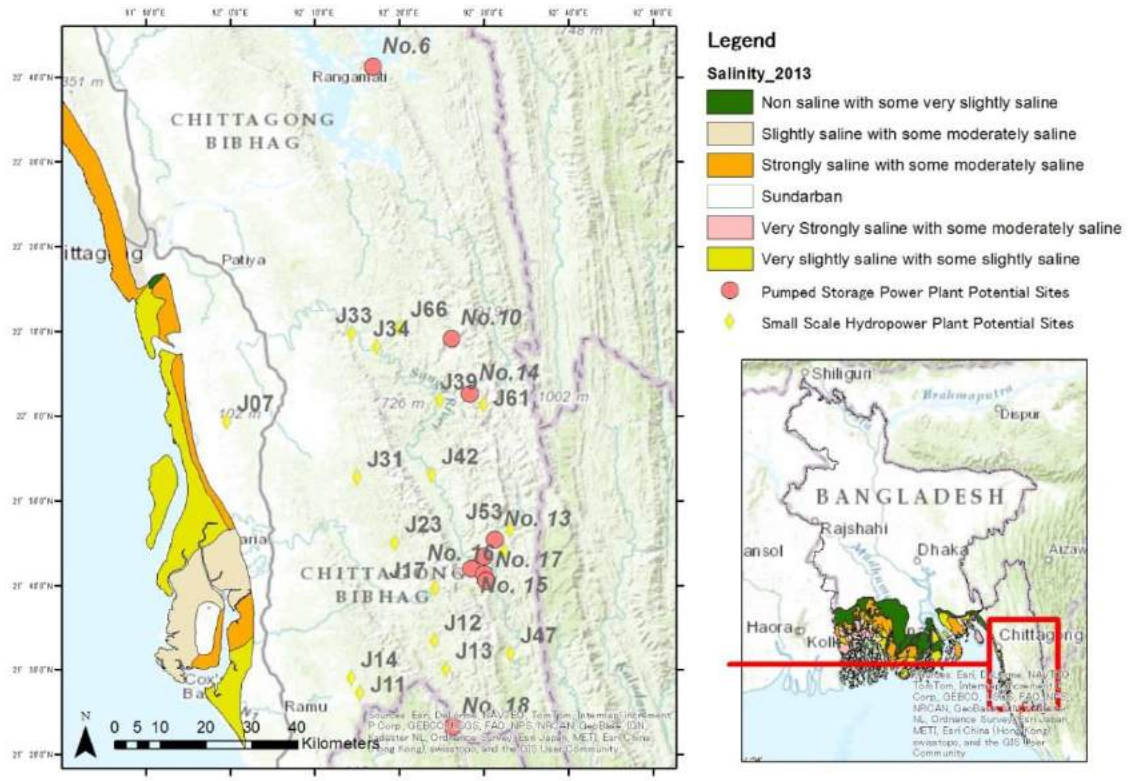
Bangladesh is repeatedly visited by severe floods. One of the biggest floods observed in 20 August 2007 is estimated as 72,972.76 km2 of flooded area based on the analysis of NODIS-Aqua by UNITAR/UNOSAT (See Figure 12-11).

Salinity of underground water is also serious along the coast in Bangladesh. The salinity affected areas are shown in Figure 12-12. None of the hydropower potential sites is located in flood or salinity affected area.



Source: Flood vectors - MODIS-Aqua (20 August 2007), UNITAR/UNOSAT 2014

Figure 12-11 Flood Affected Area in August 2007



Source: Soil Resource Development Institute SRMAF Project

Figure 12-12 Saline Affected Area

(2) Natural environment

(a) Domestic protected area

Domestic protected areas in Bangladesh are National Parks, Wildlife Sanctuary designated by Wildlife Preservation Act (1973), Ecologically Critical Areas by Environment Act (1995), Forest reserve, Protected forest by Forest Act (1927) and Botanical Garden, Eco-parks and Safari Park which are Ex-situ Conservation Areas. Official name, locations will be confirmed later. Some of the Hydropower potential sites might be in the Forest reserve.

Table 12-5 Designated Area by Wildlife (Preservation) Act, 1973

Designation	No.	Name	Location	Area (ha.)	Established	Potential site
National Park	1	Bhawal National Park	Gazipur	5,022.00	11-5-1982	
	2	Madhupur National Park	Tangail/ Mymensingh	8,436.00	24-2-1982	
	3	Ramsagar National Park	Dinajpur	27.75	30-4-2001	
	4	Himchari National Park	Cox's Bazar	1,729.00	15-2-1980	
	5	Lawachara National Park	Moulavibazar	1,250.00	7-7-1996	
	6	Kaptai National Park	Chittagong Hill Tracts	5,464.00	9-9-1999	
	7	Nijhum Dweep National Park	Noakhali	16,352.23	8-4-2001	
	8	Medhakachhapia National Park	Cox's Bazar	395.92	8-8-2008	
	9	Satchari National Park	Habigonj	242.91	15-10-2005	
	10	Khadimnagar National Park	Sylhet	678.80	13-04-2006	
	11	Baroiyadhala National Park	Chittagong	2,933.61	06-04-2010	
	12	Kuakata National Park	Patuakhali	1,613.00	24-10-2010	
	13	Nababgonj National Park	Dinajpur	517.61	24-10-2010	
	14	Singra National Park	Dinajpur	305.69	24-10-2010	
	15	Kadigarh National Park	Mymensingh	344.13	24-10-2010	
	16	Altadighi National Park	Naogaon	264.12	24-12-2011	
	17	Birgonj National Park	Dinajpur	168.56	24-12-2011	
Wildlife Sanctuary	18	Rema-Kalenga Wildlife Sanctuary	Hobigonj	1,795.54	7-7-1996	
	19	Char Kukri-Mukri Wildlife Sanctuary	Bhola	40.00	19-12-1981	
	20	Sundarban (East) Wildlife Sanctuary	Bagerhat	31,226.94	6-4-1996	
	21	Sundarban (West) Wildlife Sanctuary	Satkhira	71,502.10	6-4-1996	
	22	Sundarban (South) Wildlife Sanctuary	Khulna	36,970.45	6-4-1996	
	23	Pablakhali Wildlife Sanctuary	Chittagong Hill Tracts	42,087.00	20-9-1983	
	24	Chunati Wildlife Sanctuary	Chittagong	7,763.97	18-3-1986	J07
	25	Fashiakhali Wildlife Sanctuary	Cox's Bazar	1,302.43	11-4-2007	
	26	Dudpukuria-Dhopachari Wildlife Sanctuary	Chittagong	4,716.57	6-4-2010	
	27	Hajarikhil Wildlife Sanctuary	Chittagong	1,177.53	6-4-2010	
	28	Sangu Wildlife Sanctuary	Bandarban	2,331.98	6-4-2010	
	29	Teknaf Wildlife Sanctuary	Cox's Bazar	11,615.00	24-03-2010	
	30	Tengragiri Wildlife Sanctuary	Barguna	4,048.58	24-10-2010	
	31	Dudhmukhi Wildlife	Bagerhat	170.00	29-01-2012	

Designation	No.	Name	Location	Area (ha.)	Established	Potential site
		Sanctuary				
	32	Chadpai Wildlife Sanctuary	Bagerhat	560.00	29-01-2012	
	33	Dhangmari Wildlife Sanctuary	Bagerhat	340.00	29-01-2012	
	34	Sonarchar Wildlife Sanctuary	Patuakhali	2,026.48	24-12-2011	
	35	Nazirganj Wildlife (Dolphin) Sanctuary	Pabna	146.00	01-12-2013	
	36	Shilanda-Nagdemra Wildlife (Dolphin) Sanctuary	Pabna	24.17	01-12-2013	
	37	Nagarbari-Mohanganj Dolphin Sanctuary	Pabna	408.11	01-12-2013	

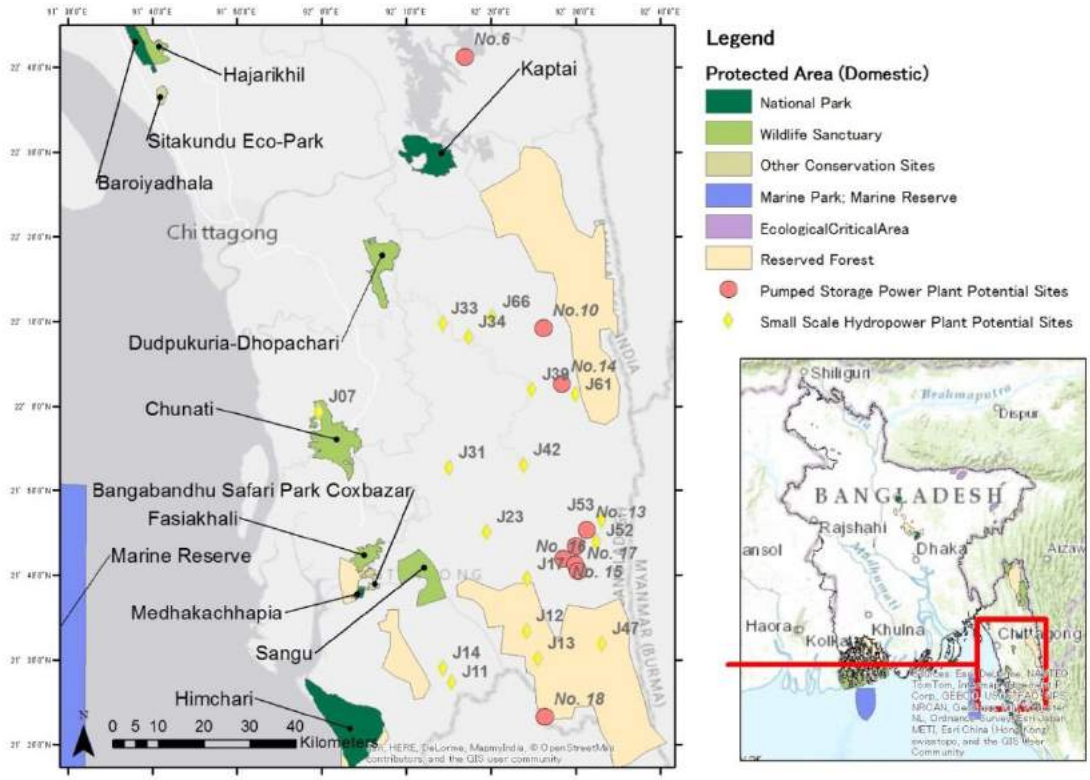
Source: JICA Survey Team

Table 12-6 Designated Area by the Other Acts

Act	Designation	No.	Name	Location	Area (ha.)	Established	Potential sites
Ex-situ Conservation Areas	Botanical Garden	1	National Botanical Garden	Dhaka	84.21	1961	
		2	Baldha Garden	Dhaka*	1.37	1909	
	Eco-parks and Safari Park	3	Madhabkunda Eco-Park	Moulavibazar*	265.68	2001	
		4	Sitakunda Botanical Garden and Eco-park	Chittagong	808.00	1998	
		5	Dulahazara Safari Parks	Cox's Bazar	600.00	1999	
		6	Modhutila Eco-Park	Sherpur	100.00	1999	
		7	Banshkhali Eco-Park	Chittagong*	1,200.00	2003	
		8	Kuakata Eco-Park	Patuakhali	5,661.00	2005	
		9	Tilagar Eco-Park	Sylhet	45.34	2006	
		10	Borshijora Eco-Park	Moulavibazar	326.07	2006	
	Others	1	Swatch of no ground Marine Protected Area	-	-	-	
		2	Marine Reserve	-	-	-	
Environment (Conservation) Act, 1995	Ecologically Critical Areas	1	The Sundarbans	-	-	-	
		2	Cox's Bazar (Teknaf, Sea beach)	*	-	-	
		3	St. Martin Island	*	-	-	
		4	Sonadia Island	*	-	-	
		5	Hakaluki Haor	-	-	-	
		6	Tanguar Haor	-	-	-	
		7	Marjat Baor	*	-	-	
		8	Gulshan-Banani-Baridhara Lake	*	-	-	
		9	Rivers (Buriganga, Bait, Turag, and Sitalakhya)	*	-	-	
Forest Act, 1927	Forest reserve	-	-	*	-	-	No. 18, J12, J13, J47
	Protected forest	-	-	*	-	-	

*: Locations or boundaries are not clear.

Source: JICA Survey Team



Source: WDPA

Figure 12-13 Domestic Protected Areas around the Hydropower Potential Sites

(b) International protected area and Key Biodiversity Area

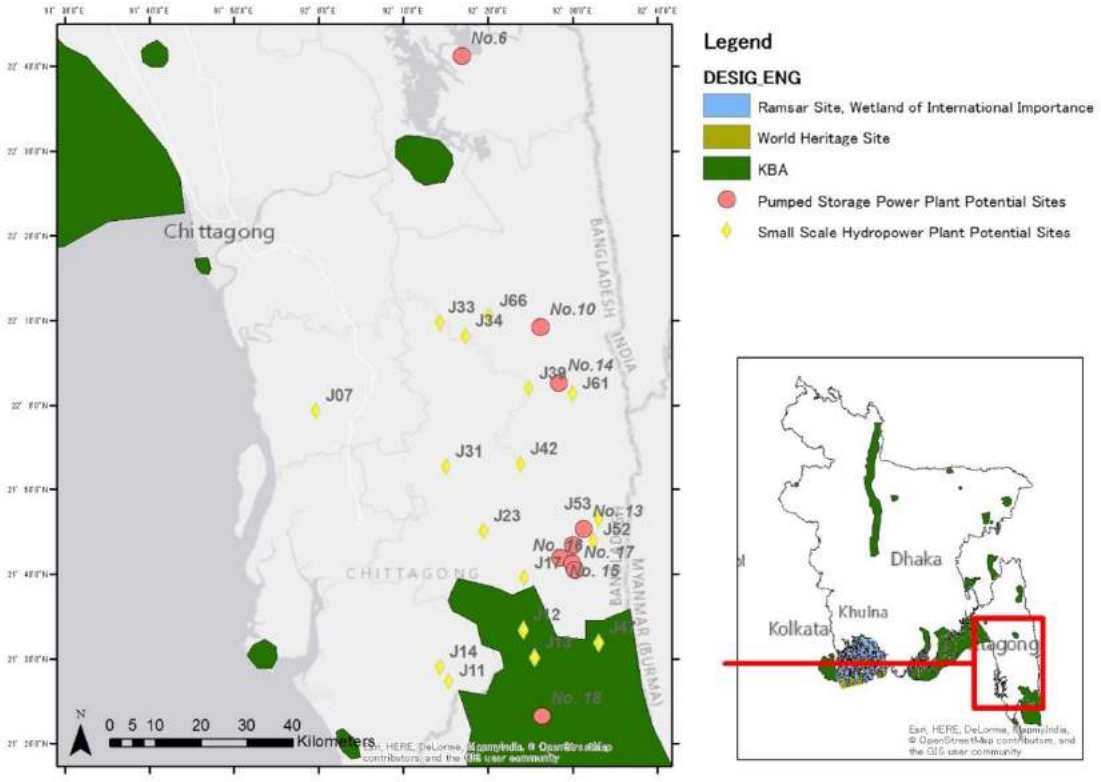
There are three protected areas registered by International treaty in Bangladesh. Registered wetlands under the Ramsal Convention are Subdarbans Reserved Forest in estuary of Khunla District, and Tanguar Haor located at the border northern part of Sylhet District. World heritage area is the Sundarbans next to southern side of the Sundarbans Ramsal wetland. All of the international protected areas are far from the Hydropower potential sites.

There are 20 Key Biodiversity Areas (KBA) in Bangladesh as shown in Table 12-7. None of them are assigned as Alliance for Zero Extinction Sites (AZEs) where are identified to prevent and safeguard key sites, each one of which is the last remaining refuge of one or more Endangered or Critically Endangered species. Some of the Hydropower potential sites fall in the KBA as shown in Figure 12-14.

Table 12-7 Key Biodiversity Areas in Bangladesh

International name	Area (ha)	Potential sites
Aila Beel	160	
Ganges-Brahmaputra-Meghna delta	75000	
Hail Haor	8906	
Hakaluki Haor	20400	
Hazarikhil Wildlife Sanctuary	2903	
Himchari National Park	1729	
Jamuna-Brahmaputra river	200000	
Lawachara / West Bhanugach Reserved Forest	900	
Madhupur National Park	8436	
Muhuri Dam	500	
Pablakhali Wildlife Sanctuary	42087	
Patenga Beach	500	
Rajkandi Reserved Forest	1000	
Rampahar-Sitapahar Wildlife Sanctuary	3026	
Rema-Kalenga Wildlife Sanctuary	1095	
Sangu Matamuhari	20000	No.18,J12, J13, J47
Sonadia Island	4916	
Sunderbans (East, South, West Wildlife Sanctuaries)	139699	
Tanguar Haor and Panabeel	1566	
Teknaf Game Reserve	11615	

Source: JICA Survey Team



Source: IBAT, WDPA

Figure 12-14 KBA around Hydropower Potential Sites

(c) Distribution of the protected species

In total 198 IUCN red list species are recorded in Bangladesh including 21 plants, 43 mammals, 52 birds, 23 reptiles, 1 amphibian, 53 fishes, and 2 invertebrates. In terms of mammals, the known distribution areas around the Hydropower potential sites are of Indian hog deer (Axis porcinus), Asian Elephant (Elephas maximus), Phayre's leaf monkey (Trachypithecus phayrei), Western hoolock gibbon (Hoolock hoolock), and Dhole (Cuon alpinus). All of them are classified as Endangered category (EN). Relatively limited distribution areas are of Indian hog deer and Asian Elephant as shown in Table 12-8. Some of the Hydropower potential sites are in the these distribution areas. It is reported that some kinds of freshwater dorphines are living in Kaptai area (Ahmed et al. 2001)[46]

Table 12-8 Number of IUCN Red List Species Recorded in Bangladesh

Taxonomic group*	EW	CR	EN	VU	NT	Total
Plants		5	3	8	5	21
Mammals		3	13	18	9	43
Birds		8	6	17	21	52
Reptiles	1	3	8	11		23
Amphibians				1		1
Fishes		2	3	15	34	54
Invertebrates			1	1	2	4
Grand Total	1	21	34	71	71	198

* : Extinct in Wild(EW), Critically Endangered(CR), Endangered(EN), Vulnerable(VU), Near Threatened(NT)
Source: IUCN

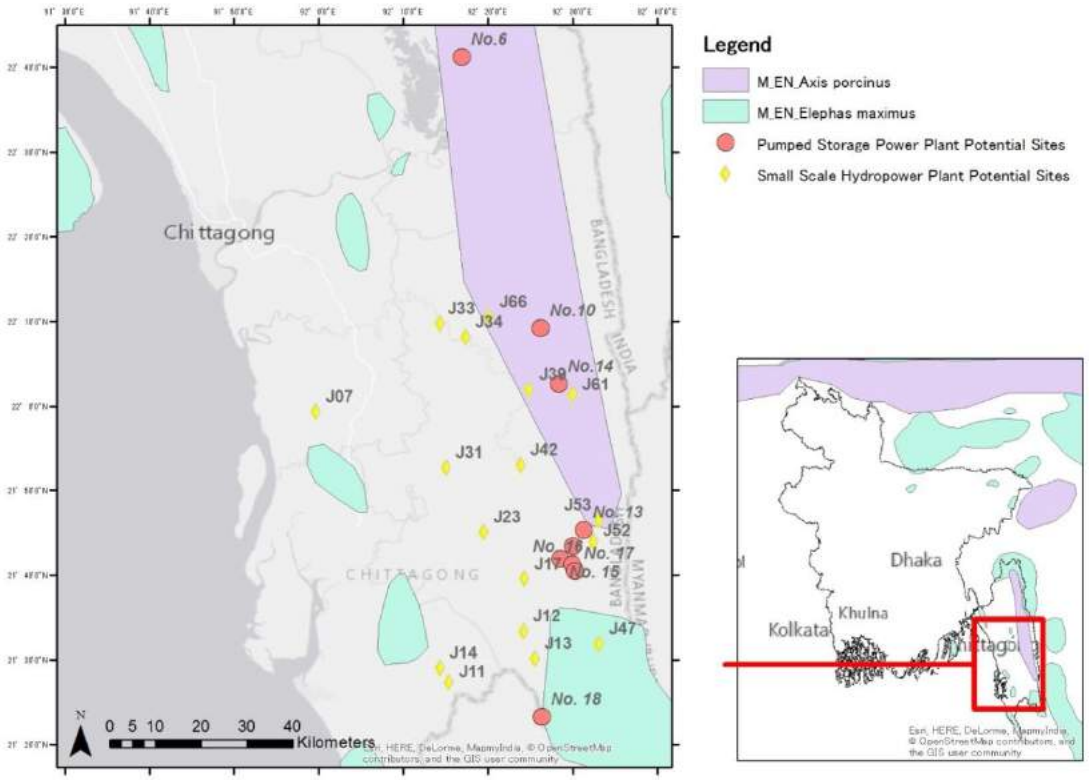
Table 12-9 Known Distribution Area of Endangered Mammals and Potential Sites

Potential sites	Indian hog deer (Axis porcinus)	Asian Elephant (*Elephas maximus*)	Phayre's leaf monkey (*Trachypithecus phayrei*)	Western hoolock gibbon (*Hoolock hoolock*)	Dhole (*Cuon alpinus*)
No.06	*		*	*	
No.10	*		*	*	
No.12			*	*	
No.13			*	*	
No.14	*		*	*	
No.15			*	*	
No.16			*	*	
No.17			*	*	
No.18		*	*	*	
J07			*	*	
J11			*	*	
J12			*	*	
J13			*	*	
J14			*	*	
J17			*	*	
J23			*	*	

[46] 2001, Ahmed, Benazir, Ali, Muhammad Edrise, Braulik, Gill & Smith, Brian D. " Status of the Ganges river dolphin or shushuk *Platanista gangetica* in Kaptai Lake and the southern rivers of Bangladesh" in *Oryx*, Vol. 35, No. 1, January. P. 61-72.

Potential sites	Indian hog deer (Axis porcinus)	Asian Elephant (*Elephas maximus*)	Phayre's leaf monkey (*Trachypithecus phayrei*)	Western hoolock gibbon (*Hoolock hoolock*)	Dhole (*Cuon alpinus*)
J31			*	*	
J33			*	*	
J34			*	*	
J39	*		*	*	
J42			*	*	
J45			*	*	
J47		*	*	*	
J52			*	*	
J53	*		*	*	
J61	*		*	*	
J66	*		*	*	

Source: IUCN

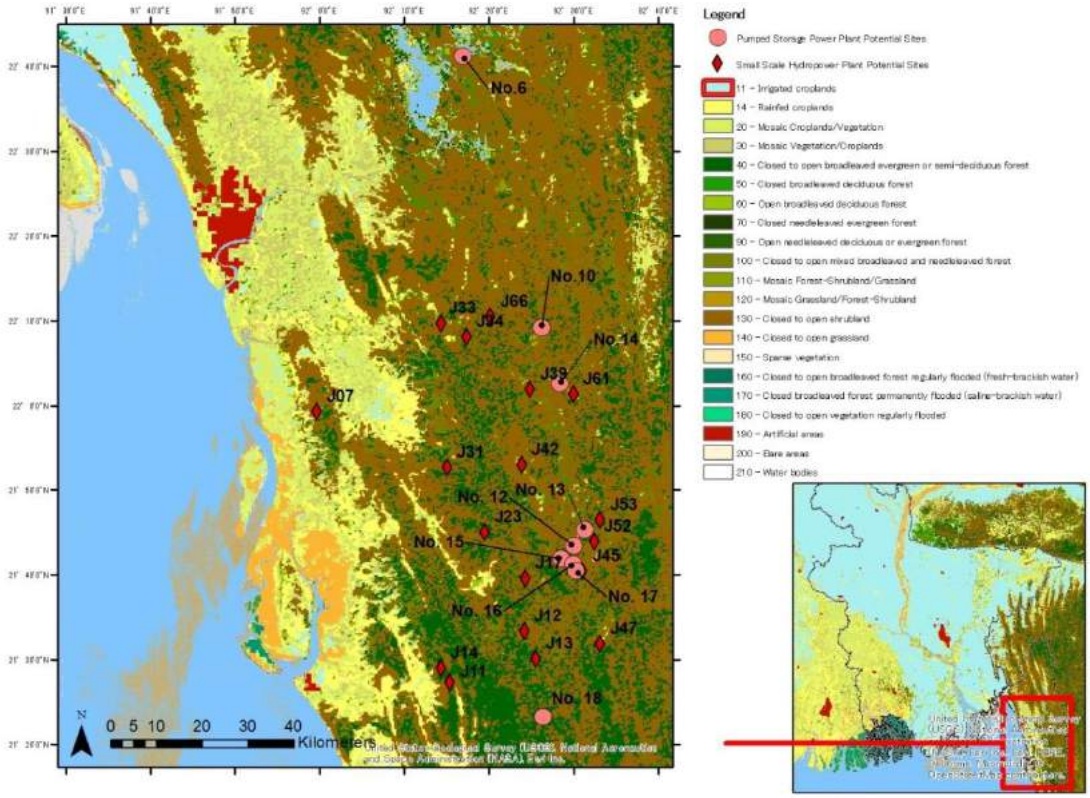


Source: IUCN

Figure 12-15 Known Distribution Area of Indian Hog Deer and Asian Elephant

(d) Vegetation

According to the GlobCover 2009 based on the satellite image, Irrigated croplands (11) are widely spread in Ganges Delta. The Chittagong Hill Tract is coverd by Closed to open broadleaved evergreen or semi-deciduous forest (40), Closed to open shrubland (130), and Mosaic Forest-Shrubland/Grassland (110). Rainfed croplancs (14) spread in the coast area of Chittagong district. Hydropower potential sites are located on the hills dominated by forest and shrubs as shown in Figure 12-16.



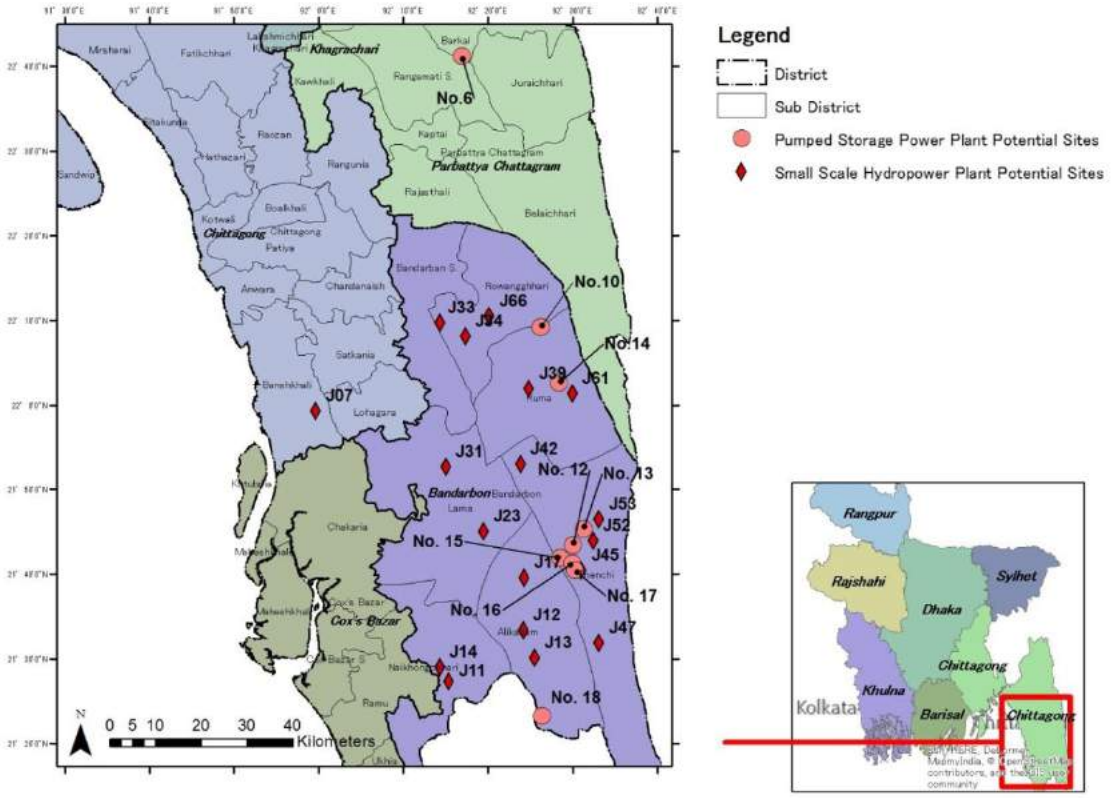
Source: GlobCover 2009 (http://ionia1.esrin.esa.int/)

Figure 12-16 Vegetation around the Hydropower Potential Sites by GlobCover (2009)

(3) Social environment

(a) Administrative sections

The highest administrative sections in Bangladesh are seven Divisions followed by District, Sub-District (Upazila), and Village (Union/Mouza). The hydropower potential sites are located in Chittagong Division including Rangamati District, Chittagong District, Bandarban District, and Cox's Bazar District.



Source: ArcGIS Online, ESRI

Figure 12-17 Administrative Boundaries around the Hydropower Potential Sites

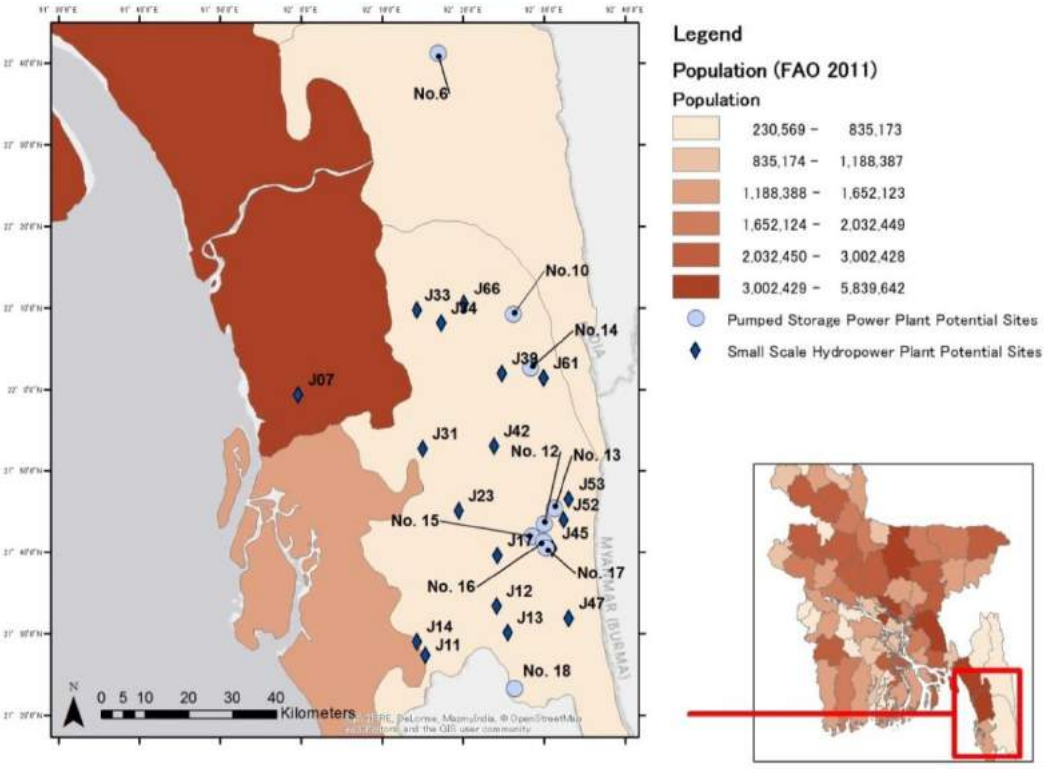
Table 12-10 Administrative Jurisdiction of the Potential Sites

District	Sub-district (Upazila)	Village (Union/Mouza)	Potential Sites	
			PSPP	SSHP
Bandarban	Alikadam	Alikadam	-	J17, J23
		Chokhyong	No.18	J12, J13
	Bandarban	Bandarban	-	J33
	Lama	Rupshipara	-	J31
	Rawangchhari	Rawangchhari	-	J34, J66
	Ruma	Paindu	No.10	
		Ruma	No.14	J39, J61
	Thanchi	Remakri	No.15, No.16, No.17	J45, J47
		Thanchi	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	-	J7
Cox's Bazar	Ramu	Kaoarkhop	-	J11, J14
Rangamati	Barkal	Shuvolong	No.6	

Source: JICA Survey Team

(b) Population

According to the census 2011, the population of Bangladesh is over 150 million (152,518,015: the eighth biggest country in the world). The population density in Bangladesh is 1,238 person/km2 which are more than triple the density in Japan (343 person/km2, 2005) cited by CIA World Fact Book 2012. Hydropower potential sites are located relatively fewer population districts. Apart from J7, all of the potential sites are located in low population area.



Source: FAO 2011

Figure 12-18 Population by Divisions around the Hydropower Potential Sites

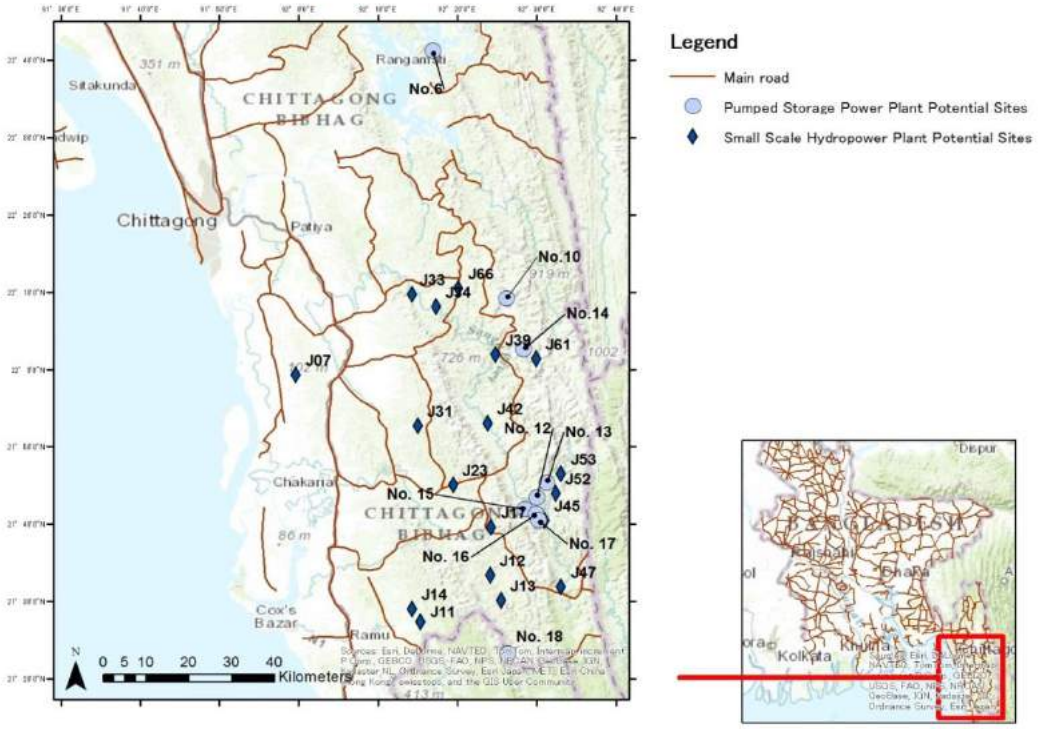
Table 12-11 Village (Union/Mouza) Population of Potential Sites

Village (Union/Mouza)	No of.H/Hs	No of Population	Potential Sites	
			PSPP	SSHP
Alikadam	5,391	28,495	-	J17, J23
Chokhyong	4,031	20,822	No.18	J12, J13
Bandarban	2,023	9,219	-	J33
Rupshipara	2,457	11,565	-	J31
Rawangchhari	1,988	8,804	-	J34, J66
Paindu	1,267	5,803	No.10	
Ruma	2,667	12,417	No.14	J39, J61
Remakri	1,281	6,119	No.15, No.16, No.17	J45, J47
Thanchi	1,547	7,599	No.12, No.13	J42, J52, J53
Silkup	4,075	20,043	-	J7
Kaoarkhop	4,373	24,004	-	J11, J14
Shuvolong	2,501	11,728	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

(c) Traffic and electricity

The road networks in Bangladesh cover whole the country. Main roads near the Hydropower potential sites are road stretching along the coast as shown in Figure 12-10. Although some roads are shown on the hill near the potential hydropower site, the conditions of the roads are not confirmed.
Electrification rates around the project sites are under 50%. Following table shows the electricity rates by Villages.



Source: JICA Survey Team

Figure 12-19 Main Roads around the Hydropower Potential Sites

Table 12-12 Percentage of Electrification around the Potential Sites

Administrative section			No of H/Hs	Electricity	Potential sites	
District	Upazila	Union/Mouza			PSPP	SSHP
Bandarban	Alikadam	Alikadam	5,391	18.70%	-	J17, J23
		Chokhyong	4,031	11.07%	No.18	J12, J13
	Bandarban	Bandarban	2,023	34.30%	-	J33
	Lama	Rupshipara	2,457	11.00%	-	J31
	Rawangchhari	Rawangchhari	1,988	27.70%	-	J34, J66
	Ruma	Paindu	1,267	28.60%	No.10	
		Ruma	2,667	42.80%	No.14	J39, J61
	Thanchi	Remakri	1,281	7.08%	No.15, No.16, No.17	J45, J47
		Thanchi	1,547	19.20%	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	4,075	34.60%	-	J7
Cox's Bazar	Ramu	Kaoarkhop	4,373	17.70%	-	J11, J14
Rangamati	Barkal	Shuvolong	2,501	27.10%	No.6	

Source: JICA Survey Team

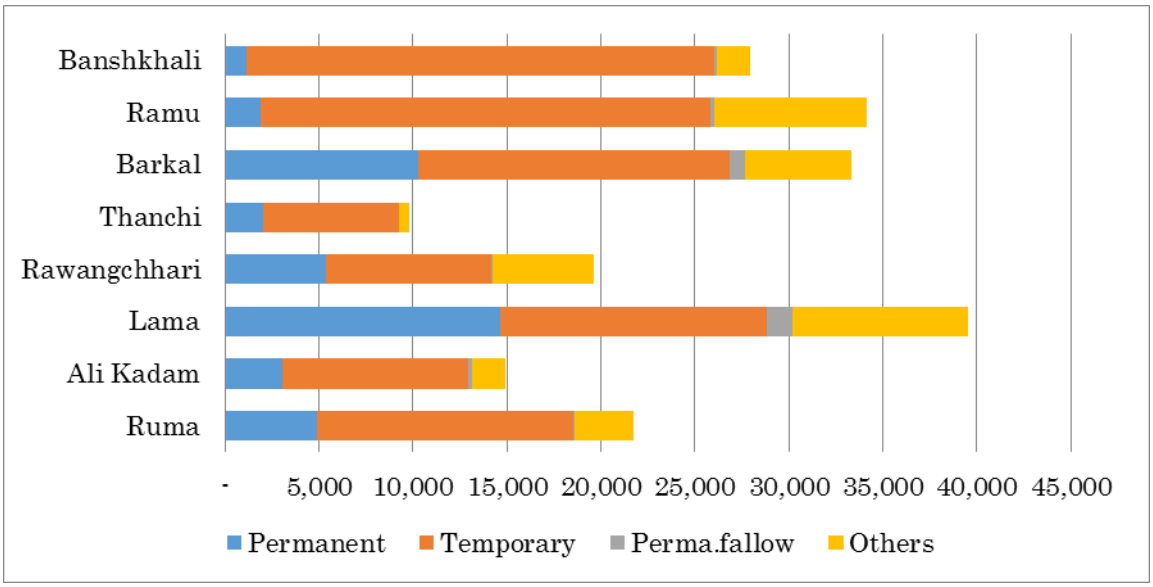
(d) Land use

The villages which potential sites locate are widely developed for farm land for permanent or temporary as shown in Table 12-13. 59% of the farm land is used for Temporary cultivation, and 22% is used for Permanent cultivation.

Table 12-13 Land Use of the Related Sub-district

District	Upazila	Land Use Area (Acre) as per Agriculture Census 2008					Potential sites	
		Operated Area (Total)	Permanent	Temporary	Perma.fallow	Others	PSPP	SSHP
Bandarban	Ruma	21,755	4,860	13,693	64	3,138	No.10, No.14	J39, J61
	Ali Kadam	14,932	3,052	9,908	159	1,813	-	J17, J23
	Lama	39,510	14,652	14,182	1,357	9,319	-	J31
	Rawangchhari	19,613	5,358	8,829	30	5,396	-	J34, J66
	Thanchi	9,806	2,037	7,220	15	534	No.12, No.13, No.15, No.16, No.17	J42, J52, J53, J45, J47
Rangamati	Barkal	32,496	10,256	16,568	811	5,672	No.6	
Cox'Bazar	Ramu	34,172	1,873	23,949	189	8,161	-	J11, J14
Chittagong	Banshkhali	40,603	1,161	24,835	165	1,773	-	J7

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011



Source: JICA Survey Team

Figure 12-20 Land Use around the Potential Sites

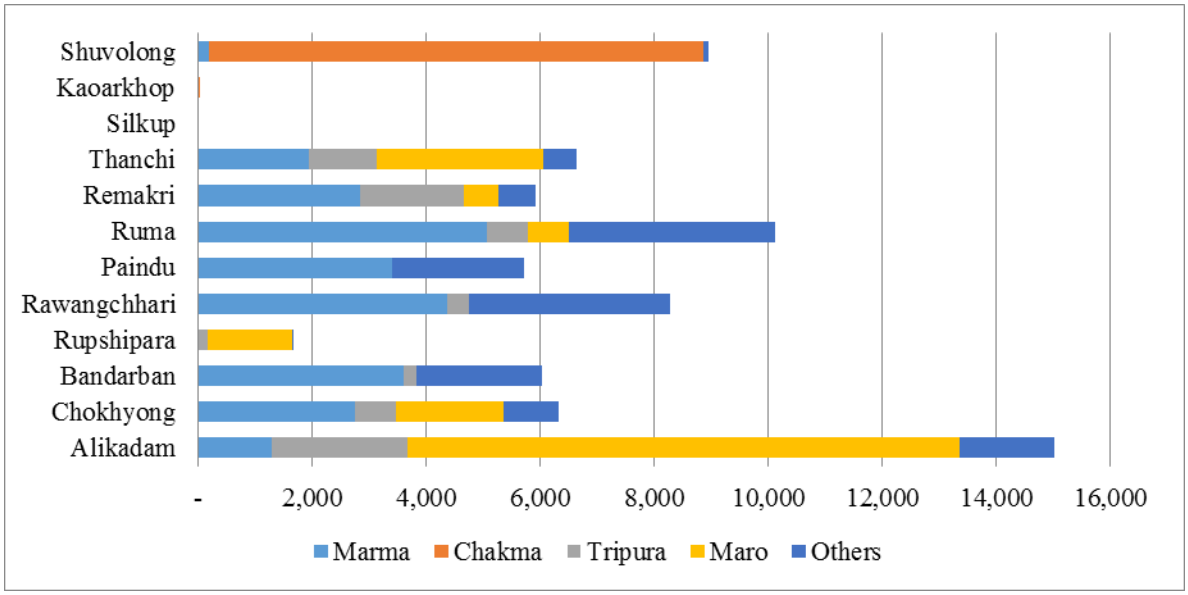
(e) Ethnic minorities and religions

According to the population census (2011) there are 27 indigenous tribes in Bangladesh. They are mainly living in Chittagong Hill Tracts (CHT), Sylhet Division, Rajshahi Division, and Mymensingh District. Majority of Shuvolong Union where No.6 locates are Chakma. Marma is relatively high rate in Bandarban District. Maro is dominated in Alikadam Union where the potential sites of J17 and J23 (See Table 12-14 and Figure 12-21) are located.

Table 12-14 Ethnicity around the Potential Site

Administrative section			Ethnicity						Potential Sites	
District	Upazila	Union/Mouza	Marma	Chakma	Tripura	Maro	Others	Total	PSPP	SSHP
Bandarban	Alikadam	Alikadam	1,286	-	2,374	9,702	1,654	15,016	-	J17, J23
		Chokhyong	2,760	-	705	1,897	949	6,311	No.18	J12, J13
	Bandarban	Bandarban	3,606	-	220	-	2,212	6,038	-	J33
	Lama	Rupshipara	-	-	175	1,469	25	1,669	-	J31
	Rawangchhari	Rawangchhari	4,361	-	395	-	3,517	8,273	-	J34, J66
	Ruma	Paindu	3,402	-	-	4	2,301	5,707	No.10	
		Ruma	5,066	-	714	719	3,609	10,108	No.14	J39, J61
	Thanchi	Remakri	2,835	-	1,822	599	670	5,926	No.15, No.16, No.17	J45, J47
		Thanchi	1,938	-	1,191	2,914	599	6,642	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	-	-	-	-	-	-	-	J7
Cox's Bazar	Ramu	Kaoarkhop	-	7	-	-	-	7	-	J11, J14
Rangamati	Barkal	Shuvolong	182	8,670	-	-	95	8,947	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011



Source: JICA Survey Team

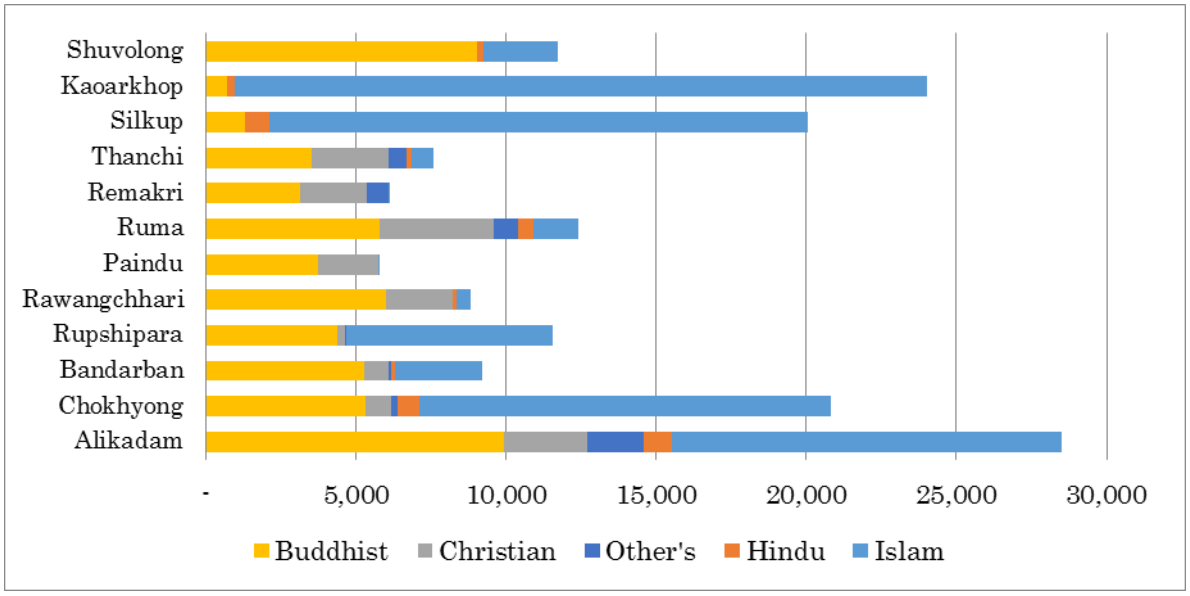
Figure 12-21 Ethnicity around the Potential Sites

According to the population census (2011) more than four religions are confirmed on the hill area. Buddhists are relatively high in Bandarban District. Some villages such as Kaoarkhop, Chokhyong are dominated by Islam as shown in Table 12-15 and Figure 12-22.

Table 12-15 Religions around the Potential Site

Administrative section			Popula-tion	Religion					Potential Sites	
District	Upazila	Union/ Mouza		Islam	Hindu	Christian	Buddhist	Other's	PSPP	SSHP
Bandarban	Alikadam	Alikadam	28,495	12,973	939	2,812	9,912	1,859	-	J17, J23
		Chokhyong	20,822	13,707	716	845	5,321	233	No.18	J12, J13
	Bandarban	Bandarban	9,219	2,921	130	824	5,271	73	-	J33
	Lama	Rupshipara	11,565	6,864	15	259	4,361	66	-	J31
	Rawangchhari	Rawangchhari	8,804	460	118	2,202	6,016	8	-	J34, J66
	Ruma	Paindu	5,803	74	-	1,983	3,746	-	No.10	
		Ruma	12,417	1,520	491	3,813	5,779	814	No.14	J39, J61
	Thanchi	Remakri	6,119	22	1	2,260	3,123	713	No.15, No.16, No.17	J45, J47
		Thanchi	7,599	746	163	2,558	3,537	595	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	20,043	17,938	795	0	1,310	0	-	J7
Cox's Bazar	Ramu	Kaoarkhop	24,004	23,023	256	-	725	-	-	J11, J14
Rangamati	Barkal	Shuvolong	11,728	2,492	201	1	9,033	1	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

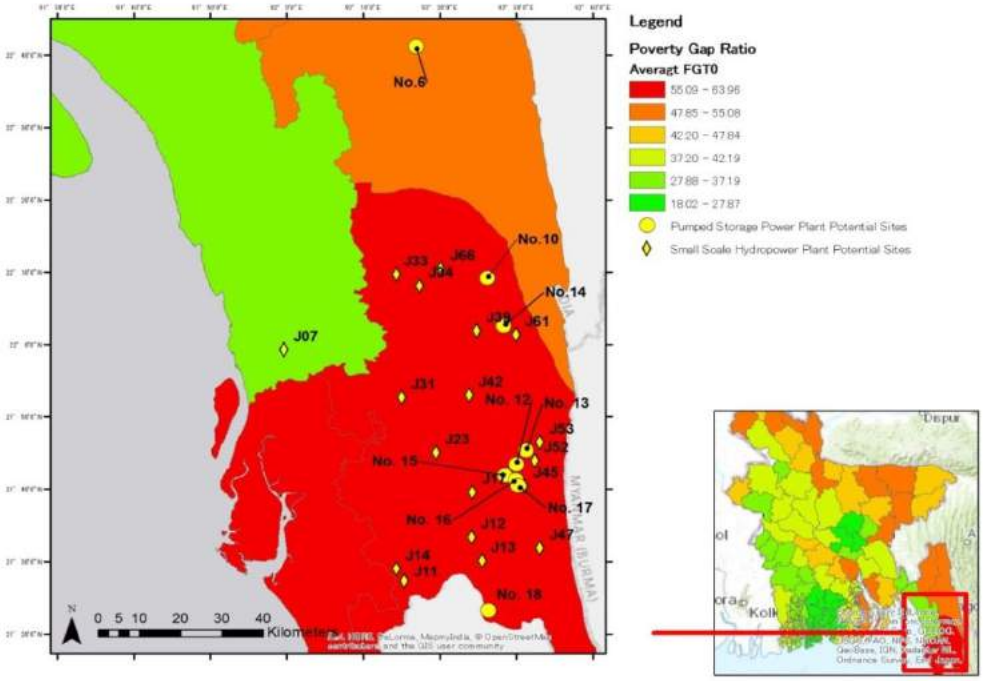


Source: JICA Survey Team

Figure 12-22 Religions around the Potential Sites

(f) Poverty and literacy rate

Poverty gap index (the average poverty gap in the population as a proportion of the poverty line) by District shows that the poverty in Eastern area and Northern area is relatively lower than the other areas as shown in Figure 12-23. The Hydropower potential sites are the most poverty area among these areas.



Source: Feature Service, 2014

Figure 12-23 Poverty Gap Index around the Hydropower Potential Sites

Literacy rate around potential sites are lower than 50%. Literacy rate of Remakri Union/Mouza where No.15m No.16 and No.17 located is 0.00%.

Table 12-16 Literacy Rate around the Potential Sites

Administrative section			Population	Literacy	Potential sites	
District	Upazila	Union/Mouza			PSPP	SSHP
Bandarban	Alikadam	Alikadam	28,495	30.50%	-	J17, J23
		Chokhyong	20,822	32.40%	No.18	J12, J13
	Bandarban	Bandarban	9,219	38.30%	-	J33
	Lama	Rupshipara	11,565	25.80%	-	J31
	Rawangchhari	Rawangchhari	8,804	31.00%	-	J34, J66
	Ruma	Paindu	5,803	21.00%	No.10	
		Ruma	12,417	28.90%	No.14	J39, J61
	Thanchi	Remakri	6,119	0.00%	No.15, No.16, No.17	J45, J47
		Thanchi	7,599	26.09%	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	20,043	34.6%	-	J7
Cox's Bazar	Ramu	Kaoarkhop	24,004	33.70%	-	J11, J14
Rangamati	Barkal	Shuvolong	11,728	48.60%	No.6	

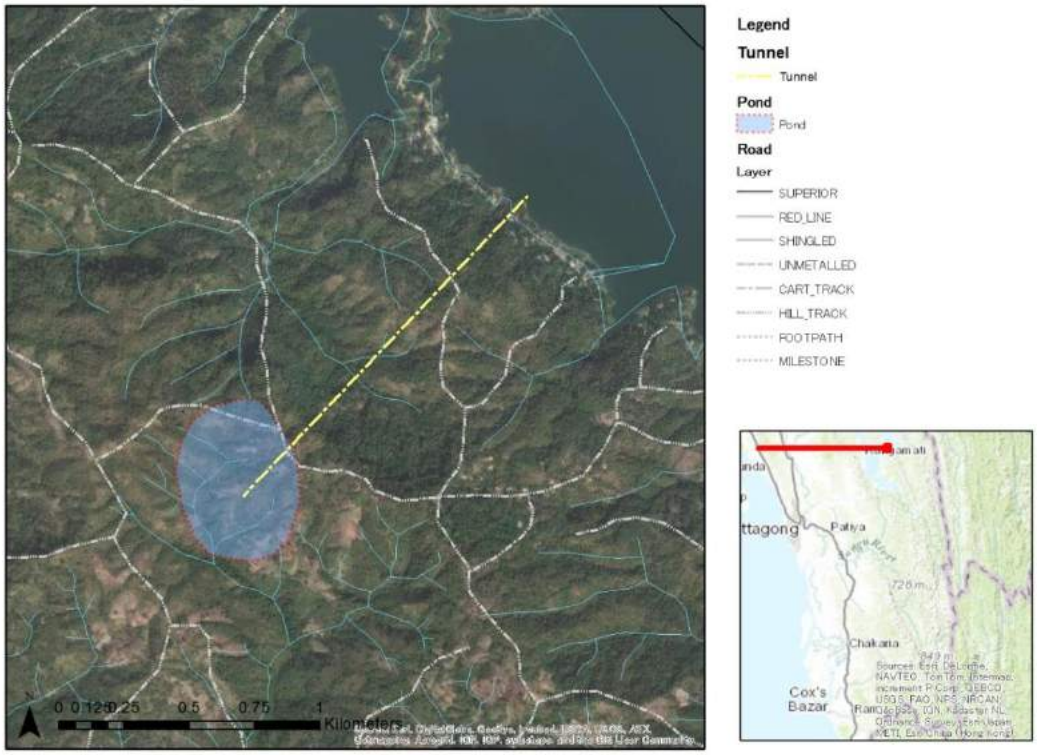
Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

12.7.2 Environmental and social impacts anticipated by project

(1) PSPP potential sites

(a) PSPP No.6

PSPP No.6 is located in Shuvolong village, Barkal sub-district, Rangamati district. Reservoir area is 21.4 ha. Some houses are confirmed at the end of water way. Farm land and Forests are seen in the reservoir area. No big house but small huts can be seen on the image. Relatively good forests are remained at the waterway route. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma and Chakma might be affected by the project.



Source: JICA Survey Team

Figure 12-24 PSPP No.6

Table 12-17 Feature of PSPP No.6

Items	Value
Effective Head (m)	176
Designed Discharge (m^3/s)	330
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	230
LWL of Lower Reservoir (m)	33
Effective Reservoir Volume (m^3)	8,400,000
Length of Waterway (m)	1,640
L/H	8.8

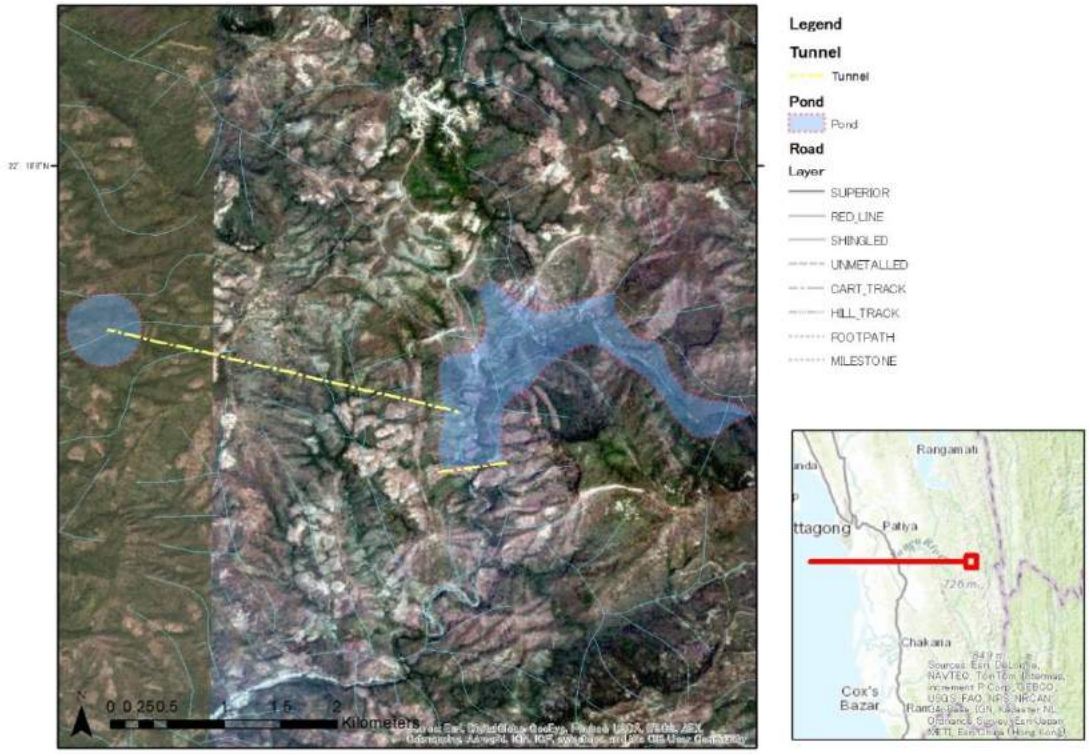


View of PSPP No. 6

Source: JICA Survey Team

(b) PSPP No.10

PSPP No.10 is located in Paindu village, Ruma sub-district, Bandarban district. Upper pond area is around 33.2 ha and Lower pond is 155.8 ha. No big house but small huts can be seen on the image. Forest coverage would be around 70%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-25 PSPP No.10

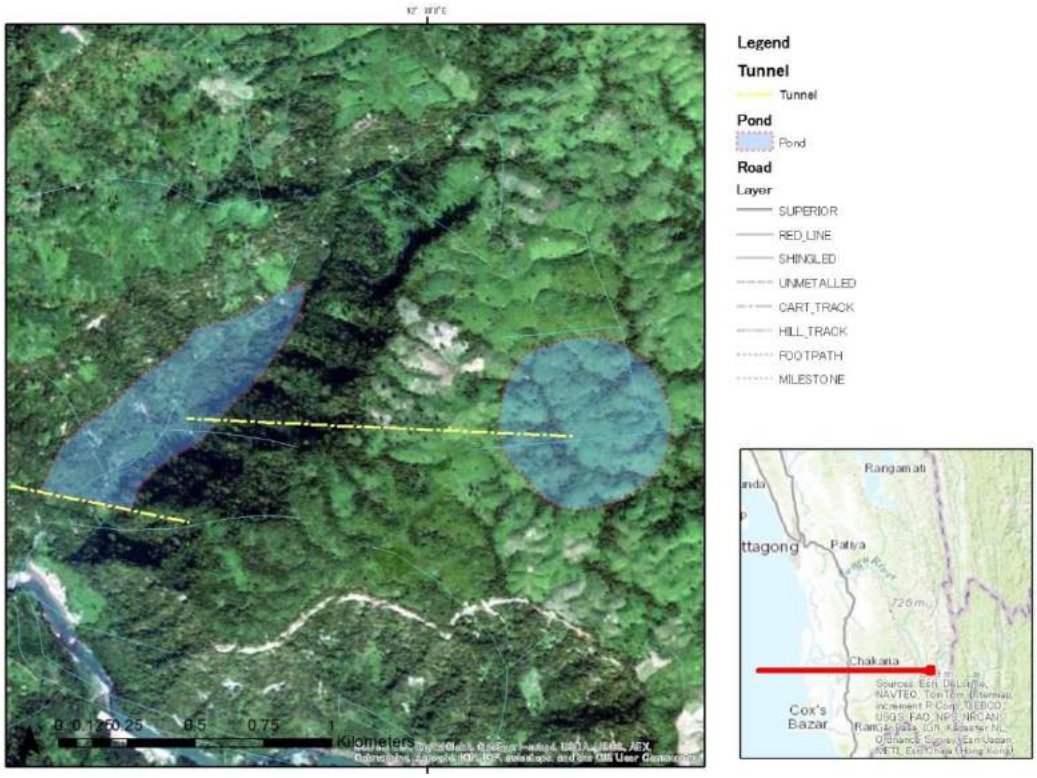
Table 12-18 Feature of PSPP No. 10

Items	Value
Effective Head (m)	185
Designed Discharge (m^3/s)	313
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	360
LWL of Lower Reservoir (m)	143
Effective Reservoir Volume (m^3)	9,400,000
Length of Waterway (m)	2,990
L/H	15.2

Source: JICA Survey Team

(c) PSPP No.12

PSPP No.12 is located in Thanchi village, Thanchi sub-district, Bandarban district. Area of upper pond is 29.2 ha and lower pond is 27.7 ha. No big house is confirmed. Small huts can be seen on the satellite image. Relatively good conserved forests are remained around the lower pond. Forest coverage would be around 60%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-26 PSPP No.12

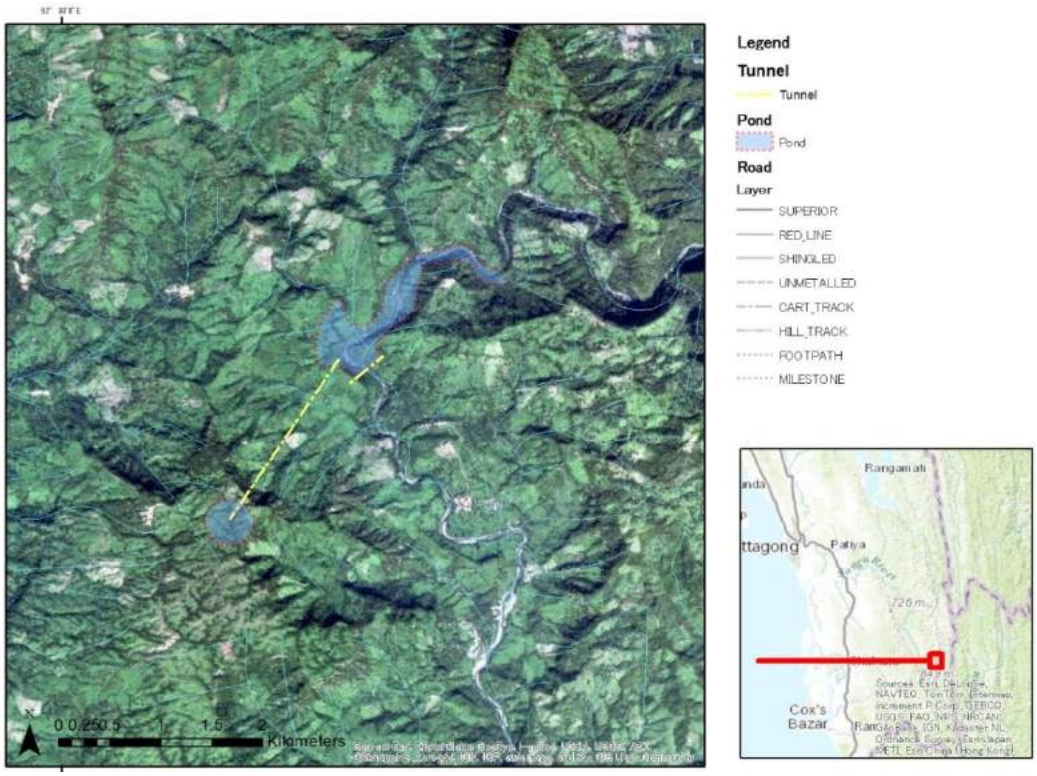
Table 12-19 Feature of PSPP No.12

Items	Value
Effective Head (m)	186
Designed Discharge (m^3/s)	312
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	340
LWL of Lower Reservoir (m)	122
Effective Reservoir Volume (m^3)	7,500,000
Length of Waterway (m)	1,330
L/H	6.7

Source: JICA Survey Team

(d) PSPP No.13

PSPP No.13 is located in Thanchi village, Thanchi sub-district, Bandarban district. Upper pond area is 15.8 ha and Lower pond area is 57.2 ha. No house but small huts are seen on the image. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-27 PSPP No.13

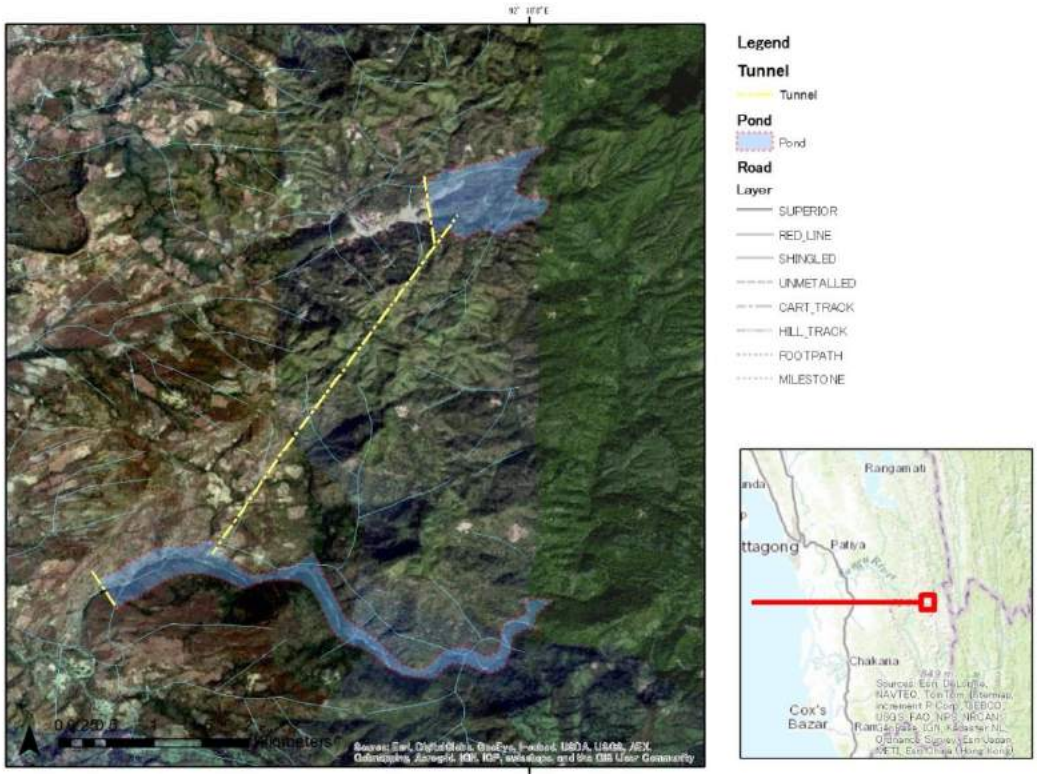
Table 12-20 Feature of PSPP No.13

Items	Value
Effective Head (m)	329
Designed Discharge (m^3/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	480
LWL of Lower Reservoir (m)	130
Effective Reservoir Volume (m^3)	4,500,000
Length of Waterway (m)	1,890
L/H	5.4

Source: JICA Survey Team

(e) PSPP No.14

PSPP No.14 is located in Ruma village, Ruma sub-district, Bandarban district. Upper pond area is 74.9 ha and lower pond area is 11.4 ha. No house and hut can be seen on the image. Forest coverage is around 70%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-28 PSPP No.14

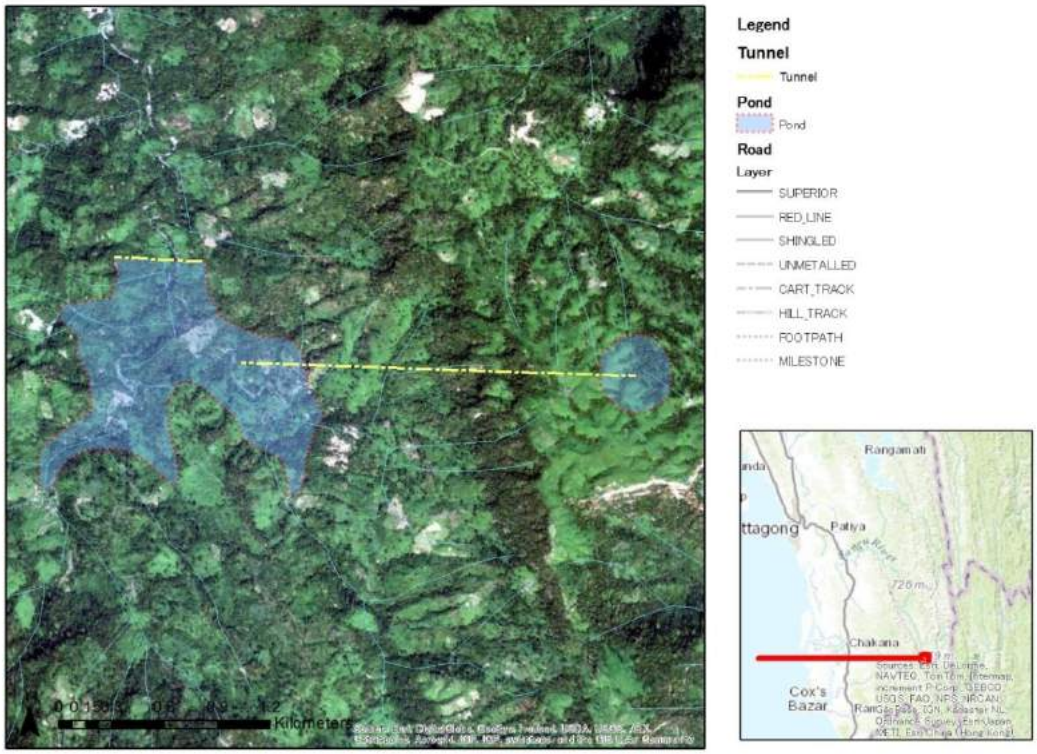
Table 12-21 Feature of PSPP No.14

Items	Value
Effective Head (m)	329
Designed Discharge (m^3/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	530
LWL of Lower Reservoir (m)	160
Effective Reservoir Volume (m^3)	4,500,000
Length of Waterway (m)	4,280
L/H	12.2

Source: JICA Survey Team

(f) PSPP No.15

PSPP No.15 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond is 13.6 ha and Lower pond is 105.5 ha. Five houses can be seen on the image. Forest coverage is around 50%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (T*rachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-29 PSPP No.15

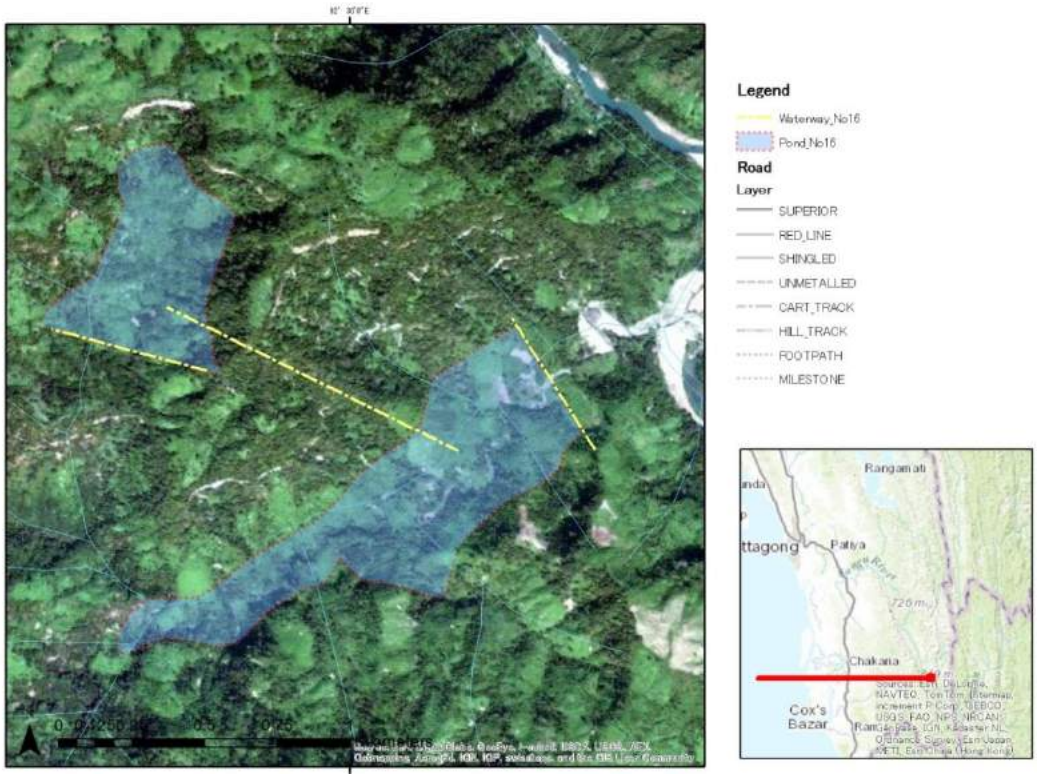
Table 12-22 Feature of PSPP No.15

Items	Value
Effective Head (m)	369
Designed Discharge (m^3/s)	157
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	540
LWL of Lower Reservoir (m)	127
Effective Reservoir Volume (m^3)	4,000,000
Length of Waterway (m)	2,100
L/H	5.3

Source: JICA Survey Team

(g) PSPP No.16

PSPP No.16 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond area is 26.5 ha and Lower pond area is 51.1 ha. No house but some huts can be seen on the image. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-30 PSPP No.16

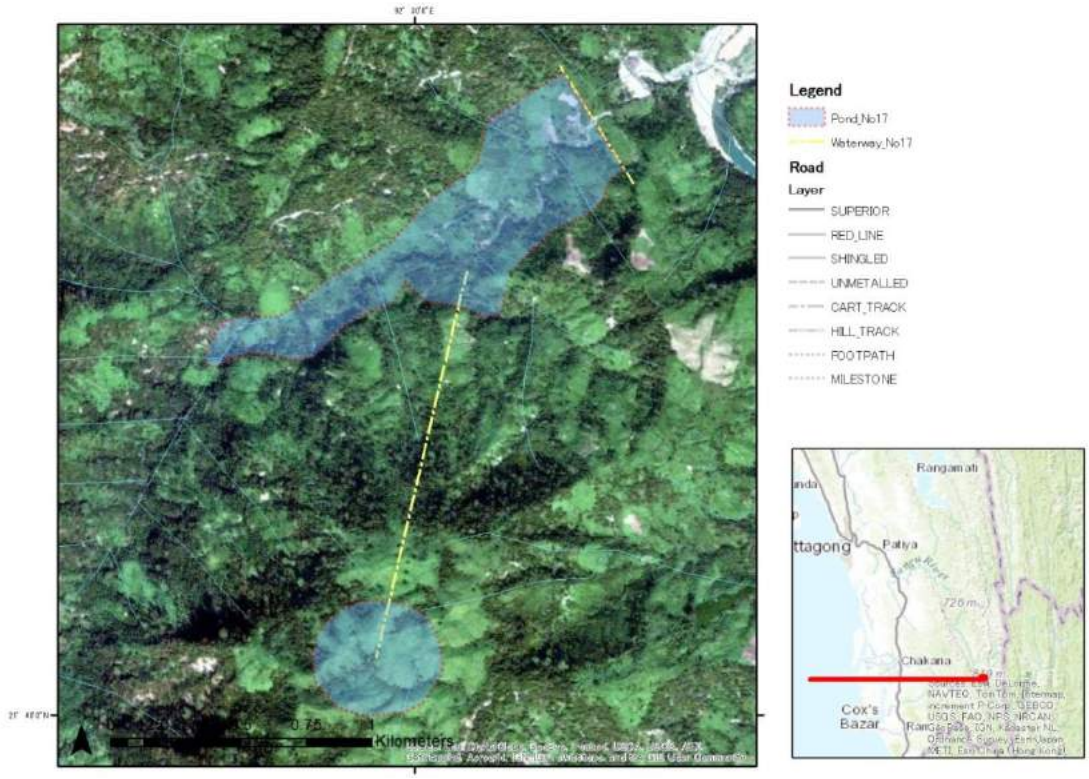
Table 12-23 Feature of PSPP No.16

Items	Value
Effective Head (m)	248
Designed Discharge (m^3/s)	234
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	395
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m^3)	5,900,000
Length of Waterway (m)	1,060
L/H	4.0

Source: JICA Survey Team

(h) PSPP No.17

PSPP No.17 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond is 15.1 ha and Lower pond is 16.4 ha. No house and hut can be seen on the image. Forest coverage is around 30%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-31 PSPP No.17

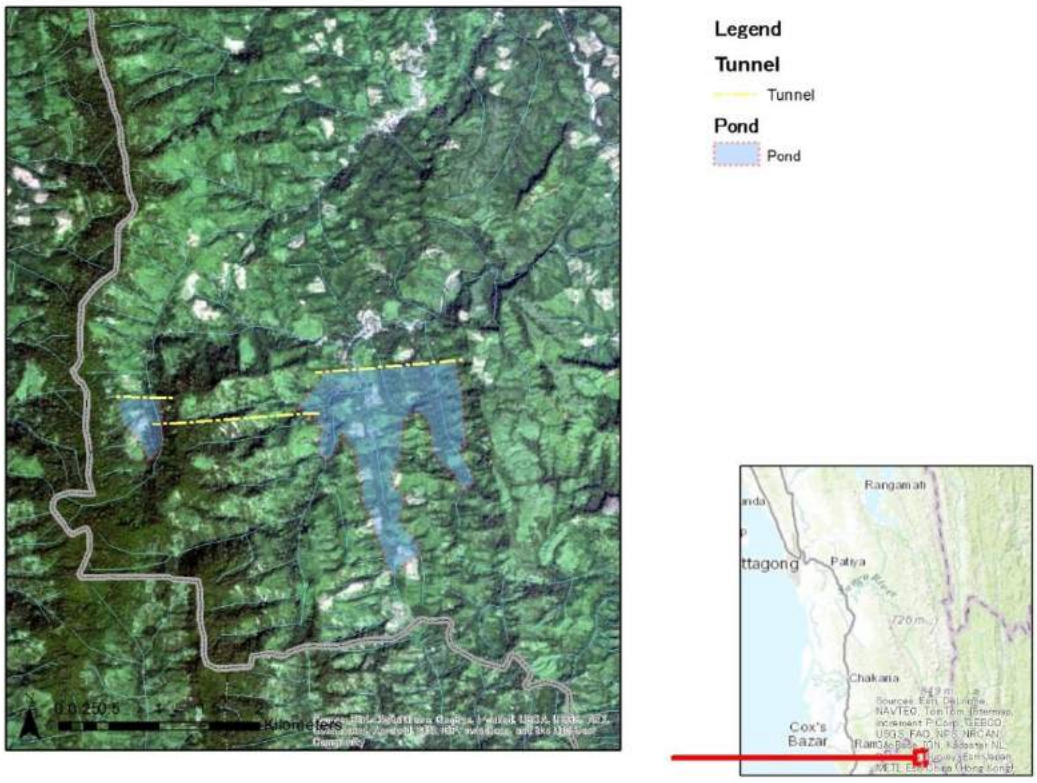
Table 12-24 Feature of PSPP No.17

Items	Value
Effective Head (m)	361
Designed Discharge (m^3/s)	161
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	520
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m^3)	8,400,000
Length of Waterway (m)	1,520
L/H	4.0

Source: JICA Survey Team

(i) PSPP No.18

PSPP No.18 is located in Chokhyong village, Alikadam sub-district, Bandarban district. Upper pond is 18.3 ha and Lower pond is 153.6 ha. No house but small hut can be seen on the image. Forest coverage is around 80%. The part of the reservoir covers Forest reserve and all of the area is in the Sangu Matamuhari Key Biodiversity Area. The project sites cover the distribution areas of Endangered mammals such as Asian Elephant (*Elephas maximus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.



Source: JICA Survey Team

Figure 12-32 PSPP No.18

Table 12-25 Feature of PSPP No. 18

Items	Value
Effective Head (m)	249
Designed Discharge (m^3/s)	233
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	405
LWL of Lower Reservoir (m)	140
Effective Reservoir Volume (m^3)	5,900,000
Length of Waterway (m)	1,580
L/H	6.0

Source: JICA Survey Team

(2) Ordinary HP/SSHP potential sites

Environmental and social impact of eighteen potential SSHPs is briefly examined. Four of the project sites are located in the protected area. Most of the project sites are located in the distribution area of two or three endangered mammal species. One to five ethnic minority groups might be affected by each ordinary HP/SSHP project.

Table 12-26 Summary of Environmental Impact of SSHPs

SSHP	River	Governorate			Protected Area	No. of affected Endangered Mammals	No. of Ethnic minority groups
		District	Upazila	Union/Mouza			
J07	Banshkhali	Chittagong	Banshkhali	Silkup	Chunati Wildlife Sanctuary	2	0
J11	Bakkhali	Cox's Bazar	Ramu	Kaoarkhop		2	1
J12	Matamuhuri	Bandarban	Alikadam	Chokhyong	Forest reserve, KBA	2	3
J13	Matamuhuri	Bandarban	Alikadam	Chokhyong	Forest reserve, KBA	2	3
J14	Bakkhali	Cox's Bazar	Ramu	Kaoarkhop		2	1
J17	Matamuhuri	Bandarban	Alikadam	Alikadam		2	3
J23	Matamuhuri	Bandarban	Alikadam	Alikadam		2	3
J31	Matamuhuri	Bandarban	Lama	Rupshipara		2	2
J33	Sangu	Bandarban	Bandarban	Bandarban		2	2
J34	Sangu	Bandarban	Rawangchhari	Rawangchhari		2	2
J39	Sangu	Bandarban	Ruma	Ruma		3	3
J42	Sangu	Bandarban	Thanchi	Thanchi		2	3
J45	Sangu	Bandarban	Thanchi	Remakri		2	3
J47	Sangu	Bandarban	Thanchi	Remakri	Forest reserve, KBA	3	3
J52	Sangu	Bandarban	Thanchi	Thanchi		2	3
J53	Sangu	Bandarban	Thanchi	Thanchi		3	3
J61	Sangu	Bandarban	Ruma	Ruma		3	3
J66	Sangu	Bandarban	Rawangchhari	Rawangchhari		3	2

Source: JICA Survey Team

During the site reconnaissance, the JICA Survey Team was able to visit the locations near the five potential sites among 18 sites.

The projects of J33, J39, 42 are planned to hold back water on the Sangu main river by dams. Since many local people are living along the Sangu river, even a small dam may causes large scale of resettlement.



Houses along the Sangu river



Houses along the Sangu river

The project of J61 and J66 are located on the tributary of Sangu River. However, J61 project has too small water flow in dry season in comparison with the planned discharge. As for J66 project is located at the center of the town of Rowanchhari so that it causes large number of resettlement.



Upstream of J66 site



Downstream of J61 site

12.8 Summary of Hydropower Potential Study

12.8.1 PSPP potential sites

In general, preferable PSPP sites have smaller waterway length per gross head (L/H), less environmental and social impacts, shorter access road required and sufficient catchment area for lower reservoir as water source. And also, possibility of expansion of the scale is one of the advantages from viewpoints of economic efficiency in development.

Table 12-27 shows the comparison of PSPP potential sites based on the results of the literature survey and site reconnaissance. The JICA survey team selected PSPP No.17 as the best preferable potential site for the first PSPP project in Bangladesh, PSPP No.13 as the second potential site.

For realization of the projects, some difficulty exists during planning and designing stages. Maps available at this moment are only 1/50,000 maps with 100m contour lines. Those maps cannot be used even for conceptual design. And site reconnaissance and site survey is limited due to security reason in the Chittagong hilly area. In addition, during preparation stage for construction, implementing agency may encounter difficulty in acquisition and compensation of land due to local sentiment against hydropower development.

In this regard, the JICA Survey Team has a concern that immediate project implementation of the PSPP projects in Chittagong hilly area may be difficult.

12.8.2 Ordinary HP/SSHP Potential Sites

The JICA Survey Team was able to visit limited number of ordinary HPs during the site reconnaissance. However, the JICA Survey Team assumes that most of the potential sites along the Sangu main river may cause large scale of resettlement due to relatively gentle slope of the river. Though there are some prospective sites in terms of technical and economic viability, those sites may not be suitable sites for development in consideration of environmental and social impact aspects.

On the other hand, the potential sites on the tributaries of Sangu River are anticipated that they have limited water flow particularly in dry season. Thus, those sites seem not financially viable.

In this regard, those potential sites seem that they are not attractive for development of hydropower projects.

Table 12-27 Comparison of PSPP Potential Sites

Site No.		No.6	No. 10	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18
Upper Reservoir	Type	Artificial Pond	Artificial Pond	Artificial Pond	Artificial Pond	Ordinary	Artificial Pond	Ordinary	Artificial Pond	Ordenary
	Dam Height							80		80
	HWL	230	360	340	480	530	540	395	520	405
	NWL	220	350	330	470	520	530	390	510	395
	LWL	190	320	300	440	500	500	365	480	375
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Lower Reservoir	Type									
	Dam Height	–	70	80	70	70	60	70	70	70
	HWL	33	173	152	160	190	157	146	146	170
	NWL	33	153	132	120	170	137	126	126	130
	LWL	33	143	122	130	160	127	116	116	140
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Waterway	Length (L)	1640	2990	1330	1890	4280	2100	1060	1520	1580
	Diameter	8.4	8.2	8.1	6.1	6.1	5.8	7.0	5.8	7.0
	Length X Diameter	13,724	24,378	10,816	11,561	26,180	12,122	**7,466**	**8,876**	11,107
Gross Head	(H)	187.0	197.0	198.0	350.0	350.0	393.0	264.0	384.0	265.0
L/H		**8.8**	**15.2**	**6.7**	**5.4**	**12.2**	**5.3**	**4.0**	**4.0**	**6.0**
Net Head		175.8	185.2	186.1	329.0	329.0	369.4	248.2	361.0	249.1
Discharge		330	313	312	176	176	157	234	161	233
Installed Capacity	(Efficiency=88%)	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
Social Aspects	Resettlement	Several HH Local Sentimental	None	None	None	None	Several Ten HH	None	None	None
Natural Environmental Aspects	Pretected Area	–	–	–	–	–	–	–	–	Shangu-Matamuhuri Wildlife
Access to the Site		52km	24km	18km	30km	29km	15km	21km	21km	
Others		–	–	Too small CA	Expansion Possibility	–	–	No Expansion	Expansion Possibility	Small CA
Comprehensive Evaluation		E	E	D	B	E	D	C	A	E

*CA: Catchment Area

Evaluation Items

Source: JICA Survey Team

12.9 Recommendations for the Next Steps

12.9.1 Possibility of project implementation

The JICA Survey Team assumes that development of some potential sites of PSPP and ordinary HP listed above may be physically possible. However, it is also anticipated that some limitation may make the project implementation difficult during the next stages. Though maps are important for planning and designing stages, the currently available maps are only 1/50,000 maps with 100m contour lines. Those maps cannot be used even for conceptual design. And not only site reconnaissance but also site investigation will be limited due to security reason in the Chittagong hilly area for the moment.

In addition, in consideration of local sentiment against hydropower development in Chittagong hilly area, there is a risk that it may be difficult to obtain local consent about development of PSPPs and ordinary HPs in the area for the moment. Implementing agency may encounter the difficulty on acquisition of land for the projects.

In this regard, the JICA Survey Team has a concern that immediate implementation of hydropower projects in Chittagong hilly area may be difficult. Thus, Hydropower projects are not necessary to be listed in the reviewed PSMP2010.

12.9.2 Reference TOR for the future projects

If the difficulty such as peace and order issues and local sentiment against hydropower development is improved, the PSPP potential sites of PSPP No. 17 and No. 13 would become possible to be implemented at the scale of 500MW to 1,000MW.

As a next step of the project implementation, a feasibility study will be conducted. For reference, the general items of Terms of Reference (TOR) for the feasibility study for PSPP projects are shown in Table 12-28 and Table 12-29.

Table 12-28 TOR for Feasibility Study on PSPP Project (1)

Task 1. Background and Necessity of Pumped Storage Power Plants
- 1-1 Overview of the power development policy in Bangladesh
  - ・To confirm development policy of power facilities
  - ・To confirm position of PSPP in the above policy
- 1-2 Overview of power demand and supply balance, power development plan
  - ・To grasp power demand growth and situation of development of power facilities
  - ・To grasp power demand forecast and development plan of power facilities
- 1-3 Confirmation of the progress of power sector reform
  - ・To confirm action plan of establishment of Balancing Market
- 1-4 Overview of power market

Task 2. Necessity of PSPP projects
- 2-1 Evaluation of necessity and justification of introduction of PSPP projects
  - ・To examine requirements of kW and kWh (peak duration hours) from the power system
  - ・To simulate demand supply balance considering wind power development (capacity and operational status)
- 2-2 Examination of applicability of Adjustable Speed (AS)-PSPP
- 2-3 Validity of finaicial assistance
- 2-4 Optimization of development schedule and transmission connection plan
  - ・To optimize development schedule
  - ・To build transmission connection plan

Source: JICA Survey Team

Table 12-29 TOR for Feasibility Study on PSPP Project (2)

Task 3. Basic design
- 3-1 Hydrological, topographical and geological survey
  - ・To make plan and execute investigations based on the conceptual design
  - ・To carry out topographic survey, borehole drilling, reconnaissance, seismic prospecting, sonic prospecting, laboratory tests
  - ・To install gauging station and measure hydrological and meteorological data
- 3-2 Comparative study on alternatives
  - ・To select location of the upper and lower ponds
  - ・To select types of dams and ponds
  - ・To determine location of powerhouse site and waterway route
  - ・To review the optimal development scale
- 3-3 Basic design of civil structure and steel structure
  - ・To execute basic design of civil structure and steel structures
  - ・To execute basic design of waterway and underground powerhouse
- 3-4 Basic design of electro-mechanical equipment
  - ・To design pump-turbines and motor-generators, including AS system
  - ・To review facilities of switch yard based on transmitting plan such as composition of GSI, layout, yard area
  - ・To review design of main circuit of low voltage, cable, GIS and earthing
- 3-5 Basic design of transmission lines
  - ・To conduct system analysis
  - ・To design transmission method and monitoring control method
- 3-6 Evaluation on the possible application of new technologies

Task 4. Overall Project Implementation Plan
- 4-1 Construction planning
- 4-2 Consulting services
- 4-3 Procurement method and package
- 4-4 Implementation plan
- 4-5 Cost estimation

Task 5. Environmental and Social Considerations
- 5-1 Related laws and regulations, system and organizations
- 5-2 Scoping
- 5-3 Environmental and Social Survey
- 5-4 Support for holding public consultation
- 5-5 Preparation of EIA report
- 5-6 Preparation of Abbreviated Resettlement Action Plan
- 5-7 Preparation of environment management plan and monitoring plan
- 5-8 Technical support and advice to Implementing Agency

Task 6. Project Implementation Structure and Operation and Maintenance Structure
- 6-1 Project Implementation Structure
- 6-2 Operation and Maintenance Structure
- 6-3 Considerations regarding Project Implementation and Operation & Maintenance

Task 7. Evaluation of the Project
- 7-1 Economic and Financial Analysis
- 7-2 Risk Analysis
- 7-3 Index of Operation Efficiency
- 7-4 Necessity of Technical Support

Task 8. Technical Transfer

Source: JICA Survey Team

Chapter 13 Renewable Energy

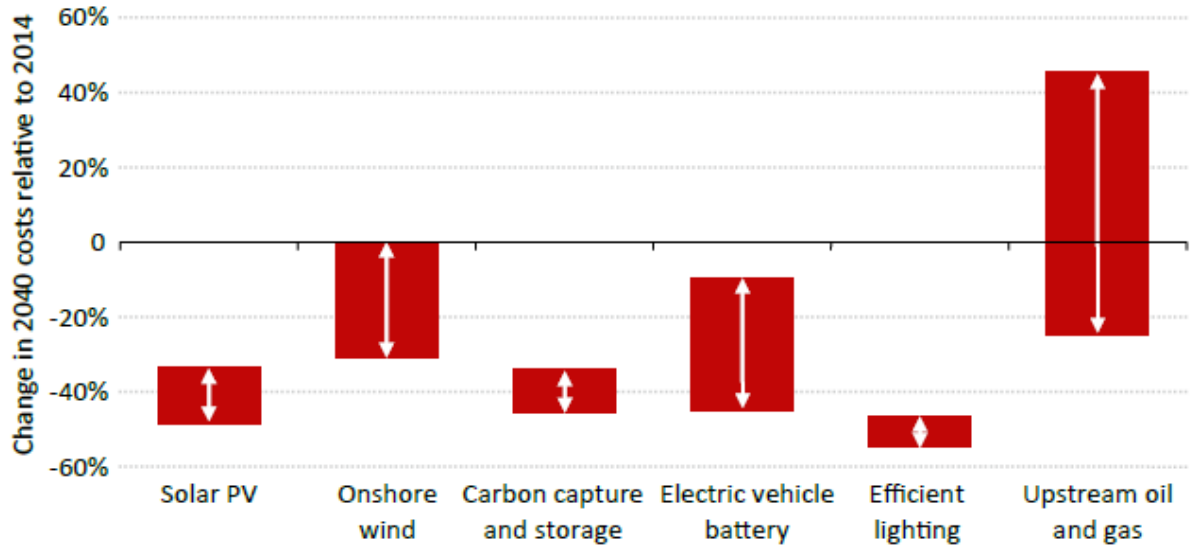
13.1 Environments around Renewable Energy[47]

13.1.1 World trend

As described in Chapter 3, the international community has committed to achieve “Affordable and clean energy - ensure access to affordable, reliable, sustainable and modern energy for all" by 2030. In addition, population and economic growth will lead to the 30% more energy consumption in the world (out of this, India will take one fourth of this additional energy consumption. This energy consumption estimate already includes population decrease in high-income countries and energy consumption decrease by energy efficiency improvement).

These circumstances have promoted the importance of renewable energy technologies ever before, as the solution to materialize economic growth, energy access improvement and the reduction of greenhouse gas emission altogether. IEA estimates that the share of “modern renewable energy” (excluding traditional solid biomass) in the world total energy demand will increase from 14% in 2014 to 19% in 2040 (in 2040, world renewable energy will take up one third out of total electricity generation, one six of thermal source, and 8% out of total fuel for the transport sector).

The cost reduction of renewable energy technologies, and the cost increase of the conventional oil and gas development and production also contributes to the dissemination of renewable energy. While the renewable energy cost reduction and technology dissemination remain uncertain, the remaining oil and gas development diggings would face more technical challenges and therefore P&D cost for gas and oil will increase with certainty.



Source: IEA World Energy Outlook 2015, Figure 1.3

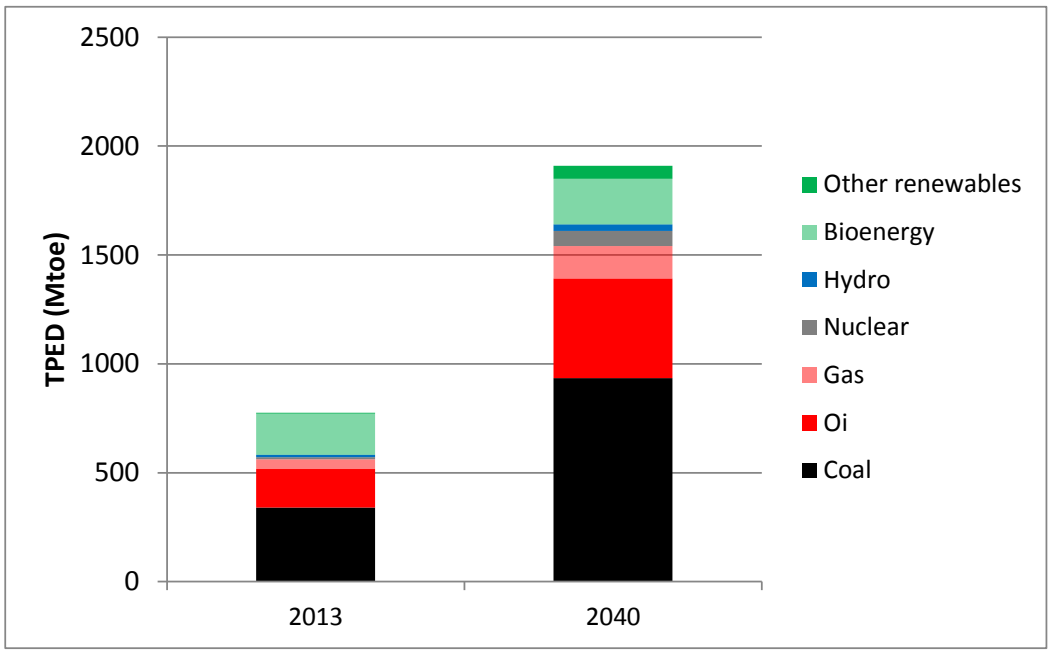
Figure 13-1 Evolution of Energy Technology Costs per Unit in the New Policies Scenario, 2014-2040

[47] IEA, World Energy Outlook, 2015、and IEA Mid-Term Market Report Renewable Energy 2015. In this IEA Report, the word “renewable energy”, if without specific note, includes hydro power (regardless of the size), wind, geothermal, solar PV, solar thermal, and tidal power, and solid biomass such as firewood or cow dung.

13.1.2 Renewable energy in India

India's energy demand has sharply increase and has become double since 2000. Especially the household energy demand has shifted from traditional solid biomass to natural gas or LPG, and the dependency on fossil fuel has deepened.

As of 2013, more than 40% of India's total primary energy demand (TPED) comes from coal, while it was 30% in 2000. Thus the dependency on coal has expanded. It is projected that the 50% of the India's TPES will come from coal in 2040.



Source: JICA Survey team, based on the IEA World Energy Outlook 2015, Annexes India: New Policy Scenario

Figure 13-2 India's TPED Breakdown, 2013 (actual) and 2040 (projection)

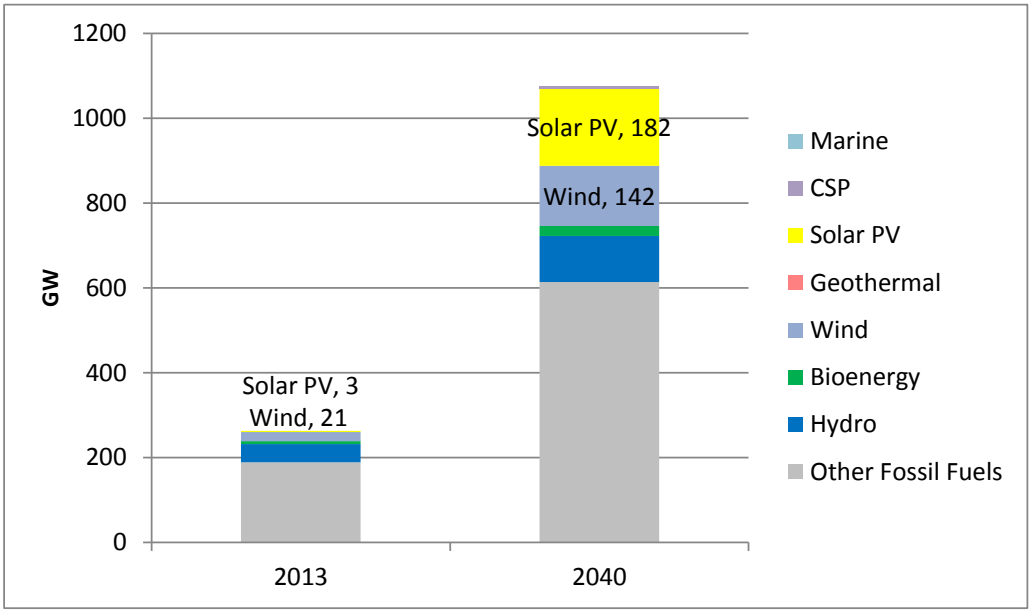
At the same time, India intends to strengthen its stable energy supply and energy security by actively enlarging renewable energy. In power generation, India plans to develop renewable energy power generations about half of the newly added capacity (MW) by 2040 (see Figure 13-2).

Especially the solar PV generation is considered as the center of the renewable energy deployment in India, where India assumes 3% of its lands are wasteland in each state and can be utilized for utility-scale solar, totaling 750GW. India has launched its national plan, Jawaharlal Nehru National Solar Mission Phase 1 since 2010, and plans to deploy 100GW by 2022 (however, IEA assess that 40GW is the realistic target by 2022, considering many impediments such as finance, solar power purchase by electric companies, land acquisition and transmission line capacity limit[48]).

India's solar PV flagship project is located in Gujarat. Gujarat state administration stipulated the solar PV deployment policy in 2009. This policy includes "exemptions for electricity duties, streamlined the land acquisition process, guaranteed evacuation of power by the Gujarat Energy Transmission Corporation, ensured that no cross-subsidy charges were levied for access within the state and guaranteed tariffs for 25 years. The 500 MW Charanka solar park in Patan – one of the largest in the world –is a notable outcome[49]".

[48] IEA WEO (2015) ibid. p.498, Box "Spotlight"
[49] IEA WEO (2015) ibid. p.535, Box 13.4

The Charanka solar park is participated by many solar PV generation companies, and ADB supported the initial feasibility study in 2004.



Source: JICA Survey team, based on the IEA World Energy Outlook 2015, Annexes India: New Policy Scenario

Figure 13-3 India's Power Generation Development (GW)

13.2 Government Policy for Renewable Energy

13.2.1 Government policy and definition

For Bangladesh, renewable energy deployment has been important to diversify energy source, and to complement on-grid rural electrification. In addition, as a low-lying land country and surrounded by the three great rivers, Bangladesh is one of the most vulnerable countries to the sea level raise. Hence renewable energy deployment is critical as climate change mitigation for Bangladesh.
MoPEMR established Renewable Energy Policy in 2008, and defined its goal as renewable energy share 5% of the total installed capacity (MW) by 2015, and 10% by 2020. According to SREDA website, the Bangladesh's total installed capacity is projected to be 13,000MW in 2015 and the renewable energy capacity 650MW by then.

Bangladesh's renewable energy target is defined as follows:

By 2015, 5% out of total generation capacity:

$$\frac{Installed\ renewable\ energy\ capacity\ (MW)\ at\ 2015}{Installed\ all\ generation\ capacity\ (MW)\ at\ 2015} \geq 5\%$$

By 2020, 10% out of total generation capacity:

$$\frac{Installed\ renewable\ energy\ capacity\ (MW)\ at\ 2020}{Installed\ all\ generation\ capacity\ (MW)\ at\ 2020} \geq 10\%$$

As seen in the Table 13-1 , Bangladesh has currently 432 MW installed renewable energy capacity. PSMP2016 projects the total installed generation capacity to be about 21,600MW in 2020, and as seen

in the Table 13-2 , the total government plan for additional renewable energy generation deployment to be 3,168 MW, which makes the cumulative capacity:3,600MW. This means that if the government actually implements the renewable energy generation as it plans, the policy target (10% renewable in 2020) would be achieved.

Table 13-1 Installed Renewable Energy Capacity (as of April 2016)

Unit: MW

RE Technology	Off-Grid	On-Grid	Total
Solar	193	1	194
Wind	1	0.9	1.9
Biomass to Electricity	1	0	1
Biogas to Electricity	5	0	5
Hydro	0	230	230
Total	200	232	432

Source: SREDA

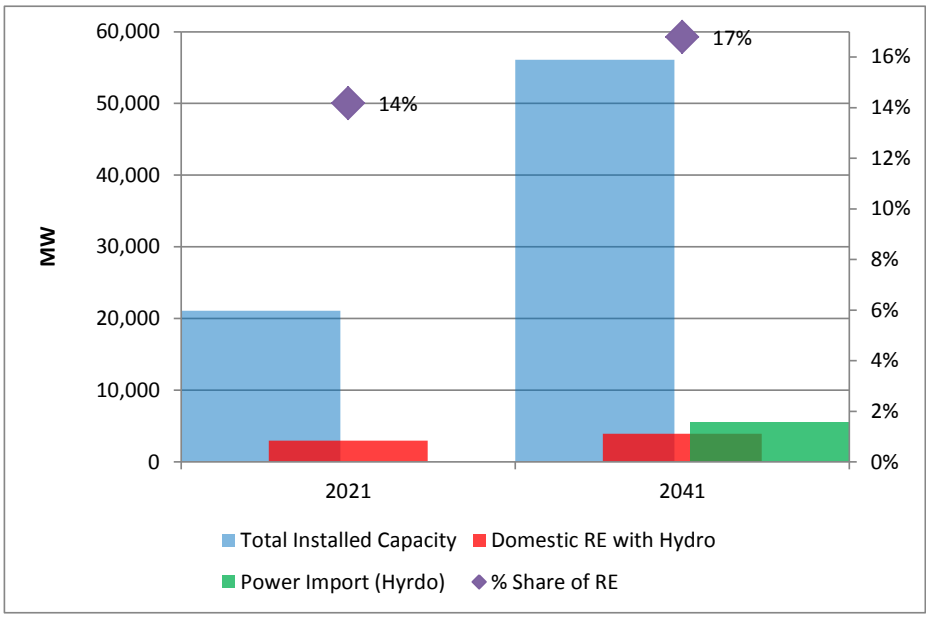
Table 13-2 SREDA Renewable Energy Year-Wise Targeted Plan (Only additions, not cumulative)

RE Technology	2015	2016	2017	2018	2019	2020	2021	Total
Solar	222	253	421.75	237	195	203	208	1739.8
Wind	0	20	250	350	350	200	200	1370
Biomass	1	16	6	6	6	6	6	47
Biogas	1	1	1	1	1	1	1	7
Hydro	0	2	2	0	0	0	0	4
Total	224	292	680.75	594	552	410	415	3167.8

Source: SREDA

Beyond 2020, GoB intends to extend the 10% renewable target by 2041, though not stipulated in the existing policy[50]. In the latest power development plan, Bangladesh will have more than 56,000 MW in 2041. To meet the 10% target, Bangladesh will need to install 5600 MW renewable energy. As described in the later section, Bangladesh may have difficulty to meet this target its domestic (within its boundary) renewable potential. However, if cross-border power import from hydro power generation is counted as hydropower, Bangladesh could have in total more than 9,000 MW (some 4,000 MW from domestic renewable, and 5,000 MW from cross-border hydropower) and easily meet the policy target, as seen in the Figure 13-4 .

[50] Interview with SREDA, June 2016.



Source: JICA Survey Team

Figure 13-4 Share of Renewable Energy Projection

It should be noted, however, that specifically regarding the variable renewable energy power generation, discussion of installed capacity does not mean much to meet the actual demand, especially given the current Bangladesh's daytime peak and technical limits[51]. This topic is further elaborated in the section 13.6 .

13.2.2 Renewable energy promotion policy and regulation

In Bangladesh, renewable energy deployment has been heavily concentrated on micro-scale off-grid SHS, except for the Kaptai Hydropower plant. However, Bangladesh is planning to deploy utility-scale (mega) solar power and wind power, accompanied with promotion policy and regulation. The current status and policy is well documented in SREDA's "Scaling Up Renewable Energy in Low Income Countries (SREP), Investment Plan for Bangladesh (October 2015)", supported by World Bank.

According to this SREDA document, utility-scale solar and wind projects will have following model and power purchase pricing mechanism:

Table 13-3 RE Project Models and Power Purchase Pricing Mechanism Plan

No.	Development Pattern (Project + Land Ownership)	Power Purchase Pricing Mechanism
1	Government Investment on Public Land	N/A
2	Private Investment (IPP) on Public Land	Auction
3	Private Investment (IPP) on Private Land	Fixed tariff for 20 years to cover levelized cost (through negotiation)

Source: SREDA Scaling Up Renewable Energy in Low Income Countries (SREP), Investment Plan for Bangladesh (October 2015)

[51] Because battery and related technologies are still uncertain at this moment, they are not factored in to the capacity projection of this Survey.

It should be noted that the FIT (feed-in-tariff), currently drafted by BERC, would be considered for those utility-scale renewable generations, but mainly for small generation or micro-grid generation. This is based on the recognition that, even though Bangladesh has decent track record for renewable deployment, it is heavily SHS-focused and not grid-connected utility-scale generations, and it would be difficult for Bangladesh to set a "proper" pricing for power purchasing from utility-scale renewable generations in the early stage.

Moreover, it is also recognized that the absence of transparent competitive bidding process has hindered the private investment for utility-scale renewable generation. Therefore, IPP's participation and pricing through transparent process is the most prioritized action for utility-scale renewable generation deployment. In December 2015, GoB achieved the closing of the Jamalpur IPP 3MW solar park project, and successfully set the tariff at 18.7 Tk/kWh. Other private-owned projects are expected to follow.
On the other hand, Bangladesh has also regulation on land usage for utility-scale solar PV. As discussed in detail later in this Chapter, utility-scale solar PV requires a vast area land. The government stipulates the policy prohibiting private projects from using agriculture or cultivable land for a utility-scale solar PV project. According to the SREDA document mentioned above, utility-scale solar PV potential becomes only 1400MW with this land-usage regulation, while 19,000MW would be possible without such regulation. However, it is appropriate for the government to take up this regulation, considering the food security for the increasing population, as well as the potential of agri-business in the future economic growth discussed in the Chapter 5. If GoB wishes to pursue further potential of solar park, it should be well reminded that pursuing the solar park potential is the trade-off of the food security and employment opportunity in rural areas.
Other incentives to be provided for renewable energy projects are listed below. Most of them are financial/accounting incentives:

- Fiscal Incentives for project investors and operators.
- Import Duty Exemption (Full/ Partial) for certain technology and equipment.
- Duty exemption for 16 items of solar panel [SRO No. 100- Law/2000/1832/Duty, Date-18/04/ 2000].
- Plants & equipments [full value] & spare parts [10% of original plant cost] without payment of customs duties, VAT & any other surcharges.
- Exemption from corporate income tax for 10 years.
- Tax exemption & repatriation facilities on royalties & technical assistance fees.
- Repatriation of equity along with dividends.
- Avoidance of double-taxation on the basis of bilateral agreements.
- Implementation Agreement [IA] & PPA ensure fair and reasonable risk allocation and payment by the purchaser is guaranteed by the GoB.
- Special Act for processing project proposals.

13.3 Organization for Renewable Energy Deployment

Governmental organizations for renewable energy promotion are, mainly SREDA, IDCOL, BREB and BPDB, which are implementing solar PV projects. The details of these organizations are described in Chapter 2.

"Partner Organizations" or POs, are non-governmental organizations working under IDCOL program. They are actually setting up renewable energy generation facilities in rural villages. Major POs are: Grameen Shakti、Rural Services Foundation (RSF), and BRAC. These three NGOs have developed more than 70% of SHS and biogas projects. These POs have been active in micro credit activities, and accumulated know-hows for door-to-door loan collection and installment management. The know-hows help for the world-fastest SHS roll-out and also technical guidance for rural areas.

Rural household can afford Taka 13,000~35,000 SHS for three years repayment (36 installment) (more precisely, in general 5% of the installment cost is met by grant from development partners, and end-user bares 40% as the down payment, and repay the rest as installment).

In addition to the POs, many local private companies have gone for the SHS market, such as Rahimafrooz, Siemens Bangladesh, ARMCO, Micro-Electronics and FirstBangladesh Solar[52].

13.4 Renewable Energy Potential in Bangladesh

13.4.1 Overview

In the SREDA's document mentioned above, Bangladesh's renewable energy potential is also assessed as seen in the Table 13-4 . It is estimated that the renewable energy potential in Bangladesh has approximately 3,700MW (in energy-wise 7,000GWh per year) to be added. It should be noted , however that this "3700MW" is still tentative number and has room to update, hence there are some inconsistencies between the potential listed in Table 13-4 and renewable energy deployment plan up to 2020 (Table 13-2).

Solar Park potential in the table below indicates the potential under the "non-agricultural land use policy" (discussed in 13.2.2). Wind park potential in the below table is only based on the existing study and still waiting for an assessment to be completed for update. Waste to Energy indicates only the accumulation of existing plans, mainly due to the difficulty to assess the scale of waste available for plants. For mini hydro, PSMP2016 conducted its site survey and details can be referred in Chapter 12.

Table 13-4 Renewable Energy Potential in Bangladesh

Technology	Resource	Capacity (MW)	Annual Generation (GWh)
Solar Park	Solar	1,400*	2,000
Solar Rooftop	Solar	635	860
Solar Home Systems (SHS)	Solar	100	115
Soar Irrigation	Solar	545	735
Wind Park	Wind	637**	1,250
Biomass	Rice Husk	275	1,800
Biogas	Animal Waste	10	40
Municipal Waste	Municipal Waste	1	6
Mini Hydro	Hydropower	60	200
Mini Grid, Micro Grid	Hybrid	3***	4
Total		3,666	7,010

*Case 1 (agricultural land excluded) estimate **Case 1 (flood-prone land excluded) estimate ***Based on planned projects only, not a theoretical maximum potential, because there is potential overlap with off-grid solar systems. Either could be used to serve off-grid demand.

Source: SREDA-World Bank "Scaling Up Renewable Energy in Low Income Countries (SREP) Investment Plan for Bangladesh", October 2015

[52] JETRO Report "BOP Potential Needs Survey, Bangladesh Energy Sector" (Japanese only), March 2011

13.4.2 Solar

Solar and wind power resource assessment in 2007, supported by UNEP and GEF confirmed the vast potential of solar PV generation in Bangladesh[53], and the explosive deployment of SHS has been observed.

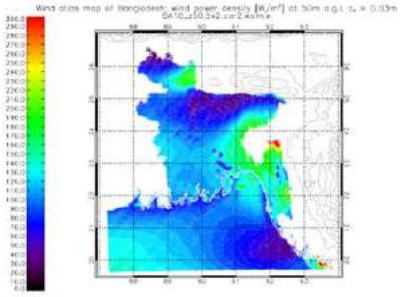
However, Bangladesh has also a major obstacle to deploy large-scale solar PV, which is land availability. Solar PV technology has low energy-intensity and requires large area land. For SHS, the land availability did not matter. On the other hand, 30MW solar generation for example requires approximately 60ha. land. This means that the 30MW solar generation would require 200 farmers' farmland (an average Bangladesh small-scale farmer's farmland is 0.3ha[54]) .Bangladesh government has already stipulated a policy prohibiting farmland use for private solar projects, which limits the solar park potential to 1,400MW.

The SREDA document also estimates the solar rooftop potential (on-grid) and solar irrigation potential (off-grid), 634MW and 545MW respectively. Details of SHS can be referred in 16.4.4 "Off-Grid Electrification" Section of this Report.

13.4.3 Wind

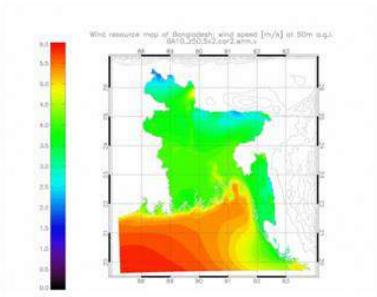
Even though Bangladesh quite often encounters cyclones, the development of wind power generation is yet limited (there are only two points, Muhuri Dam 900 kW and Kutubdia 1000 kW). The above mentioned SREDA document estimates the Bangladesh's wind potential as 624MW, based on the desk-top review of available study and data.

The above "potential" is yet finalized and has much room to change. Wind power potential was studied in the past; however, detail was not enough for investment opportunity identification. Currently USAID-supported Wind Resource Assessment is being conducted and will be completed in 2018.



Source: SREDA homepage

Figure 13-5 Wind Power Density



Source: SREDA homepage

Figure 13-6 Wind Speed

Source: JICA Survey Team

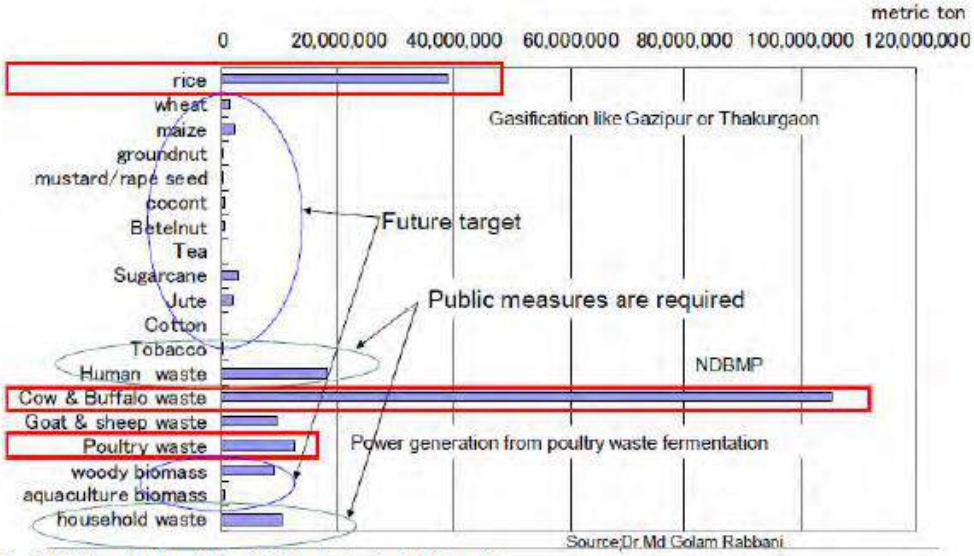
13.4.4 Biomass and biogas power generation, and waste to energy

Bangladesh biomass resource has characteristics of having rich animal waste from livestock industry, but little forest resource (e.g. firewood) available due to protection against deforestation. Among these,

[53] United Nations Environment Program (UNEP) and the Global Environment Facility (GEF) ,"Solar Wind Energy Resource Assessment (SWERA)", February 2007

[54] FAO "Characterisation of small farmers in Asia and Pacific", April 2010 http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/APCAS23/documents_OCT10/APCAS-10-28_-Small_farmers.pdf

it has been pointed out that rice husk has good potential as biomass generation resource in terms of the production amount and resource availability throughout year (JICA past studies also pointed out the risk husk potential). IDCOL has two rice husk power plants in Gazipur and Thakurgaon.



Source: Dr Md Golam Rabbani, Bangladesh Agricultural University
Note: The original metric volume data of biomass are as of following time; 1) rice in 2009,2) cow and buffalo in 2005,3) human census in 2001, 4) forests and wood processing in 2003, 5) aquaculture in 2008 ,and 6) municipal and solid waste in 2008.

Source: JICA Preparatory survey on renewable energy development project, Final Report (November, 2012)

Figure 13-7 Biomass Energy Potential in Bangladesh and IDCOL's Program and Projects

The SREDA-World Bank document estimates the biomass power generation potential as 274MW.

In addition, out of biogas potential to be discussed in detail later, biogas power generation potential is quite limited only to 9.4MW (i.e. 1,131MWh/day) . JICA Biogas survey, to be discussed in the next section, has even less estimate 73MWh/day.

In order to promote biogas power generation, it should also be noted that hydrogen sulfide generated under anaerobic fermentation is quite harmful and technical barrier. The hydrogen sulfide, if not properly removed from the biogas, is highly corrosive for generator-connected turbine. This gas is also highly harmful to human/animal body. Therefore, hydrogen sulfide removal technology and cost reduction is also one of the barriers to promote biogas power generation.

Furthermore, it should be noted that, despite the huge volume of municipal waste is produced daily in Bangladesh (over 13,000 tons in Bangladesh, and 4,400 tons in Dhaka), there are multi-folded issues to overcome, in order to materialize the "waste-to-energy" potential. Specifically material collection and transport to plant (both power plant and gasification)are the issue-baring processes. In order to collect waste and transport in a proper and sustainable manner, many factors such as municipal governments' capacity, financial situation and citizen's awareness need to be appropriate[55]. In this sense, "waste-to-energy" project can be attainable only after when solid waste management is properly implemented. Also, a nature of waste (e.g. low calorific value) can be an issue for efficiency and economic viability of a waste-to-energy project. Therefore, it is difficult to estimate the potential of waste-to-energy project solely based on the volume of municipal waste, and project-to-project feasibility study needs to be carried out to specify the potential.

[55] JICA, Strategy Paper on Solid Waste Management, March 2015

13.4.5 Hydropower

Refer to the Chapter 12, including mini/micro hydro power potential

13.4.6 Biogas as cooking fuel

In this subsection, the potential and importance of biogas as a cooking fuel is discussed based on JICA supported study "Biogas Generation and Demand Survey in Bangladesh (March, 2015)". Especially in the context of SDG Goal 7 "Affordable and clean energy", biogas in Bangladesh has great potential to serve as a cooking fuel in rural areas, though it has a limited impact to meet the entire gas demand.

<<Definition and History>>
Biogas can be obtained through anaerobic fermentation of high-water containing organic waste, such as animal waste, food waste and sewage sludge. Biogas contains approximately 60% of methane, where natural gas contains almost 100% of methane. The appropriate range of air temperature for the anaerobic fermentation is between 25 degree to 45 degree Celsius, and Bangladesh fits to the atmospheric condition. In fact, Bangladesh started its biogas study in the late 1970s.

<<Positioning and Current Status>>
In the early stage of biogas deployment, the purpose of the biogas plant (digester) construction was to improve the living environment of livestock businesses and their surroundings, and biogas energy supply was just a "sub product". From this point, the biogas project in Bangladesh should not be evaluated merely by the economic comparison with other energy alternatives. Currently, Bangladesh produces biogas 190,000 m3/day. The substantial roll-out of biogas digester has started since the late 1990s, and so far approximately 80,000 biogas digesters have been developed and more than 60,000 have been under operation (reasons why nearly 20,000 digesters suspend operation are such as difficulty to collect animal wastes, loss of animals due to illness, or manufactures unable to maintain damaged/broken digesters).

<<Biogas Plant Type and Sales Channel>>
Biogas digester types vary from a small and suitable for one household to a large and suitable for livestock business. A typical small size is to produce biogas 1.2m3/day from 3-4 cattle heads, and can be used for one cooking burner. The most popular biogas digester is 3.2m3/day type, capable to supply cooking fuel for 6-8 people. A Large size digester plant is as large as 1,000m3/day, developed within a daily farm. The plant is supplying cooking energy, as well as fuel for generating power (if the entire gas is used for power generation, the plant can generate 260kW). The produced gas and electrical power are being supplied to the owner's house, as well as surrounding households. The proportion of gas and electrical power are determined by the local needs, and not fixed.

The 48 POs are selling biogas digesters nationwide. The produced biogas is currently being supplied only to the digester-adjacent households, and not connected to the grid mainly due to the impurities of the biogas. However, cylinder bottling is technically possible, and economically viable if the biogas digester has a production capacity more than 500m3/day. Cylindered biogas could be reached to remote areas.

<<Price and Plant Life>>
The price of the biogas plant construction ranges from 13,000 Taka, including a 1.2m3/day digester and civil work. For a rural household, this price is even expensive and the initial investment is one of the bottlenecks for biogas digester roll-out to be addressed. The most popular digester, 3.2m3/day production capacity, prices 36,000 Taka. Most of plant construction is subsidized by the government about 30% of its cost (13,500 Taka is subsidized the government for 3.2m3/day digester construction).

Many of the biogas digester currently marketed in Bangladesh have in fact poor quality and get cracks only after a few years of operation. However, the above-mentioned JICA Biogas survey shows that the biogas users (current and potential) expect 20-30 years of plant life.

<<Impact of Biogas Deployment>>
The above-mentioned JICA Biogas study suggests that Bangladesh has biogas potential at firm 1.2 million m3/day, six times more than the current 190,000 m3/day from some above 60,000 plants. This 1.2 million m3/day gas has as much energy as 25 mmcfd natural gas. This is derived from the below:

- According to the JICA Biogas survey, 65% of biogas is methane, and calorific value per m3 of biogas is estimated to be 5500 k cal., equivalent to 23.02740 MJ/m.
- Bangladesh natural gas has calorific value 39.59 MJ/m3, which means the biogas has 58.1% calorific value of the natural gas.
- According to the JICA Biogas survey, about 110,000 poultry and daily farms are positive to construct biogas digester if a decent subsidy is provided for plan construction, while 80,000 poultry farms and 70,000 daily farms exist in Bangladesh.
- From the 110,000 poultry and daily farms, approximately 1.2 million m3/day biogas could be produced.
- 1.2 million m3 biogas /day = 1.2 *0.581 million m3 natural gas / day = 1.2 * 0.581 * 35.3147 million cubic feet natural gas /day [56]= 24.61 mmcfd

This approximately 25 mmcfd "natural gas equivalent" seems small to the country's total demand to the natural gas, 2,500 mmcfd. However, the biogas directly from a digester contains impurities and grid connection is not appropriate without investment to purification facilities. Thus the biogas is suitable for off-grid cooking fuel for households. The Bangladesh's household demand for natural gas (mainly as cooking fuel) is estimated to be 290 mmcfd. In this sense, the biogas has potential to meet roughly 10% of the households' natural gas demand.

Moreover, it should be noted that only 8% of entire population in Bangladesh has access to the grid gas. The grid gas users are quite Dhaka-centric (out of 2.4 million contracts of grid gas in Bangladesh, 1.7 million or 70% of the national grid gas connections are in Dhaka area), and very few population have access to grid gas outside of Dhaka area. According to the BBS statistics in 2014, more than 94% of the rural population in Bangladesh uses traditional solid biomass for cooking[57]. If the solid biomass users can gain access to the biogas, its social impact is enormous.

One example of the social impact is the liberation from the respiratory diseases caused by the incomplete combustion of solid biomass. According to the World Health Organization (WHO), solid biomass incomplete combustion by using inefficient traditional cook stove produces toxic substances, so called "black carbons", such as mono dioxide and particle matters, and these substances cause respiratory diseases. WHO warns that 3 billion still need to depend on solid biomass, and 1.5 million die from the respiratory diseases caused by the indoor air pollution (and many of the victims are women and children, because they cook inside of the house or more exposed to the toxic substances for their low height) [58]. WHO claims that the indoor air pollution is the second major cause of illness in low income countries, next to the poor access to the safe water and incomplete sanitary environment. Bangladesh Department of Environment estimates 30 million for the replacement need of indoor cooker in the rural areas in the next 5 years[59].

In addition, using biogas improves combustion efficiency, reduces time to collect solid biomass and enable

[56] The unit converter is referred in IEA website: https://www.iea.org/statistics/resources/unitconverter/
[57] Bangladesh Bureau of Statistics, "Statistical Pocket Book Bangladesh", 2014
[58] WHO, "Fuel for Life, Household Energy and Health", 2006
[59] Meeting with Department of Environment and Survey Team, April 2016.

people to allocate more time for more value-added activities (such as supervising child study or side work). The JICA Biogas survey indicates that the potential need for biogas is quite high in rural areas, and estimates that about 60% of rural household (approximately 15 million households out of 25 million) perceive solid biomass very inconvenient If biogas is affordable, the potential demand for biogas could be 25 million m3/day, roughly equivalent to 500 mmcfd of natural gas (approximately 5,000 ktoe). This is about twice more than the current natural gas demand for Residential (household) sector (approximately 2,700 ktoe).

Furthermore, the JICA survey suggests the maximum potential of Bangladesh biogas production capacity could be 9 million m3/day, if utilizing municipal wastes as well. Out of this maximum potential, JICA Biogas survey proposes 3 million m3/day (equivalent to 63mmcsd natural gas, or 602ktoe/year) is technically feasible. The 3million m3/day biogas could meet the 10% of natural gas projected demand of the household sector in the 2030s (the 10 years average household sector's natural gas demand of 2030s is projected to be about 6,200ktoe/year). The earlier mentioned SREDA-World Bank document also estimates Bangladesh's biogas potential 3.4 million m3/day (or 950,000 biogas plant x 3.2m3/day).

<<Economic Comparison with LPG (1) >>
Even though the biogas has much more potential than just "cooking fuel", economic analysis shows the affordability of biogas to the users and to the national coffer, especially compared with LPG.

- Suppose 110,000 poultry and daily farms construct biogas plants and produce 1.2million m3/day biogas. This means that an average plant capacity is about 11m3/day.
- Based on the current biogas plan construction cost 36,000 Taka for 3.2m3/day digester, 11m3/day model digester construction cost could be 120,000 Taka. 110,000 plants construction would cost 110,000 * 120,000 = 13.2 billion Taka (JICA Biogas survey shows that many biogas experts perceive biogas plant cost 10,000 ~ 15,000 per 1m3/day to be appropriate).
- IDCOL's financial model for biogas program would be as follows, provided with development partner's grant:

  a) Subsidy: 40%
  b) Loan: 40%
  c) Down payment: 20%
  Total : 100%

- Here, a household bares the 60% of the total cost (loan and down payment), plus interest rate 5-8% (depending on PO's program). Hence the "macro" charge to the user would be at most 13.2 billion*(0.2+0.48)=8.98 billion Taka. The charge to the national coffer is the subsidy part, financed mainly by the development partners, and would be 13.2 billion * 40% = 5.28 billion (interest rate from the development partners is negligible).
- Therefore the macroeconomic total cost of biogas digester deployment is 8.98+ 5.28 = 14.26 billion Taka.

If the 1.2 million m3/day biogas equivalent (in terms of calorific value) LPG is purchased, the LPG cost would be 47.5 million Taka/day, from the below conversion chart.

LPG Price per Heat Value

Item	Value	Source
LPG Unit Cost for Sale	1050 Tk/cylinder (12kg)	JICA Survey Team. This is not an official price, but observed marketed price
LPG Unit Cost for kg	87.5 Tk/kg	From calculation
LPG Heat Value per kg	50.8 MJ/kg	JICA Consultant information to JICA, 2014
LPG Price per Heat Value	1.72 Tk/MJ	From calculation

Biogas Heat Value

Item	Value	Source
Biogas in Bangladesh Heat Value	5500 kcal/m3	JICA Survey team
Biogas in Bangladesh Heat Value in MJ	23.02740 MJ/m3	From calculation (1 kcal = 0.0041868 MJ)

The equivalent calorific value of LPG would cost: 1.72 Tk/MJ * 27,633 MJ/day = 47,528,554 Taka/day = 47.5 million Taka/day

14.26 billion Taka / 47.5 million Taka/day≈300 days.

Therefore, biogas plant construction would cost as same as the "one-year" LPG purchase cost.

<<Economic Comparison with LPG (2) >>
Another analysis suggests the affordability of biogas digester for "a user (farm)", compared with LPG.

As already mentioned in the section 11.4.6, the affordability issue of LPG, an average household consumes two cylinders of LPG per month. Hence the LPG purchase cost would be 2,100 ~ 2,600 Taka per month. This is approximately 25% of the average rural household's monthly income. Compared with the fact that the average rural household's expenditure trend of fuel (conventional solid biomass, such as firewood) is 2~6% of its monthly income, the LPG cost is unsustainably higher (for further detail, see Chapter 10).

On the other hand, if a farm installs a biogas digester, household members can produce biogas for their self-consumption, and can sell the residual gas to neighbouring households. The willingness to pay for the biogas is assumed to be somewhere between the conventional solid biomass and LPG, and the sales profit of the biogas can be an additional income to the digester-installed farm (In the model 11 m^3/day digester, approximately 280m^3=330 cubic feet per month could be sold). In addition, slurry as a bi-product of digester can be used as organic fertilizer (after drying process). The digester-installed farm can reduce the cost of chemical fertilizer, and also sell the residual organic fertilizer.

More in-detailed financial and economic feasibility analysis requires further study on the willingness to pay to the biogas and many other factors. For example, financial IRR requires the cost of biogas installation, repayment terms and conditions, operation and maintenance cost of biogas digester. Economic IRR (internal rate of return) further requires the value (willingness to pay) of the biogas and organic fertilizer, and the cost of solid biomass and chemical fertilizer as the economic benefits. However, the study in the

past and other analysis suggest the biogas digester installation is both economically and financially viable[60].

<<Is a high-spec digester a panacea?>>
By recognizing the poor quality issue of the conventional ceramic biogas digester, SREDA is currently negotiating with National Board of Revenue to exempt the duties on imported glass fiber digester materials, to promote glass fiber digester as the new generation one to roll out.

However, the glass-fiber digester also shows many issues – installation, operation and maintenance – and should not be seen as "panacea". For example, a glass-fiber digester costs 1.5 times higher than the conventional one, and the down payment and monthly repayment for a user is obviously more. Furthermore, a glass-fiber digester dorm has thickness (4-6mm) and prone to prone to cracking during transportation, and susceptible to bear loads and tensile stress in the worst conditions. It also has a large size dorm (for example, the 11 m3/day model could have 3-4m diameter) and would be difficult to transport with a Bangladesh's traditional truck (capable to carry more than 5 tons, and approximately the head to tail length and outer width of a traditional truck are 5.5 m and 2.4 m respectively); hence would not be cost effective.

Therefore, it is recommended to conduct a survey to analyze pros and cons of both conventional and glass-fiber digester, and develop a flexible deployment program to respond to various users' needs (for example, various digester sizes, dorm materials, financial programs depending on the down payment).

Regarding the macro-economic impact of the glass-fiber digester, the construction cost would be 50,000 Taka for the most popular 2.4m3/day capacity[61]. With this figure, the above analysis would be modified as follows:

- The 11m3/day production capacity digester would be 220,000 Taka, based on the 2.4m3/day digester price. The 110,000 plant construction cost would be 10,000 * 220,000 = 24.2 billion Taka.
- Here, a household bares the 24.2 billion *(0.2+0.48)=16.46 billion Taka. The charge to the national coffer is the subsidy part, financed mainly by the development partners, and would be 24.2 billion * 40% = 9.68 billion.
  (16.46+ 9.68) billion Taka / 47.5 million Taka (for LPG) =550 days

Therefore, higher model biogas plant construction would cost as same as the "a year and half" of LPG purchase cost.

It should be noted that the charge to the national coffer, 5.28 billion Taka (conventional ceramic digester) to 9.68 billion Taka (glass fiber digester), is much less than the subsidy to BPC which once reached 86 billion Taka in FY2012. Biogas plant does not only bring energy access, but also better hygiene and healthier environment to rural people. Biogas also is carbon neutral fuel, which is LPG is not.

<<Barriers to Biogas Deployment>>
Biogas deployment could bring many impacts, however, there are some barriers to address. The development partners are currently identifying the major barriers and countermeasures for biogas deployment, and the followings are the potential reasons[62]: 1) POs have less experience in handling

[60] IDCOL and Netherlands Development Organization (SNV), "Final Report on Technical Study of Biogals Installed in Bangladesh," December 2005 (https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/77-1.pdf). In this study, FIRR counts the cost reduction of solid biomass and chemical fertilizer as benefits and it should be in fact EIRR. However, the value shows some 50% (with subsidy) and some 20-30% (without subsidy). Furthermore, the sales profit of residual biogas or organic fertilizer is not counted as benefit. If the benefit were factored-in, the FIRR could be well above the threshold (e.g. the interest rate for the loan 8%).

[61] According to the World Bank Dhaka Office.

[62] Based on the information provided by the World Bank Dhaka Office.

biogas digester than SHS, 2) Bangladesh society have negative perception to biogas digester from the past experiences (cracks after a few years usage, etc.), 3) few manufactures can properly maintain biogas plants. The IDCOL financial model may not have much room to improve.

In addition, the above-mentioned glass-fiber digester is higher cost, and the financial barrier and other issues should be addressed according to the in-depth analysis and countermeasures.

13.4.7 Biofuel

In a global trend, consumption of biofuel is growing significantly, mainly as a substitute of transport (road transport) fuel. In 2005 biofuel consumption was 19 Mtoe (1.2% of total road transport fuel), but it grew to 64 Mtoe in 2013 (3.3% of the same). Obviously this trend stems from the need of CO2 emission reduction, and energy security enhancement by diversifying transport fuel mix (and reduction of oil import). More than 60 countries now have policy on biodiesel blending mandates has supported its growth[63].

India also has policy to promote biofuels (biodiesel). The National Policy on Biofuels (2009) has an indicative target on 20% by the end of 2017, where conventional gasoline and diesel would be replaced by E20 (20% of bioethanol blended gasoline) and B20 (20% of biodiesel blended diesel). India's R&D for biofuel has launched recently and yet made any substantial progress. However, it was announced that Indian Oil Corporation (IOC) succeeded in producing bio-hydrogenated diesel by catalytic hydrotreatment of non-food oil. Central Salt Marine and Chemical Research (CSMCR) and National Environmental Engineering Research Institute (NEERI) are doing R&D for algae biodiesel[64]. Also, India's energy company Reliance Power is active on financing biofuel business overseas (e.g. US and Malaysia) especially on algae fuel technology.

In Bangladesh, on the other hand, biofuel policy has yet placed, and university/industry R&D is still in nascent stage. Though further detailed on-site survey is required for better recommendation, based on the general knowledge, it seems that if Bangladesh wishes to pursue the biofuel potential, algae technology for biodiesel is one (and maybe the best) option.

The main reasons are 1) food-versus-fuel concern, 2) Technology and cost, and 3) limited and availability in Bangladesh (summary can be seen in the Figure 13-8 .)

Among various biofuel, bioethanol are mostly produced in Brazil and USA, where vast land and high quality cultivating conditions are available for large amount of sugarcane and corn production for bioethanol (and food production). In such countries, land use for food OR fuel does not matter. On the other hand Bangladesh has limited land and also growing population. In addition, as Bangladesh keeps economic development and per capita income increases, demand on food also will increase. Therefore, in terms of agricultural land usage, Bangladesh should prioritize food security over bioethanol production.

Furthermore, non-food bioethanol sources, such as agriculture residue, wood materials or used oil are currently having technological issues thus cost and/or energy balance challenges. For example, cellulose separation process from these non-food sources for bioethanol production may require more cost and/or energy than food sources.

Provided that bioethanol seems to have little feasibility for Bangladesh, biodiesel could be an option. ASEAN countries such as Malaysia or Indonesia produce industrial scale biodiesel (e.g. palm and

[63] IEA WEO (2015) ibid., pp.362-363

[64] New Energy Foundation, Asia Biomass Office "Status of Biodiesel Fuel in India" https://www.asiabiomass.jp/english/topics/1310_02.html

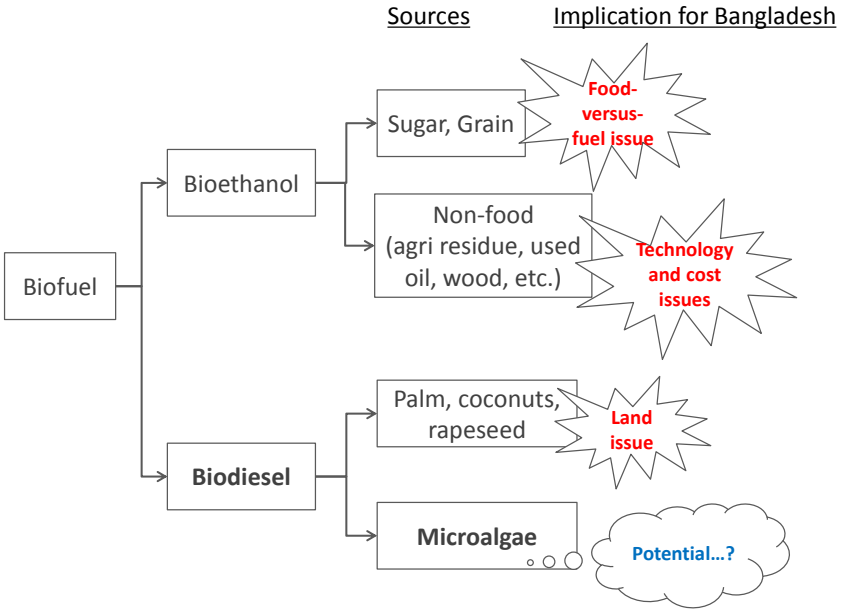
coconut) from plantations with some thousand hectare areas, based on a long tree plantation history. On the other hand, Bangladesh has little plantation background, nor available land for mass scale of plantation. Therefore, conventional material based biodiesel seems not feasible for Bangladesh.

The rest option is algae-based biodiesel. It is known that algae have better productivity (oil yield) per unit area than other conventional biodiesel sources[65]. As a country with limited available land, algae-based biodiesel may a good option.

However, it should be noted that in the last decade, many biofuel ventures entered the microalgae biodiesel R&D and now most of them have exited. The main reason is the difficulty to cultivate microalgae for the industrial production scale.

Botryococcus braunii is one kind of microalga, known for is nature to produce oil, almost 50% of its dry weight and easiness to obtain crude oil from it (i.e. little external energy is required for crude oil). In theory, if a large amount of Botryococcus braunii can be cultivated, a good amount of crude oil (i.e. half of the algae's dry weight) could be produced. However, this alga is by nature very slow to grow, hence difficult to produce at industrial scale.

One potential of the technological breakthrough is to breed a high-speed growing subspecies of Botryococcus braunii, through stupendous R&D process (e.g. one or two subspecies could be successfully bred out of more than ten million strains).



Source: JICA Survey Team

Figure 13-8 Biofuel Sources and Implication to Bangladesh

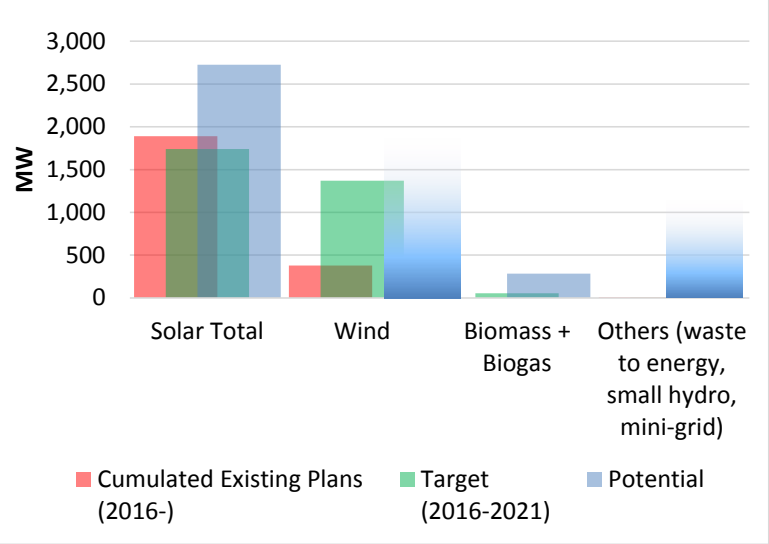
[65] In Y. Chisti's "Biodiesel from microalagae"(http://www.massey.ac.nz/~ychisti/~yc.html) is one of the most well-known paper to address the potential of microalgae as biodiesel source, indicating that algae have 10-20 times higher productivity than other sources. However, it should be noted that the algae productivity indicated in this paper is based on a test tube in a lab, not in the actual outdoor environment.

13.5 Gap between Planning and Potential

13.5.1 Approaches to closed the gap (RE technologies other than biogas and biofuels)

In this section, the difference between the existing plans provided by SREDA in June 2016 (see the Table 13-2), and the potential discussed in the previous section is analyzed. The details of deployment plan (renewable generation) can be referred in the Appendix.

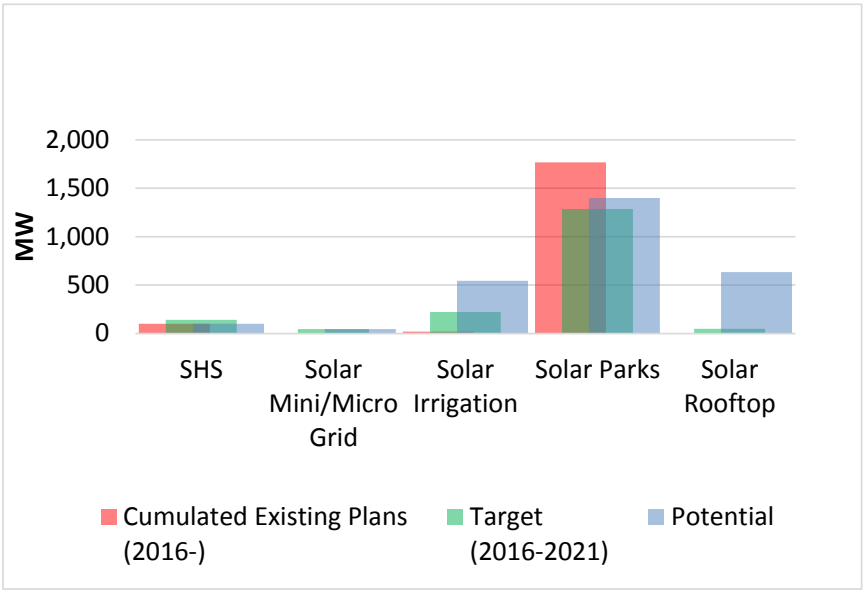
As seen in the below figure and discussed in the previous section (13.4) , Bangladesh's renewable energy potentials are yet fully identified. Despite this issue, it is obvious that the current project pipelines overly concentrate on solar PV technologies, and other renewable technologies, such as wind, biomass, biogas, waste to energy and mini hydro are tunneled and far distance to utilize its potential (Figure 13-9).



Source: JICA Survey Team

Figure 13-9 Gap among Project Pipeline, Target and Potential)

As observed in the Figure 13-10 , although solar irrigation pump has big potential, installation is small. It is supposed that power will be supplied to irrigation pump from the grid in the electrified area, and installation capacity will not reach the potential. Installation speed is assumed to the half of existing plan's speed.
Solar park plans on the other hand exceed the potential and will be screened with established procedures in SREDA, based on the investor's financial soundness, technical soundness, land use and tariff proposed from the project side.



Source: JICA Survey Team

Figure 13-10 Solar PV Gap among Project Pipeline, Target and Potential

Barriers to the other renewable energy projects and countermeasures are described in the SREDA's "SREP" document, "3.4 Barriers to RE" and later.

13.5.2 Biogas

Since 1996 to 2004, the Government took initiative to roll out 22,000 biogas digesters, in which NOGs such as Grameen Shakti and BRAC, and Local Government Engineering Department (LGED) played a central rolls for implementation. From 2005, Netherland (SNV) supported biogas digester.

As of today, there are in total 80,000 biogas digesters installed but only 62,400 digesters under operation and producing 190,000 m3/day biogas. The reasons of roughly 20,000 digesters not operating are multifold; insufficient (collected) row materials (animal waste), loss of cattle due to illness, or insufficient maintenance for broken digester.

As discussed in the previous section, JICA Biogas study and SREDA-World Bank document estimate the Bangladesh's biogas potential 3 to 3.4 million m3/day by 2041. JICA Survey Team suppose this potential is attainable based on the following assumptions:

- Mid-term target is the additional 0.6 million m3/day in the mid 2020s (accumulated total 0.8 million m3/day).
- By 2025, if the 55,000 farms, the half of the previously discussed 110,000 farms with willingness to introduce biogas digester, introduce digesters, the additional biogas production can reach 0.6 m3/day.
- The 550,000 digesters between 2021 to 2025 can be constructed in each Upazila (there are in total 64 Upazilas in Bangladesh).

In order to materialize this construction speed, specifically the number of capable contractors and their capacity, as well as the availability of domestic manufactures, is the key to success.

13.5.3 Biofuel

Based on the assumption that Bangladesh is in a nascent stage of R&D for biofuel, the following table could serve as a reference on how to reach biodiesel industrial production. It should be well reminded that microalgae-based biodiesel production is not attainable without sound agricultural experience of breeding microalgae. In addition, it should also be reminded that biofuel is low unit price business and large scale production and market is required to make the biofuel business economically feasible. Therefore, it is recommendable to start from breeding microalgae to produce a small amount of high-value added products, such as high-function substances.

Table 13-5 Roadmap to Microalgae-based Biodiesel Sustainable Production (Reference)

	Short term	Medium Term	Long Term
Purposes	**High-function substances** Phycocyanin, astaxanthin, high-concentration DHA/EPA, beta carotene, **Medical, Cosmetics** Polysaccharide, radioisotope, antibody drugs, etc. **Others** Food, feed additive, etc.	**Nutritional supplements** Omega3 fatty acid, vitamin supplement, etc. **Health food** Spirulina pill, Chlorella pill, etc. **Food with palatability**	**Biofuels** Bioethanol, biodiesel, jet fuel, etc. **Biochemical materials** Biopolymer
Unit Price (USD per kg dry material)	> 100	10 – 100	< 5
Market Scale (1 million USD)	< 1,000	> 1,000	> 10,000
Production Scale (ha)	< 10	< 1,000	> 1,000
Initial Investment (USD 1 million)	< 10	10-1,000	> 1,000

Source: Chitose Laboratory Corporation

The following is an image of large volume of microalgae cultivation for biodiesel production in Japan. In this pond with 1500 m^2 surface area, under suitable climate conditions and over the year cultivation, at least a few tons of crude oil can be produced.



Source: Chitose Laboratory Corporation

Figure 13-11 Microalgae Biofuel Cultivation Image

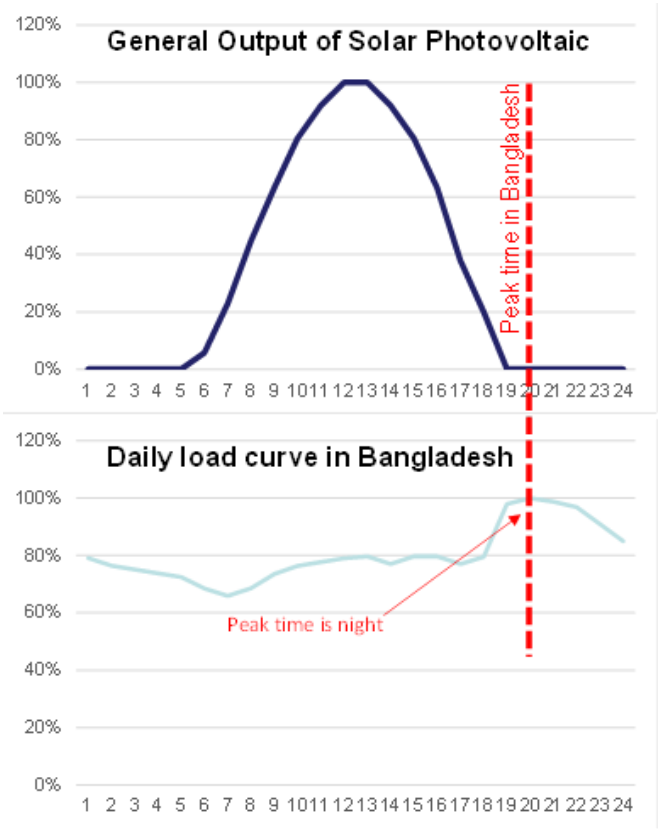
13.6 Integration of the Renewable Energy into Power Development Planning

In Japan, the supply capacities of renewable energy such as solar or wind are calculated by actual values from the site. The JICA Survey Team proposes that the following coefficients can adopted until enough actual values are gathered from renewables in Bangladesh.

Solar: 0 - 21% x Total installed capacity
(Coefficient is changed each month)

Wind: 0 - 7% x Total installed capacity
(Coefficient is changed each month)

But the Power Development Plan is a plan for peak time and the peak time of electricity demand in Bangladesh is night, so the Solar Photovoltaic does not work at peak time. Therefore, electric power (kW) from solar is not considered in the power development plan and electric energy (kWh) is considered. If daily load curve is changed from night peak to day peak in future, electric power (kW) from solar will be considered in the power development plan.



Source: JICA Survey Team

Figure 13-12 Peak of Solar Supply and Electricity Consumption

13.7 Substantial Renewable Energy into Grid Connections

13.7.1 Variable renewable energy grid connections

In Bangladesh, it is estimated that the potential of grid-connected Variable Renewable Energy (VRE) such as solar and wind, of which power output can vary in the short period, can be 4,200GWh/year (SREDA-World Bank, 2015). In comparison with the total power generation of 82,000GWh in 2020 and 307,000GWh in 2040, the impact of grid-connected VRE is limited and does not require a drastic transformation of the conventional power system development planning.

In fact, IEA discuss that if the VRE is within the 5-10% of the annual total grid-connected power generation (GWh), because such output variation and unpredictability can occur by load change or unplanned power plant outage, and is manageable by the conventional power network planning and operation[66].

However, Bangladesh is still under development phase of power generation and network. Therefore grid-connected utility-scale VREs should be properly integrated in to the power system development plan to ensure appropriate reserve margin and network capacity. Also, currently Bangladesh does not have technical regulation or standard for grid-connected utility-scale VREs. Hence these regulations and standards need to be developed and implemented.

[66] IEA, "The Power of Transformation - Wind, Sun and the Economics of Flexible Power Systems", 2014

13.7.2 Large hydro via cross-border power import

Outside of its boundary, Bangladesh has a huge potential to exploit renewable energy: a regional hydropower potential in the South Asia. It is estimated that Bangladesh can import about 5,000 MW hydropower mainly from Nepal and north-west India around 2041. Further details are discussed the Chapter 14.

Chapter 13 Attachment

Details of Renewable Energy Deployment Plan (Power Generation) by 2021

Attachment Details of Renewable Energy Deployment Plan (Power Generation) by 2021

※It is assumed that renewable energy generation development, of which installation year is not identified, will be installed till 2021.

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2015	11,513		11,513						
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2016	17,500			17,500					
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2017	18,000				18,000				
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2018	17,500					17,500			
IDCOL	Solar(Solar Home Systems)		SHS @existing	113,662	113,662							
IDCOL	Solar(Solar Home Systems)		SHS @2015	6,709		6,709						
IDCOL	Solar(Solar Home Systems)		SHS @2016	15,500			15,500					
IDCOL	Solar(Solar Home Systems)		SHS @2017	15,000				15,000				
IDCOL	Solar(Solar Home Systems)		SHS @2017	16,036					16,036			
IDCOL	Solar(Solar Mini Grid)	Complete	100 kWp PGEL solar mini grid project	100	100							
IDCOL	Solar(Solar Mini Grid)	Complete	100 kWp GHEL Solar Mini Grid project	100		100						
IDCOL	Solar(Solar Mini Grid)	Complete	141 kWp Shouro Bangla Ltd mini grid	141		141						

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Mini Grid)	Complete	141 kWp Hydron Bangladesh Pvt. Ltd. Solar Mini Grid	141		141						
IDCOL	Solar(Solar Mini Grid)	Under Construction	148.5 kWp AVA Development Society Solar Mini Grid	149		149						
IDCOL	Solar(Solar Mini Grid)	Under Construction	158.3 kWp GRAM er Alo Ltd. solar mini grid	158		158						
IDCOL	Solar(Solar Mini Grid)	Under Construction	177 kWp Solar Electro Bangladesh Ltd Solar Mini Grid	177		177						
IDCOL	Solar(Solar Mini Grid)	Committed	167 kWp Baraka Renewable Energy Limited Solar Mini Grid	167		167						
IDCOL	Solar(Solar Mini Grid)	Committed	130 kWp Solargao Limited Solar Mini Grid	130		130						
IDCOL	Solar(Solar Mini Grid)	Proposed	Tauras Energy Limited solar mini grid	150		21	21	21	21	21	21	21
IDCOL	Solar(Solar Mini Grid)	Proposed	161.75 kWp G-Tech Solutions Ltd Solar Mini Grid	162		23	23	23	23	23	23	23
IDCOL	Solar(Solar Mini Grid)	Proposed	187.5 kWp Parasol Energy Ltd Solar Mini Grid	188		27	27	27	27	27	27	27
IDCOL	Solar(Solar Mini Grid)	Proposed	200 kWp Superstar Renewable Energy Limited Solar Mini Grid	200		29	29	29	29	29	29	29
IDCOL	Solar(Solar Mini Grid)	Proposed	200 kWp Intraco Limited Solar Mini Grid	200		29	29	29	29	29	29	29

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Mini Grid)		SMG @existing	0								
IDCOL	Solar(Solar Mini Grid)		SMG @2015	994		994						
IDCOL	Solar(Solar Mini Grid)		SMG @2016	2,257			2,257					
IDCOL	Solar(Solar Mini Grid)		SMG @2017	1,603				1,603				
IDCOL	Solar(Solar Irrigation)	Complete	GRAM 01 (05)	36	36							
IDCOL	Solar(Solar Irrigation)	Under Construction	GRAM 02 (18)	36		36						
IDCOL	Solar(Solar Irrigation)	Complete	SDRS (3)	36	36							
IDCOL	Solar(Solar Irrigation)	Complete	ARS (7)	36	36							
IDCOL	Solar(Solar Irrigation)	Under Construction	Solargao 01 (34)	36		36						
IDCOL	Solar(Solar Irrigation)	Under Construction	Solargao 02 (10)	36		36						
IDCOL	Solar(Solar Irrigation)	Complete	RDF-1	80	80							
IDCOL	Solar(Solar Irrigation)	Complete	RDF-1	0								
IDCOL	Solar(Solar Irrigation)	Complete	RDF-2	350	350							
IDCOL	Solar(Solar Irrigation)	Complete	RDF-2	0								

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	1,259		1,259						
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	0		0						
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	380	380							
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	0								
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	0								
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-2	100		100						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-2	0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-3	220		220						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-3	0		0						
IDCOL	Solar(Solar Irrigation)	Complete	Grameen Shakti	11	11							
IDCOL	Solar(Solar Irrigation)	Complete	RCNSL	2	2							
IDCOL	Solar(Solar Irrigation)	Complete	AVA (6)	64	64							
IDCOL	Solar(Solar Irrigation)			0								

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)	Complete	NUSRA	39	39							
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)	Under Construction	RREL (10)	196		196						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)	Complete	4SL	63	63							
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)	Complete	GHEL-6	32	32							
IDCOL	Solar(Solar Irrigation)	Under Construction	GHEL-15	148		148						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	GHEL-25	361		361						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)			0		0						
IDCOL	Solar(Solar Irrigation)	Under Construction	AID-1	76		76						
IDCOL	Solar(Solar Irrigation)	Under Construction	AID-2	170		170						
IDCOL	Solar(Solar Irrigation)			0								
IDCOL	Solar(Solar Irrigation)		SIPS @existing	0								

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)		SIPS @2015	0		0						
IDCOL	Solar(Solar Irrigation)		SIPS @2016	3,830			3,830					
IDCOL	Solar(Solar Irrigation)		SIPS @2017	3,653				3,653				
IDCOL	Bio	Under Construction	KKT	100	100							
IDCOL	Bio	Complete	Phenix	450	450							
IDCOL	Bio	Under Construction	SEAL	400	400							
IDCOL	Bio	Under Construction	United	25	25							
IDCOL	Bio	Under Construction	Zobaida	25	25							
IDCOL	Bio	Under Construction	Ummi Kulsum Agro Ltd.	36	36							
IPP(SunEdision Energy Holdings (Singapore) Pvt Ltd.)	Solar(Solar Parks)	Planning	200 MW (AC) Solar Park on BOO Basis at Teknaf, Coxes Bazar	200,000				40,000	40,000	40,000	40,000	40,000
IPP(Beximco Power Co. Ltd & TBEA XinJiang SunOasis Co. Ltd)	Solar(Solar Parks)	Planning	200 MW (AC) Solar Park at Gaibandha District, Bangladesh	200,000				40,000	40,000	40,000	40,000	40,000
IPP(HETAT-DITROLIC- IFDC Solar)	Solar(Solar Parks)	Planning	50 MW (AC) Solar Park at Sutiakhali, Mymensingh District	50,000				10,000	10,000	10,000	10,000	10,000

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IPP(EDISUN – Power Point & Haor Bangla-Korea Green Energy Ltd.)	Solar(Solar Parks)	Planning	32 MW (AC) Solar Park, Dharmapasha, Sunamganj	32,000				6,400	6,400	6,400	6,400	6,400
IPP(Intraco CNG Ltd & Juli New Energy Co. Ltd.)	Solar(Solar Parks)	Planning	30 MW (AC) Solar Park, Gangachora, Rangpur	30,000				6,000	6,000	6,000	6,000	6,000
IPP(JPL)	Solar(Solar Parks)	Planning	20 MW (AC) Solar Park, Coxbazar	20,000				4,000	4,000	4,000	4,000	4,000
IPP(Eiki Shoji Co. Ltd. Japan & Sun Solar Power Plant Ltd)	Solar(Solar Parks)	Planning	10 MWp Grid-Tied Solar Power Project, Gowainghat, Sylhet	10,000				2,000	2,000	2,000	2,000	2,000
IPP(Blue Mountain Ltd.)	Solar(Solar Parks)	Planning	100 MW (AC) Solar Park Baradi , Naryanganj	100,000				20,000	20,000	20,000	20,000	20,000
IPP(Beximco Power Co. Ltd)	Solar(Solar Parks)	Planning	30 MW (AC) Solar Park Panchgarh	30,000				6,000	6,000	6,000	6,000	6,000
IPP(Golden Harvest and DREPL Consortium)	Solar(Solar Parks)	Planning	10 MW (AC) Solar Park Gowainghat, Sylhet	10,000				2,000	2,000	2,000	2,000	2,000
IPP(Green Housing & Energy Ltd.)	Solar(Solar Parks)	Planning	5 MW (AC) Solar Park, Patgram, Lalmonirhat	5,000				1,000	1,000	1,000	1,000	1,000
IPP(Greenswitch Elcon Bangladesh Ltd)	Solar(Solar Parks)	Planning	50 MW (AC) Solar Park, Bhola	50,000				10,000	10,000	10,000	10,000	10,000
BPDB	Solar(Solar Parks)	Planning	Installation of a 100 MWp Solar PV based grid connected Power generation plant at Sonagazi, Feni District	100,000				100,000				

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
BPDB	Solar(Solar Parks)	Planning	In Chittagong district at Rangunia near Karanafuli river 60 MW Solar park on BOO basis	60,000				60,000				
BPDB	Solar(Solar Parks)	Planning	Gangachara Solar Park	55,000			55,000					
BPDB	Solar(Solar Parks)	Planning	Dharala 30 MW Solar park on BOO basis near Dharala river of Kurigram District	30,000			30,000					
BPDB	Solar(Solar Parks)	Planning	Sarishabari, Jamalpur 3 MW grid connected solar PV power plant	3,000		3,000						
BPDB	Solar(Solar Mini Grid)	Planning	Tough to reach Haor area R/E based pilot project at Salna of Sunamganj of 650 KW Mini grid system	650				130	130	130	130	130
BPDB	Solar(Light)	Planning	Solar street lighting in 8 City Corporation (SSLPCC) project					0				
BPDB	Solar(Solar Rooftop)	Planning	Rooftop solar on govt buildings at Jamalpur District	813				163	163	163	163	163
BPDB	Waste	Planning	Keraniganj Municipal waste to Electricity Project	7,000				1,400	1,400	1,400	1,400	1,400
BREB	Solar(Solar Irrigation)	Planning		7,000				1,400	1,400	1,400	1,400	1,400
NWPGCL	Solar(Solar Parks)	Planning	Faridpur Solar Park	100,000				20,000	20,000	20,000	20,000	20,000

Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
NWPGCL	Solar(Solar Parks)	Planning	Sirajganj Solar Park, Sirajgonj	7,600		7,600						
EGCB	Solar(Solar Parks)	Planning	Sonagazi 200 MW Wind Solar Hybrid Power Plant	200,000				200,000				
APCL	Solar(Solar Parks)	Planning	Ashuganj Solar Park	80,000				16,000	16,000	16,000	16,000	16,000
RPCL	Solar(Solar Parks)	Planning	Mollarhat 200 MWp Solar PV Power plant project	200,000				40,000	40,000	40,000	40,000	40,000
RPCL	Solar(Solar Parks)	Planning	Padma's Char Solar Park	200,000				40,000	40,000	40,000	40,000	40,000
RPCL	Wind	Planning	200 MW Wind based Power Project	200,000				40,000	40,000	40,000	40,000	40,000
DPDC	Solar(Solar Rooftop)	Planning	Solar rooftop system at other Government buildings rooftop as per Secretariat bldg. model					0	0	0	0	0
DESCO	Solar(Solar Rooftop)	Planning	Rooftop solar system installation at DESCO's distribution area Government organization					0	0	0	0	0
IPP(consortium of PIA group & Bangladesh Alternative Energy System Ltd.)	Wind	Planning	100 MW wind power project by consortium of PIA group & Bangladesh Alternative Energy System Ltd. At Anwara Chittagong	100,000				20,000	20,000	20,000	20,000	20,000

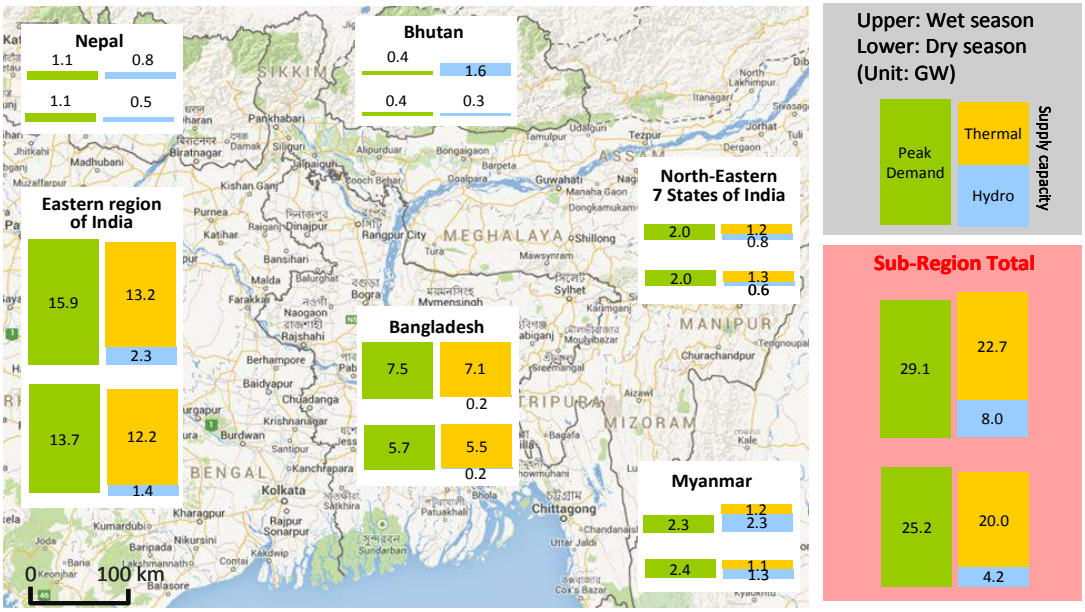
Company	Type	Status	Project Name	Capacity (kWp)	-2014	2015	2016	2017	2018	2019	2020	2021
IPP(US-DK Green Energy (BD))	Wind	Planning	60 MW wind power project at Cox's bazar by US-DK Green Energy (BD)	60,000				12,000	12,000	12,000	12,000	12,000
IPP(M/s. ReGen Powertech Limited)	Wind	Planning	M/s. ReGen Powertech Limited solar-wind hybrid Power project	18,000				3,600	3,600	3,600	3,600	3,600
	Wind	Planning	Wind resourse Assesment project by Vestas Asia Pacific Wind Technology Pvt Ltd					0	0	0	0	0
BADC	Solar(Solar Irrigation)	Planning	Solar Irrigation Project by BADC	3,750				750	750	750	750	750
SREDA	Solar(Solar Home Systems)		SREDA Existing	0	28,338							
SREDA	Solar(Solar Irrigation)		SREDA Existing	0	430							
SREDA	Solar(Solar Rooftop)		SREDA Existing	0	11,000							
SREDA	Solar(Solar Rooftop)		SREDA Existing	0	2,300							
SREDA	Solar(Solar mini grid)		SREDA Existing	0	900							
SREDA	Wind(Wind)		SREDA Existing	0	2,000							
SREDA	Bio(Bio)		SREDA Existing	0	3,964							

Chapter 14 Power Import and Nuclear Power

Industrial diversification and advancement are essential in order to achieve further economic development in Bangladesh. To this end, improvement of the quality of the power supply, such as stabilization of network voltage and frequency, is a prerequisite. In addition, in anticipation of the growing share of coal-fired thermal power generation in the medium and long term, the exploitation of renewable energy resources with low environmental burden under the climate change perspective is envisaged.
On-grid large-scale hydropower development seems to be an effective measure to overcome the aforementioned issues. However, due to its flat geographical features, Bangladesh lacks prospective hydropower potential over 1 MW apart from the existing Kaptai hydro power plant (230MW). In contrast, there is abundant water power resource potential in the countries surrounding Bangladesh, namely Bhutan, Nepal, Myanmar, and the Indian States of the North East and West Bengal (collectively "neighboring countries"). Thus, it is expected that Bangladesh imports electricity out of such hydropower generation via power interconnections with such neighboring countries for stable base load supply, energy fuel diversification, and climate change mitigation.

14.1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh

The neighboring countries of Bangladesh have rich hydropower potential. However, the amount of development at present is small, and a great amount of development can be expected in the future.
The electric power supply and demand situations in the rainy season and dry season in 2014 in the neighbouring countries (Eastern region and Northeastern states in India) of Bangladesh are shown as follows.

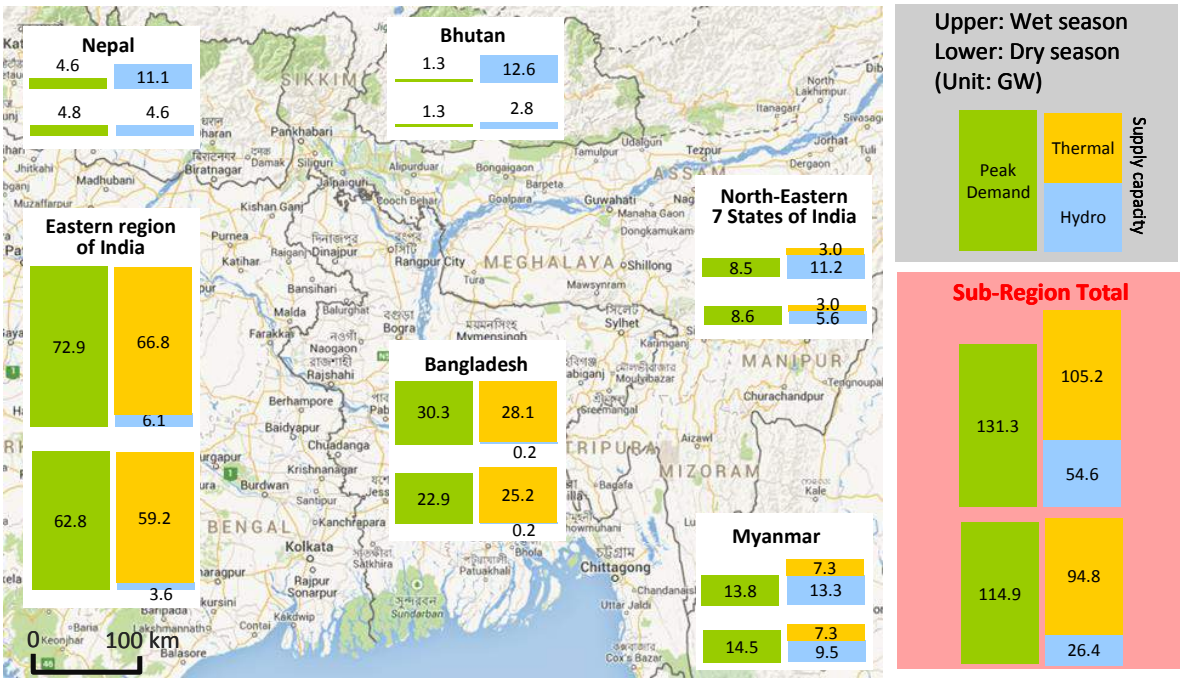


"Map data©2014 AutoNavi Google" Source: JICA Survey Team

Figure 14-1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh (2014)

The supply capacity from hydropower is about 25% of the whole supply capacity in this area at present because there is not a lot of hydropower development yet. Because a lot of hydroelectric power plants in these regions are the run-of-river type, the amount of power generation decreases below half in the dry season, though a lot of power generation can be expected in the rainy season. Therefore, the supply capacity is slightly insufficient in the dry season because the supply capacity from hydropower decreases remarkably, though power demands also decrease a little.

The electric power supply and demand situation forecast in 2030 is shown below in addition to that mentioned above.



"Map data©2014 AutoNavi Google"

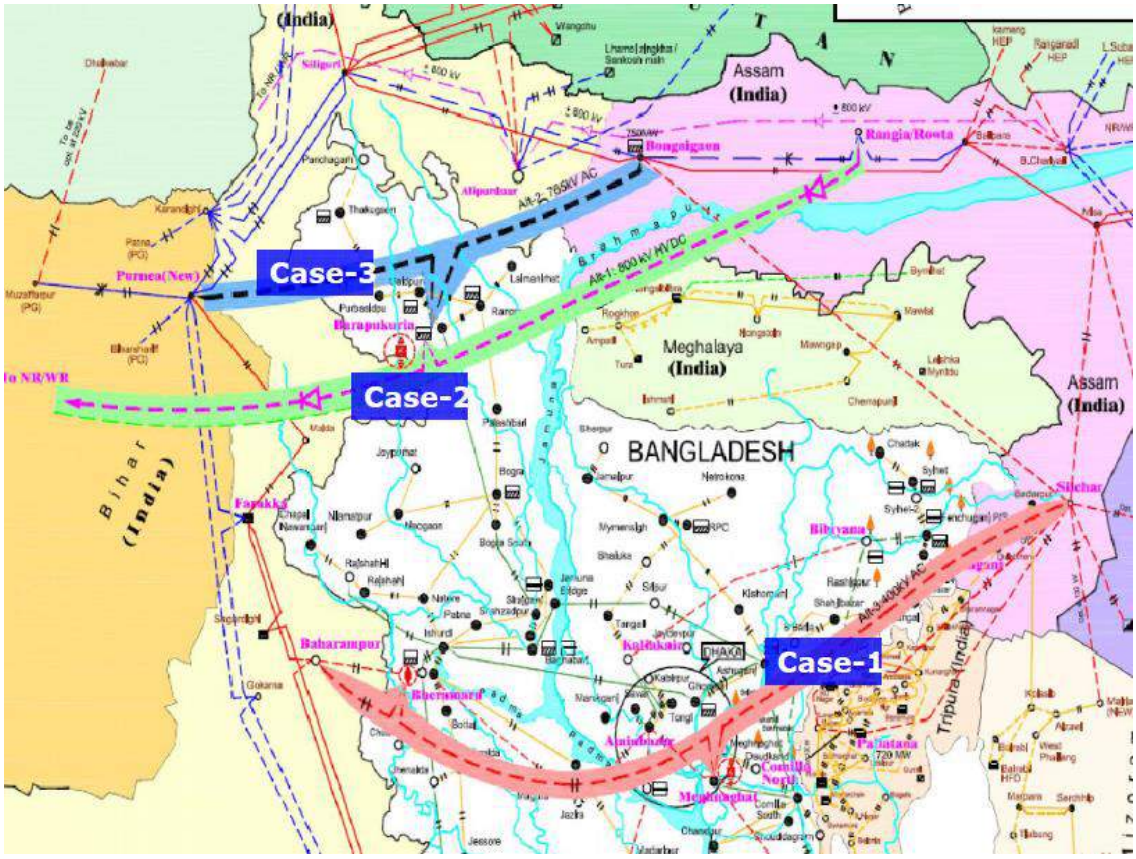
Source: JICA Survey Team

Figure 14-2 Electric Power Supply and Demand Situation in the Neighbouring Countries of Bangladesh (2030)

Hydropower development can be actively executed in Nepal, Bhutan, India's northeastern states, and Myanmar, and the capacity of the hydropower plants is expected to increase approximately by 10GW in each. As a result, the supply capacity from hydropower will increase to about 35% of the whole supply capacity in the rainy season. On the other hand, the supply capacity of hydropower in the dry season decreases below half, and a lack of supply capacity is feared in Nepal, which mainly supplies electricity by hydropower. However, because demand decreases greatly and the reserve capacity of thermal power can be secured in Bangladesh, which mainly supplies electricity by thermal power, enough supply capacity can be secured in the region as a whole.

14.2 Possibility of International power trading in Bangladesh

Transmitting hydropower from Bhutan and Nepal to Bangladesh is impossible without the consent of India, which is geographically located between Bangladesh and these countries. In order to tackle this problem, three new cases of inter-connection have begun to be planned.



Source: JTT Report

Figure 14-3 Grand Design of Bangladesh – India Interconnection Line

In June 2015, Bangladesh and India published a joint declaration, following a summit meeting between Prime Ministers from each country. Among other things, both PMs welcomed the consensus between Bangladesh and India to evacuate power from the North-eastern region of India (Rangia/Rowta) to Muzaffarnagar of India through Bangladesh, constructing a ±800 kV, 7000 MW HVDC multi-terminal bi-pole DC grid line with suitable power tapping points at Barapukuria in Bangladesh. Prime Minister Modi agreed in principle to consider Bangladesh's request to provide adequate power from this line for Bangladesh keeping in view the grid security of both countries. Noting Bangladesh's interest in importing power in the BBIN framework, the Indian PM agreed to favorably consider such imports subject to grid security, transmission, interconnection and the applicable laws, rules and regulations of the respective countries.

14.3 Selection of Hydropower Development Candidate Area for Bangladesh

14.3.1 Evaluation Criteria Setting

The JICA Survey Team proposes a set of evaluation criteria for the selection of candidate areas for hydropower development for Bangladesh, as is shown in the following table.

Table 14-1 Evaluation Criteria for Candidate Area Selection for Hydropower Development

	Evaluation Items	Evaluation Viewpoint	Importance
1	Political willingness for power trades with Bangladesh	Including hydropower development policy and institutional supporting measures	High
2	Demand-Supply Balance in hydropower development host country	The more surplus energy (even during the dry season) the host country secures, the more points earned. (with more opportunity to receive energy for Bangladesh)	Medium
3	Hydropower development potential volume	The more potential there is, the more opportunity to identify economically viable sites. Thus, higher score earned.	Medium
4	Interconnection modality with Bangladesh	Direct connection to Bangladesh is preferable over indirect connections through other network systems.	Medium
5	Proximity to the connection point in Bangladesh	The closer the better. This criterion includes ease of transmission line construction.	High
6	The value of electricity at the receiving point in Bangladesh	Connection to an area where there are fewer power sources is favored.	Low

Source: JICA Survey Team

All these evaluation items are of great importance in selecting candidate areas for hydropower development for Bangladesh. However, “political willingness for power trades with Bangladesh” and “proximity to the connection point in Bangladesh” are considered to be the most important.

14.3.2 Possible Candidate Areas for Hydropower Development to be connected with Bangladesh

(1) Possible Areas for Interconnection

The JICA Survey Team considers the following six areas to be possible candidate areas for hydropower development to be connected with Bangladesh.

Table 14-2 Candidate Areas for Hydropower Development to be Connected with the Bangladesh System

	Hydropower Development Area	Connecting point in Bangladesh	Connection Modality
1	Eastern Nepal	West (Bheramara)	To transmit energy to the closest substation in India and to connect the existing BTB in West Bangladesh through the Indian domestic network.
2	Western Bhutan	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
3	Eastern Bhutan	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
4	Meghalaya State, India	East (Bibiyana)	To directly connect with Bibiyana S/S
5	Arunachal Pradesh State, India	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
6	Western Myanmar	South	To directly connect with Anowara S/S

	Hydropower Development Area	Connecting point in Bangladesh	Connection Modality
		(Anowara)	

Source: JICA Survey Team

(2) Connection Illustration of Potential Hydropower Development Areas

The following map shows an illustration of the connection of hydropower development areas with Bangladesh.



Source: JICA Survey Team

Figure 14-4 Connection Illustration of Hydropower Development Areas with Bangladesh

14.3.3 Screening Based on the Evaluation Criteria

(1) Political Willingness for Power Trades with Bangladesh

In all the areas except Myanmar, the Governments are very much willing to undertake power trading with Bangladesh. It should be noted that the Government of Bhutan has the intention to prioritize hydropower development in the eastern area over the western area, where hydropower development is rather active, in order to seek balanced economic development in the country.

(2) Demand-Supply Balance in hydropower development host country

Nepal currently faces severe power shortages due to its lack of supply capacity, exercising rotational

load shedding routinely. It is expected that large hydropower plants will start operating in the near future, improving the demand-supply situation in the wet season. However, as this will not solve the demand-supply balance in the dry season, the securing of an energy surplus to sell to the rest of the region would not be envisaged. On the other hand, both in Bhutan and the State of Arunachal Pradesh, where there is enough supply capacity, it is possible to sell their surplus capacities to the rest of the region. In the State of Meghalaya, where it sells wet season surplus to other states and purchases power back in the dry season on a regular basis, surplus capacity in the dry season cannot be expected.

(3) Hydropower development potential volume
There is huge hydropower development potential in all the areas except for the State of Meghalaya. However, from the viewpoint of pumped-storage, there is prospective potential in Meghalaya.

(4) Interconnection modality with Bangladesh
It is possible to connect with the Bangladesh power system directly from the State of Meghalaya and Myanmar. On the other hand, transmitting energy through the Indian grid is prerequisite when Bangladesh receives power from Nepal or Bhutan. In the case that Bangladesh imports hydro energy from Bhutan or Arnachal Pradesh, Bangladesh can tap energy at the northern receiving point though a proposed ±800kV HVDC link between Northeast and Central India via Bangladesh. When Bangladesh purchases energy from Nepal, it would receive it at Bheramara BTB, where capacity augmentation is envisaged, passing a long way through Indian domestic power transmission network.

(5) Proximity to the connection point in Bangladesh
If hydropower in the State of Meghalaya is connected directly to Bibiyana S/S in Bangladesh, only 50km of transmission I lines are required. In the case of smaller capacity, such as 132kV transmission, the distance to the nearest substation may be approximately 20 to 30km. In transmitting hydro energy from Bhutan or Arunachal Pradesh, it will be prerequisite to be connected to Rangia S/S where an eastern AC/DC conversion station is located for the proposed ±800kV HVDC link between Northeast and Central India via Bangladesh. Because eastern Bhutan is close to Rangia S/S, transmission distance is within 100km. However, in evacuating hydro energy from western Bhutan, the transmission distance may exceed 200km. Also, receiving hydro energy from Arunachal Pradesh may require transmission lines over 200km. In the case of receiving hydro energy from Nepal, connection to the nearest substations in India allows Bangladesh to use the Indian domestic power networks. Therefore, transmission distance is considered to be less than 100km. Connection of hydro energy from Myanmar may require a transmission distance of over 200km.

(6) The value of electricity at the receiving point in Bangladesh
Connection to the load center may be the most valuable. However, each of the hydropower potential target areas in question is distant from the load center in Bangladesh. The next favorable case is connection to areas with supply capacity deficit. Because power plants are concentrated to the east of the Jamuna River, any supply capacity west of the Jamuna River will be highly appreciated. The currently proposed power receiving point along the proposed ±800kV HVDC link between Northeast and Central India is located at Barapukuria, east of the Jamuna River. Therefore, the value of electric power with this link is considered to be a little bit higher than that of electricity to be received east of the Jamuna River from the Indian State of Meghalaya or Myanmar. The value of hydro energy from Myanmar in particular may be relatively lower at the power receiving point because thermal power development at a larger scale is envisaged in southern Bangladesh.

(7) General Evaluation

The results of the screening mentioned above are summarized in the following table.

Table 14-3 Screening Results

		Weight	Nepal	Bhutan		India		Myanmar
			East	West	East	West	Arunachar	West
1	Political will for electricity export	3	5	3	5	2	5	2
2	Demand & supply balance	2	2	5	5	2	5	2
3	Hydro power potential	2	5	5	5	4	5	4
4	Connection method	2	3	2	2	5	2	5
5	Distance to connecting point	3	4	2	4	2	2	2
6	Value of electricity at connecting point	1	4	4	4	2	4	2
	Total		51	43	55	36	49	36

Source: JICA Survey Team

As a result of the above comparison, it is considered that hydropower development in the Indian State of Meghalaya and Bhutan is relatively promising. As for Nepal, when its supply-demand situation improves, the area would become promising.

With regard to Myanmar, without having an opportunity to visit, the JICA Survey Team can hardly confirm detailed information such as the Government's willingness to undertake power trading with Bangladesh. However, depending on the results of the confirmation on local situations, Myanmar may become a good candidate area for hydropower development for Bangladesh.

14.4 Selection of Hydropower Development Candidate Sites

Previous Chapter confirms two areas, namely East Bhutan and the Indian State of Meghalaya, as the most prioritized areas for hydropower development for Bangladesh.

14.4.1 Evaluation Criteria Setting

The following table shows a set of evaluation criteria to score potential hydropower sites and select development candidate sites.

Table 14-4 Evaluation Criteria for Hydropower Development Candidate Sites

	Items to be evaluated	Evaluation Viewpoint	Weight
1	Preference of the Government of Bangladesh	Larger generation capacity is preferable	5
2	Economy of the potential site	Evaluated by unit construction cost (USD/MWh) based on computation of construction cost and annual generation	5

	Items to be evaluated	Evaluation Viewpoint	Weight
		volume	
3	Required construction cost of dedicated transmission lines for energy evacuation	Unit transmission cost (USD/MWh) being calculated with construction cost estimate based on transmission line length and voltage level	2
4	Environmental issues	Evaluated on whether there is an existence of environmentally protected areas, endangered species or indigenous population nearby	4
5	Geological issues	Evaluated on whether there is a possibility of landslide during construction and sedimentation during operation	4
6	Issues for power export to Bangladesh	Evaluated by possibility of utilization of related transmission lines for power transmission to Bangladesh and energy output volume	3
7	Ease of construction and implementation	Status for construction access road, and availability of utilities/infrastructure such as electricity for construction	2
8	Operational flexibility	Evaluated by water storage capacity – the point is higher in the case of seasonal output adjustment	1
9	Project status	Evaluated by credibility of project feasibility based on progress of project preparation	1
10	Prospects for future JICA assistance	Evaluated on whether there is another sponsor for development funding and on total project cost (size)	3

Source: JICA Survey Team

Each of the potential sites is evaluated and scored alongside each of the above evaluation criteria with the highest score being five points. However, any potential sites with their scores in 4) Environmental issues and 5) Geological issues being two points or below will not be selected as candidates due to serious risk exposure, even if the total scores are relatively larger than others.

14.4.2 Comparison and Screening of Hydropower Development Sites alongside the Evaluation Criteria

(1) East Bhutan

In the eastern part of Bhutan, there are three sites and five power plants, Kuri-I (formerly known as Rotpashong), Gamri-I, Gamri-II, Nyera Amari-I and Nyera Amari-II for which pre-feasibility studies (Pre-F/Ss) have been conducted. The following table summarizes the techno-economic comparison among these five proposed power plants.

Table 14-5 Hydropower Development Potential Candidate Sites in East Bhutan

	Kuri-I	Gamri I	Gamri II	Nyera Amari I	Nyera Amari II
Installed caopacity Unit size × Units	1,230MW (205MW×6)	45MW (22.5MW×2)	85MW (42.5MW×2)	125MW (62.5MW×2)	317MW (105.67MW×3)
Design annual energy	5,265GWh	215.69GWh	399.90GWh	614GWh	1,556GWh
Construction cost (million)	USD 1,686.5	BTN 3,620 (USD 56.6)	BTN 5,587 (USD 87.3)	BTN 12,490 (USD 195.2)	BTN 22,291 (USD 348.4)
Unit construction cost per annual energy	USD 320/MWh	USD 262/MWh	USD 218/MWh	USD 318/MWh	USD 224/MWh
Length of T/L	400kV 140km	132kV 8km	132kV 36km	220kV 16km	220kV 66km
Construction cost of T/L	USD 70 million	USD 11 million		USD 22 million	
Unit construction cost	USD 13.3/MWh	USD 17.9/MWh		USD 10.1/MWh	

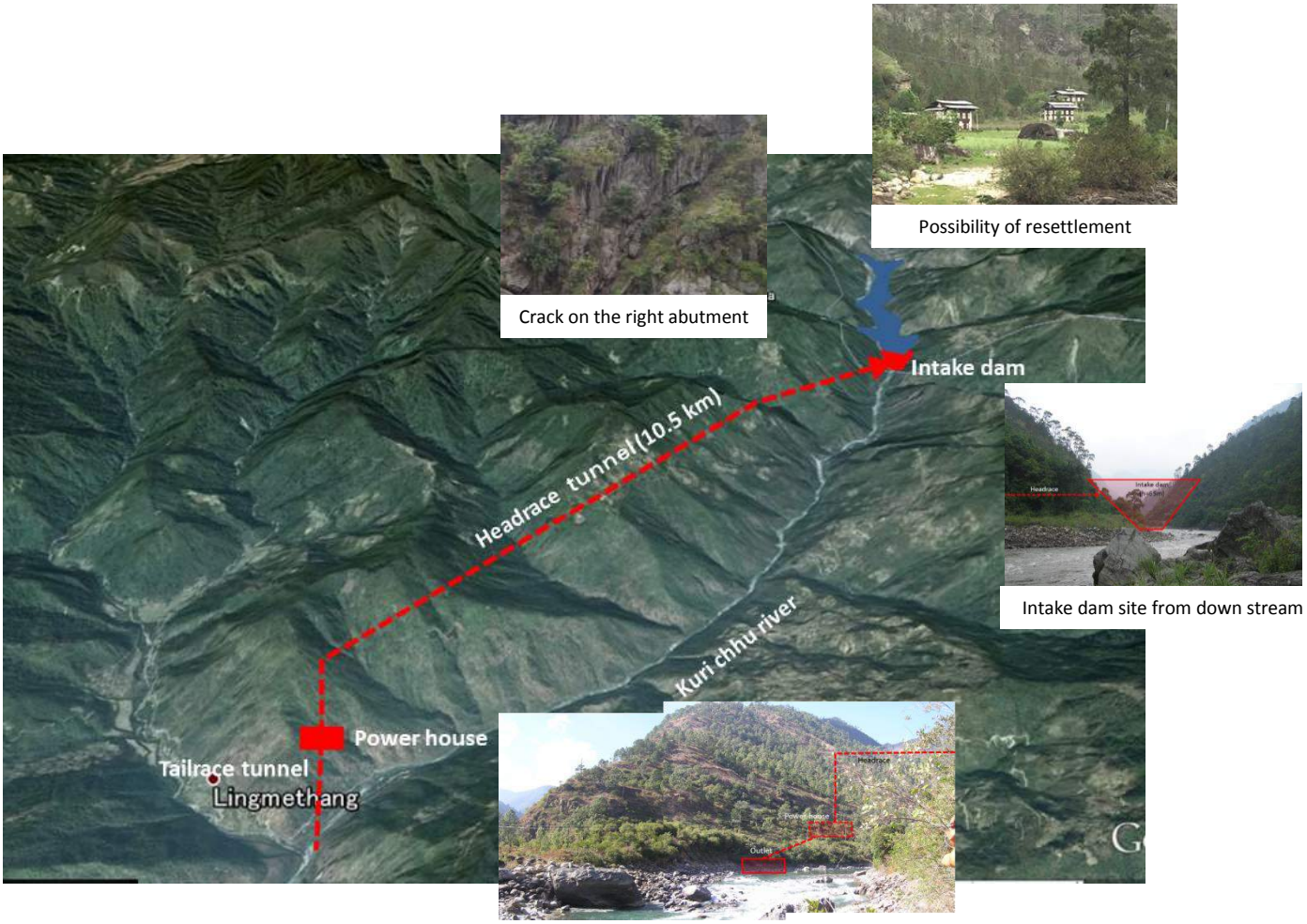
Source: JICA Survey Team

Table 14-6 Evaluation Results for Potential Hydropower Sites in East Bhutan

	Evaluated items	Weight	Kuri-I	Gamri I, II	Nyera Amari I, II
1	Preference of the Government of Bangladesh	5	5	1	3
2	Economy of the potential site	5	3	4	4
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	4	4
4	Environmental issues	4	3	2	3.5
5	Geological issues	4	4	3	2
6	Issues for power export to Bangladesh	3	3	2	3
7	Ease of construction and implementation	2	4	2	3
8	Operational flexibility	1	2	2	2
9	Project status	1	4	3	3
10	Prospects for future JICA assistance	3	2	4	3
	Total (weighted)		105	80	94

Source: JICA Survey Team

Kuri-I records the highest total score, followed by Nyera Amari and, in turn, Gamri. Kuri-I fits the expectation of the GOB in terms of its larger scale of development. Because there seem to be no significant impediments to development, the JICA Survey Team selects Kuri-I as the most prioritized development candidate.



"Image©2015CNES/Astrium, Image© 2015AutoNavi, Image ©2015Google" Source: JICA Survey Team

Figure 14-5 Outline of Kuri I Project

- All the facilities except the intake dam are constructed underground. However, the JICA Survey Team considered that a ground or semi-underground type powerhouse would be possible, so placement position of the powerhouse is an essential study point at the detailed design stage.
- Numerous trends of joints and cracks are seen on the rock surface on both the right and left river side. Detailed investigation and examination for these cracks on the right bank should be conducted in the FS stage.
- There are no settlements at the dam site, but part of the highway along the reservoir near the intake dam needs to be relocated due to the reservoir, and 3 permanent houses and other small facilities in Autsho village need to be resettled.

(2) The Indian State of Meghalaya

In the State of Meghalaya, there are three potential sites for conventional hydropower development with sizable capacity and considerable progress in project preparation, namely Mintdu Leshka-II, Umngot and Nongkohlait. The following table summarizes the techno-economic comparison among the three proposed power plants.

Table 14-7 Hydropower Development Potential Candidate Sites in Meghalaya

	Mintdu Leshka II	Umngot	Nongkohlait
Installed caopacity Unit size × Units	280MW (70MW x 4)	240MW (80MW x 3)	120MW
Design annual energy	895.29 GWh	838.73 GWh	379.34 GWh
Construction cost	INR 29,400 million (USD 460.5 million)	INR 15,646 million (USD 245 million)	INR 3,262 million*[1)] (USD 51.1 million)
Unit construction cost per annual energy	USD 514/MWh	USD 292/MWh	USD 135/MWh*[1)]
Length of T/L	220kV 98km	220kV 111km	220kV 95km
Construction cost of T/L	USD 27 million	USD 31 million	USD 27 million
Unit construction cost	USD 30.2/MWh	USD 37.0/MWh	USD 71.2/MWh

*[1)]: Data from Pre-F/S in 2004 Source: JICA Survey Team

The southern part of Meghalaya state has very steep geographical features, and has a lot of appropriate site of PSPP. Moreover, it is assumed that the optimal scale of the power plant will be 1,500MW class because it can expect a high head that exceeds 600m. However, a concrete site survey has not been done for the PSPP of Meghalaya state up to now.

Table 14-8 Evaluation Results for Potential Hydropower Sites in Meghalaya

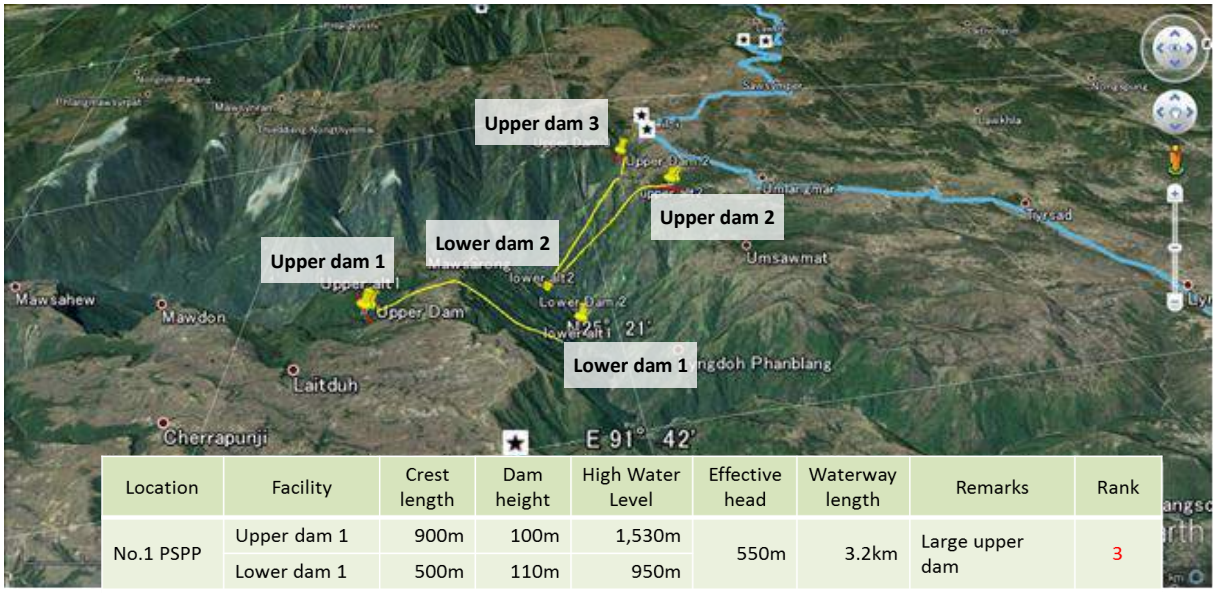
	Evaluated items	Weight	Mintdu Leshka II	Umngot	Nongkohlait	PSPP
1	Preference of the Government of Bangladesh	5	3	3	2	5
2	Economy of the potential site	5	2	3	4	4
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	3	2	4
4	Environmental issues	4	4	3	2.5	4
5	Geological issues	4	2	4	4	4
6	Issues for power export to Bangladesh	3	4	4	4	4
7	Ease of construction and implementation	2	4	3	3	3
8	Operational flexibility	1	2	4	2	5
9	Project status	1	4	4	3	1
10	Prospects for future JICA assistance	3	4	4	4	3
	Total (weighted)		95	102	95	118

Source: JICA Survey Team

When the hydropower of Meghalaya state is developed, it will be difficult for Bangladesh to import the whole quantity of power in order to transmit part of it to Meghalaya state and states in the vicinity. In short, because Bangladesh can only receive almost half of the amount of development, the development of a larger scale site is more preferable. Conventional hydropower is a development scale

of about 200MW, so the amount of receipt in Bangladesh is only about 100MW. On the other hand, because the PSPP is a development scale of 1,500MW class, almost 1,000MW can be expected for receipt in Bangladesh.
Based on the above-mentioned view, the JICA Survey Team selects PSPP as a development priority site in Meghalaya state.

The JICA Survey Team has conducted site surveys of candidate pumped storage power plant sites, and the three potential sites are proposed as suitable sites for a pumped storage power plant site in Meghalaya. However, this proposal is based on visiting and watching from the road on the plateau and desk study.



Location	Facility	Crest length	Dam height	High Water Level	Effective head	Waterway length	Remarks	Rank
No.1 PSPP	Upper dam 1	900m	100m	1,530m	550m	3.2km	Large upper dam	3
	Lower dam 1	500m	110m	950m				
No.2 PSPP	Upper dam 2	550m	40m	1,550m	690m	3.2km	Excavation of upper pond	2
	Lower dam 2	300m	140m	830m				
No.3 PSPP	Upper dam 3	450m	100m	1,500m	640m	4.1km		1
	Lower dam 2	300m	140m	830m				

"Image©2015DegitalGlobe, Image©2015CNES/Astrium, Image Landsat©2015Google" Source: JICA Survey Team

Figure 14-6 Three Candidate Sites for PSPP in Meghalaya

Because of the very steep geographical features, there are many suitable sites which satisfy the conditions of a location for the PSPP in the southern part of Meghalaya state, and a high head that exceeds 600m can be expected. Therefore, it is assumed that the optimal scale of the power plant will be 1,500MW class. However, no concrete survey on PSPP in Meghalaya state has been performed up to now at all. That is to say, sites that have geological issues or environmental issues etc. can be excluded, and an excellent, economical site can be selected.

A 400kV double-circuit transmission line with a length of 90km from the power plant to Bibiyana S/S in Ba Transmission Line Development Plan will be constructed. If the line is connected to the India system, it is an option to extend it to Killing substation in India by constructing an additional 100 km transmission line in a northerly direction.

14.5 Recommendations on Regional Power Interconnection

14.5.1 Challenges and Countermeasures of Power Imports

The challenges arising from importing power and their countermeasures are as follows.

(1) Energy Security

In the case of importing power from other countries, the risk of supply interruption caused by adverse relationships between the two countries needs to be considered. Electric power, which is different from other types of supply, is technically easy to shut down even in minutes. So it is necessary to avoid excessive reliance on other countries in order not to place oneself in a serious situation. Specifically, the capacity of imported power from one country should be within the limit of generating reserve margin and also 10% of all supply capacity in order to continue the supply in the event of supply interruption. In the case of Bangladesh, imported power from Bhutan and Nepal has to be transmitted through India. Therefore, imported power from Bhutan and Nepal should be within 10% of all supply capacity.

(2) Compliance with Commissioning Timing of the Transmission Lines in India

The power import plan through India hinges on commercial operation of the Case 2 HVDC (±800kV) interconnection line or the Case 3 HVAC (765kV) interconnection line. These interconnection lines shall be constructed in close cooperation with India after fully understanding and confirming India's needs.
When hydropower capacity exceeds 3,000MW in Arunachal Pradesh, the ±800kV inter-state transmission line currently under construction reaches its full transmission capacity, giving rise to a need for the construction of the Case 2 interconnection line. On the other hand, there seems to be no reason for India to realize the need for the Case 3 line for the time being. However, need for the Case 3 line's construction will arise if construction of the Case 2 line is delayed due to a delay in the hydro power development in Arunachal state, or high construction costs etc.

(3) Massive blackout due to large scale power loss of supply

It is desirable to import as much power as possible through one connecting point from the viewpoint of economic efficiency. However, if a huge amount of power is transmitted through one connecting point, it can lead to the risk of massive blackout, such as blackout across the entire country during the shutdown of the connecting line. Massive blackout occurred on 1st November 2014, triggered by 500MW power loss of the BTB break down on the inter-connection line from India. In order to avoid this risk, the limit of the power loss level needs to be worked out, by checking sufficiently continuous power generators' operation during frequency drop and the load shedding scheme during large scale power supply loss. Based on this result, the maximum level of import capacity in one inter-connection point has to be decided. In concrete terms, it is preferable that the amount of imported power through one connecting point is within 10% of the demand.

(4) Mutual Interference due to Grid Accidents

Conducting power trading means transmission lines are connected between two neighboring countries, which will lead to the threat of mutual interference due to grid accidents. But it is possible to minimize the influence by connecting DC lines. Current inter-connection lines between India and Bangladesh apply DC lines or non-connected lines by switching the load. There will be a few mutual interferences due to grid accidents in these two cases.

14.5.2 Proposals on Power Import Planning

Reflecting the aforementioned issues, the Survey Team proposes the following two power import plans for Bangladesh.

(1) High Case Scenario

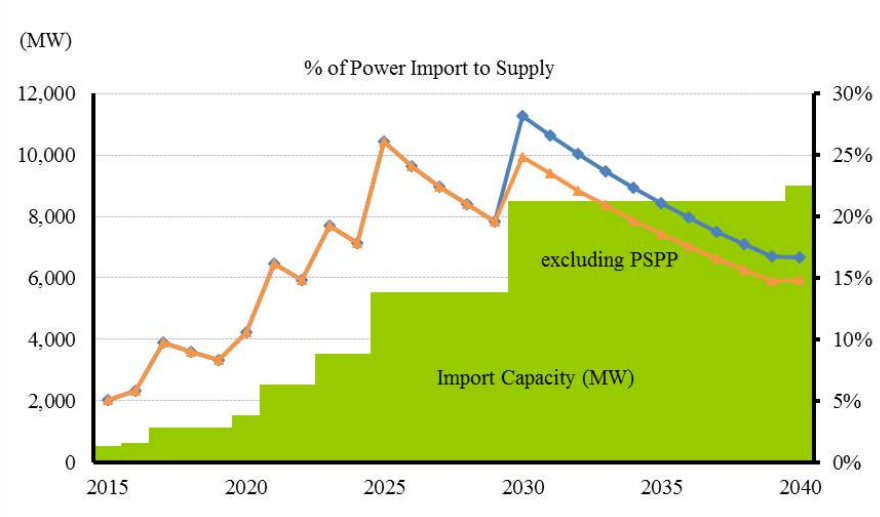
The High Case Scenario, in which more electric power can be expected due to operation of the Case 2 line and Case 3 line starting on schedule, is shown below.

Table 14-9 Power Import Plan (High Case Scenario)

		MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100	2016	Some load (100MW) in Comilla (N) S/S will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	1,000	2021	Additional extension of Bheramara HVDC Power import from Nepal (including GMR)
5	Tripura - Comilla	400	2020	Construction of HVDC (500MW) in Comilla (N) S/S. Some load (100MW) in Comilla (N) S/S will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	1,000	2023	Power import by using Case 2 T/L (±800kV DC)
7	Rangia/Rowta - Barapukuria	1,000	2025	Power import by using Case 2 T/L (±800kV DC)
8	From Nepal (Purnea - Barapukuria)	1,000	2025	Power import by using Case 3 T/L (initially 400kV AC)
9	Bongaigaon/Rangia - Jamarpur	1,000	2030	Power import from Bhutan
10	Bibiyana - Meghalaya (PSPP)	1,000	2030	PSPP in Meghalaya State
11	From Nepal	1,000	2030	Power import by using Case 3 T/L (upgrade to 765kV AC)
12	Cox's Bazar - Myanmar	500	2040	Power import from Myanmar
	Total	9,000		

Source: JICA Survey Team

The following figure shows the import volume and its share against the total supply capacity in the high case scenarion power import plan.



Source: JICA Survey Team

Figure 14-7 Future Power Import Volume and its Share (High Case Scenario)

The share of power imports against the total supply capacity will be between 20% and 25% within the permissible range, albeit a little bit large.

(2) Low Case Scenario

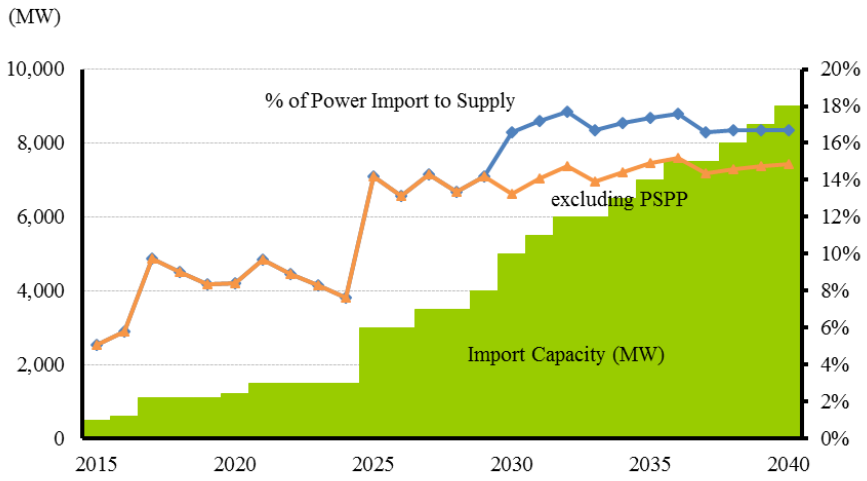
The Low Case Scenario, in which excessive import of electric power from neighboring countries is not expected, is shown below.

Table 14-10 Power Import Plan (Low Case Scenario)

		MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100 100	2016 2020	Some load (100MW+100MW) in Comilla will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	500 500	2027 2031	Additional extension of Bheramara HVDC Power import from Nepal
5	Tripura - Comilla	300	2020	Construction of HVDC (500MW) in Comilla. Some load (100MW+100MW) in Comilla will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	1,000	2025	Power import by using Case 2 T/L (±800kV DC)
7	Rangia/Rowta - Barapukuria	500 500	2036 2039	Power import by using Case 2 T/L (±800kV DC)
8	From Nepal (Purnea - Barapukuria)	500 500	2025 2029	Power import by using Case 3 T/L (initially 400kV AC)
9	Bongaigaon/Rangia - Jamarpur	500 500	2032 2034	Power import from Bhutan
10	Bibiyana - Meghalaya (PSPP)	1,000	2030	PSPP in Meghalaya State
11	From Nepal	500 500	2035 2038	Power import by using Case 3 T/L (upgrade to 765kV AC)
12	Cox's Bazar - Myanmar	500	2040	Power import from Myanmar
	Total	9,000		

Source: JICA Survey Team

The following figure shows the import volume and its share against the total supply capacity in the low case scenarion power import plan.



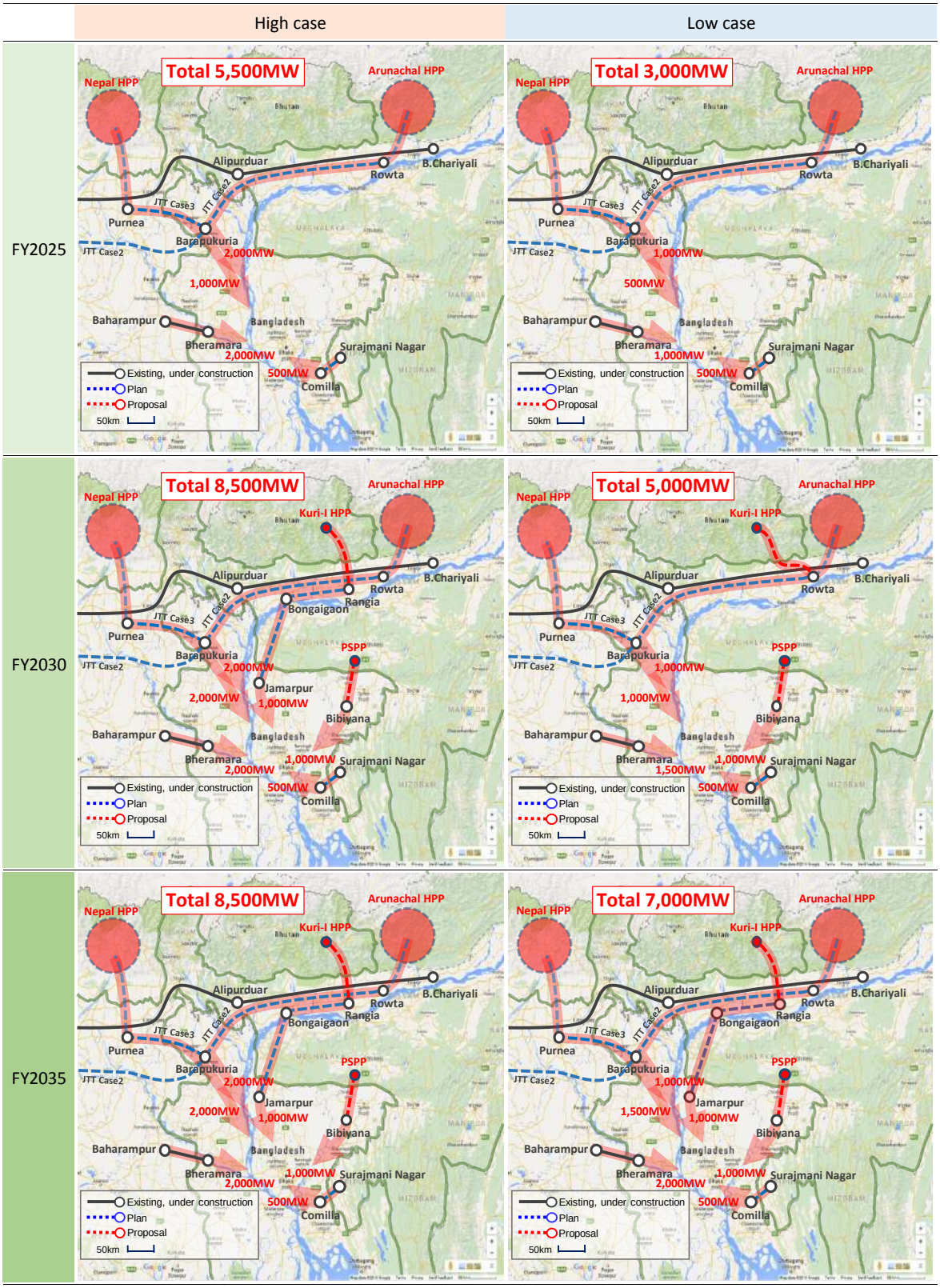
Source: JICA Survey Team

Figure 14-8 Future Power Import Volume and its Share (Low Case Scenario)

The share of power imports against the total supply capacity will be approximately 15% within the appropriate range after 2025.

(3) Power import situation

The power import from neighboring countries situation in 2025, 2030 and 2035 is shown below.



Source: JICA Survey Team

Figure 14-9 Power Import Situation

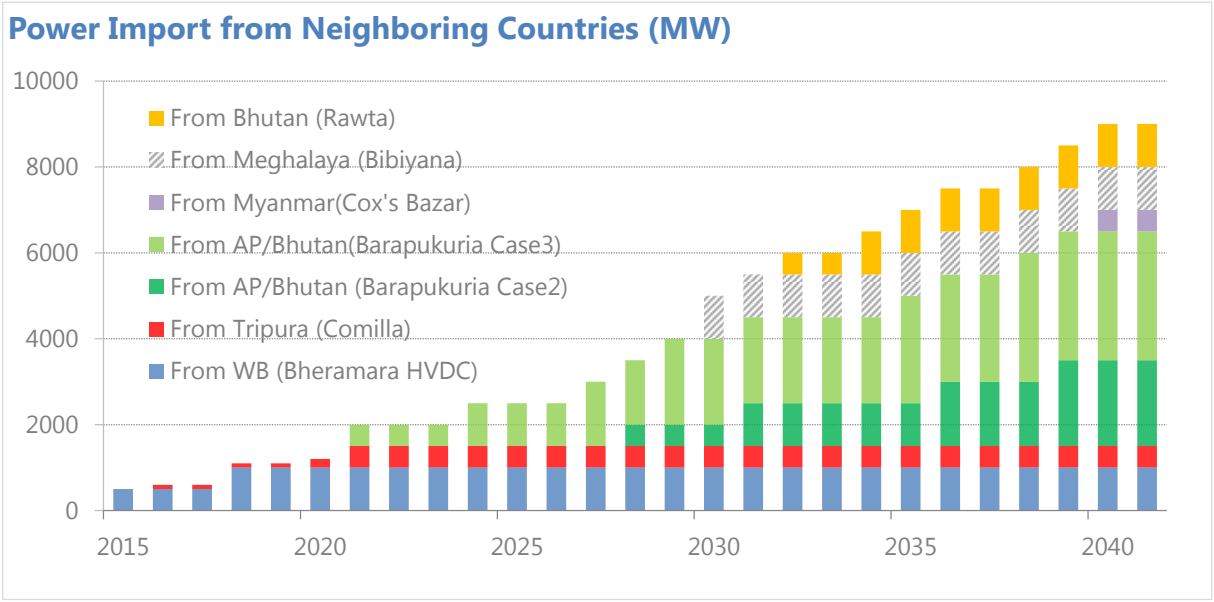
(4) PSMP2016 Scenario

The following table and figure show the PSMP2016 scenario based on the low case scenario, following discussions with the relevant institutions.

Table 14-11 PSMP2016 Scenario

Project Name	Location	Capacity (MW)	Company	COD (FY)
Bheramara-Bharampur HVDC		1000		
Bheramara-Bharampur HVDC Phase 1(from India)	India	500	BPDB	2013
Bheramara-Bharampur HVDC Phase 2 Bheramara - Baharampur (India)	India	500	BPDB	2018
Comilla - Tripura HVDC		500		
Comilla - Tripura HVDC Phase 1-1 (100MW) (India)	India	100	BPDB	2016
Comilla - Tripura HVDC Phase 1-2 (100MW) (India)	India	100	BPDB	2020
Comilla - Tripura HVDC Phase 2 (300MW) (India)	India	300	BPDB	2021
Case 2 HVDC (Barapkuria S/S)		2000		
Case 2 HVDC (Barapkuria S/S) Phase I-1 Bheramara - Baharampur Arunachal, India (East India)	Arunachal, India (East India)	500	BPDB	2028
Case 2 HVDC (Barapkuria S/S) Phase 1-2 Bheramara - Baharampur Arunachal, India (East India)	Arunachal, India	500		2031
Case 2 HVDC (Barapkuria S/S) Phase II	Arunachal, India	500	BPDB	2036
Case 2 HVDC (Barapkuria S/S) Phase III	Arunachal, India	500	BPDB	2039
Case 3 HVDC (Barapkuria S/S)		3000		
Case 3 HVDC (Barapkuria S/S) Phase I From India (Purnea - Barapukuria) (India)	India	500	BPDB	2021
Case 3 HVDC (Barapkuria S/S) Phase II Phase I From India (Purnea - Barapukuria) (India)	India	500	BPDB	2024
Case 3 HVDC (Barapkuria S/S) Phase III From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2027
Case 3 HVDC (Barapkuria S/S) Phase IV From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2029
Case 3 HVDC (Barapkuria S/S) Phase V From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2035
Case 3 HVDC (Barapkuria S/S) Phase VI From Nepal (Purnea - Barapukuria) (Nepal)	Nepal	500	BPDB	2038
Bibiyana - Meghalaya (PSPP) (India)	Meg	1,000	BPDB	2030
Cox's Bazar - Myanmar	Myan	500	BPDB	2040
Rawta - Jamarpur HVDC		1,000	BPDB	
Rawta - Jamarpur HVDC PhaseI Bongaigaon/Rangia - Jamarpur (Bhutan)	Bhutan	500		2032
Rawta - Jamarpur HVDC PhaseII Bongaigaon/Rangia - Jamarpur (Bhutan)	Bhutan	500	BPDB	2034
Total		**9,000**		

Source: JICA Survey Team



Source: JICA Survey Team

Figure 14-10 PSMP2016 Scenario

14.5.3 Implementation Arrangement

Agreement acquisition with India is indispensable in order to achieve the plan for power imports from the neighboring countries that are mentioned above. In particular, it is important to negotiate tenaciously on the following items.

- Advanced development of the Case 3 line
  The Case 3 line is more flexible than the Case 2 line, and more effective for Bangladesh. Because Bangladesh can import electric power from various regions by using the Case 3 line it is important that it aims to advance development of this line.
- Securing power transmission capacity in India
  Bhutan and Nepal are positively in favor of electric power exports to Bangladesh. However, when Bangladesh imports electric power from the two countries, it must pass through the Indian system. It is especially important to match the system development plan in India and to advance the plan if necessary in order to secure the power transmission capacity in India.
- Direct connection of PSPP in Meghalaya state to Bangladesh system
  The PSPP is a very effective tool for stabilizing the system and improving the power quality. It is necessary to connect the generator directly to the Bangladesh system to enjoy such an effect. As for the PSPP in Meghalaya state, large-scale development of 1,000MW or more is possible at each site. Therefore, it is possible to secure economy even if the system is divided into two parts at the power plant and half of the generators connect with the Bangladesh system directly.

The existing communication channel suffices for discussions over bilateral power trades between Bangladesh and India. However, if power trades with Bhutan and Nepal are involved, the use of the Indian network is inevitable. Bilateral discussions between a seller (Bhutan or Nepal) and a buyer (Bangladesh) are not enough to facilitate such power trades. A multilateral framework that includes India is a prerequisite.

To provide a discussions platform of this kind, a group of countries comprising Bangladesh, Bhutan, India and Nepal (BBIN) has been formulated. BBIN holds Joint Working Groups (JWGs) twice a year. Therefore, it seems to be most effective to discuss regional power trades and interconnection in JWGs for the implementation of specific projects.

14.6 Nuclear Power Generation

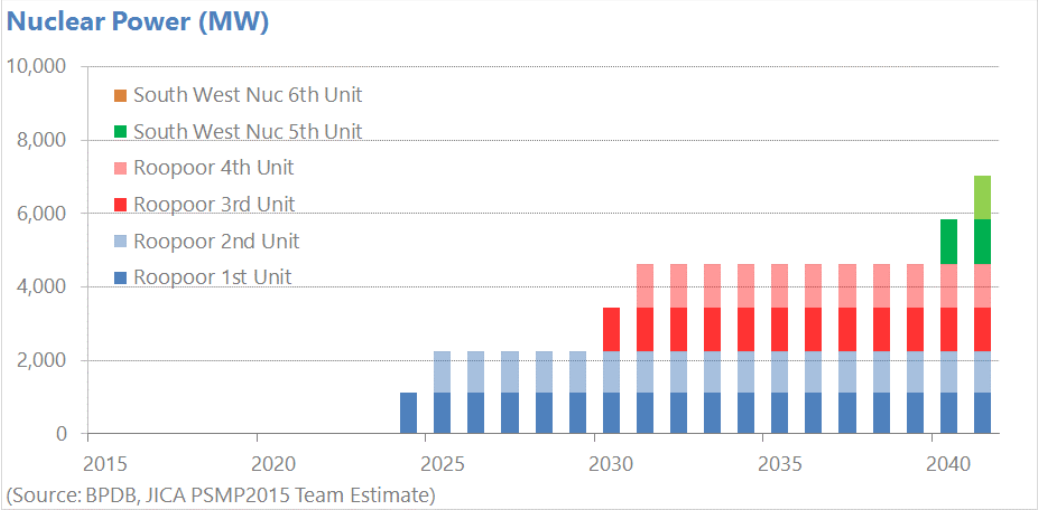
14.6.1 Nuclear Power Generation in PSMP2016

PSMP2016 aims to create a well-balanced power generation environment that maximizes the respective advantages of different types of power generation methods, including nuclear power, thermal power, hydropower generation, and power imports from neighboring countries, from the comprehensive perspective of stable supply, or energy security, environmental performance, and economic efficiency.

Daily power demand, or load curve varies according to season, temperature, and time of day. Since electricity cannot be stored, and must be used as it is produced. Gas and oil based thermal power generation, by virtue of its ability to respond quick flexibly to ever-changing power demand, supplies middle and peak load. Nuclear power, power import, hydropower, and coal-based thermal power generations are considered as a base load energy. This combination of different types of power sources is commonly referred to as the best mix of power sources. In this PSMP2016, nuclear power generation plays an important role in providing a stable base load.

The following figure shows the PSMP2016 scenario on nuclear power generation, following discussions with the relevant institutions. It is assumed the first unit 1200MW is to start operations by 2024 and the second 1200MW by 2025 on PSMP2016. These figures are preconditioned in the power development planning without alternative cases, which means nuclear power is assumed as one of the Fixed Factors in terms of generation capacity in the simulation, considering the government's nuclear power projects planning.

However, realization of these plans may face some challenges. In this sub-chaper, situation in Bangladesh will be put together, and those challenges be pointed.



Source: JICA Survey Team

Figure 14-11 Nuclear Power Development on PSMP2016

14.6.2 Development of Nuclear Power Generation in Bangladesh[67]

Peaceful uses of Nuclear Technology were initiated in Bangladesh in early 1960's under the framework of the then Pakistan Atomic Energy Commission (PAEC). After independence, Bangladesh

[67] IAEA Country Nuclear Power Profiles, 2016 update

became a Member State of the Agency in 1972. The Bangladesh Atomic Energy Commission (BAEC) was formed in 1973 by Presidential Order No. 15 with the goal of utilization of Nuclear Science & Technology for national development. The nuclear establishment in the country existed and carried out related activities even before its independence from Pakistan. The Commission was entrusted with the following charter of duties: "Promotion of the peaceful uses of atomic energy in Bangladesh, the discharge of International obligations connected therewith, the undertaking of research, the execution of development projects involving nuclear power stations and matters incidental thereto." Since then, the Commission pursued various R&D projects, established a number of research and service providing centres with necessary laboratory facilities and equipment, trained working scientists and developed supporting facilities that can be used to meet the fast changing trends of scientific and technological pursuits of the modern world.

The Law on Nuclear Safety and Radiation Control was enacted in 1993. Considering that BAEC was the only national institution that has expertise and trained human resources needed for the enforcement of the law, it was also given nuclear regulatory responsibility. On 12 February 2013, a separate regulatory organization was set in order to separate promotional responsibilities from the regulatory ones, in order to attain the required transparency in nuclear safety and radiation control especially in all stages of licensing and inspection of nuclear facilities and radiation sources.

Some of the key events milestones for Bangladesh national Nuclear Power program are as follows, and among those events, one of the most important milestones are also highlited.

- 1963: Rooppur site selected for implementation of NPP
- 1971-78: 1987-88: Feasibility studies for site and first NPP conducted. Further feasibility studies for site and first NPP conducted.
- 1996: National Energy Policy identifies nuclear power as an option
- 2000: Bangladesh Nuclear Power Action Plan (BANPAP) approved by the government
- 2010: National Parliament approves first NPP project and new structure for NP program development (equivalent NEPIO) were formed (National Committees, Technical Committee, Working Group).
- 2011: IGA with Russia signed for the first NPP with two VVER units, each of 1000 MW
- 2012: Bangladesh Atomic Energy Regulatory Act (BAER) was passed in the National Parliament on 19th June 2012.
- 2013: Bangladesh Atomic Energy Regulatory Authority was formed as a separate entity on 12th February 2013.
- 2015: General Contract for EPC was signed with Russian Enginnering Company for main stage construction of Rooppur NPP
- 2016: Inter-Governmental State Credit Agreement for financing the main stage construction of Rooppur NPP.

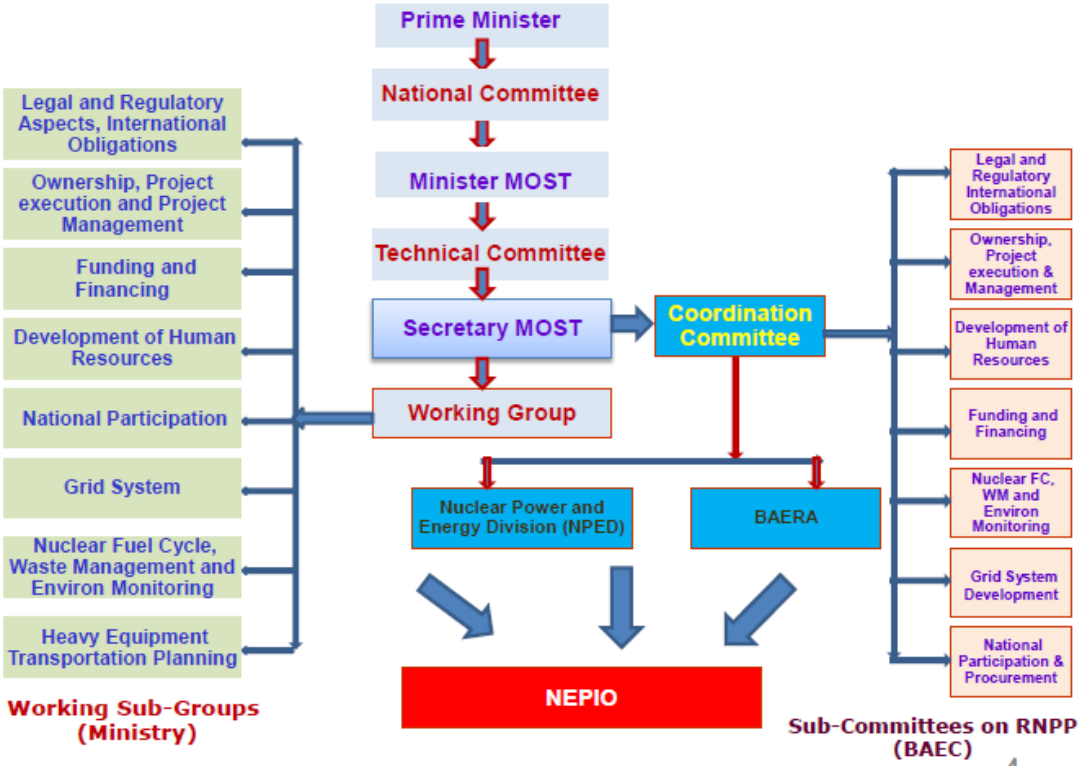
14.6.3 Implementation framework

The nation and the government have been showing their strong commitment; the National Parliament of Bangladesh passed a resolution in 2010: “In order to overcome the increasing power crisis in the country nuclear power plant shall be established immediately”. The government formed high-level committees in 2010, headed by the Prime Minister, to perform the tasks recommended in the IAEA Nuclear Energy Series Publications for the development of Policy Documents and Infrastructure Development – This set of committees, the Nuclear Energy Program and Implementation Organization (NEPIO), together with the government, have been performing the necessary actions towards realization of nuclear power plants.

According to the Nuclear Power Plant Act 2015, Bangladesh will set up the Nuclear Power Company of Bangladesh (NPCB) to run the plant, though ownership remains with the BAEC in accordance with

the recommendation from NEPIO. In the NPCB, the Science and technology secretary will be the director and chairman of the company. The other directors will include BAEC chairman, an additional or joint secretary from the science and technology ministry, Finance Division and the Economic Relations Division, a representative from FBCCI, Power Development Board chairman and Power Grid Company of Bangladesh Limited managing director.

Regarding nuclear power development, BAEC is strictly following IAEA guidelines. In NEPIO, there is a National Committee headed by prime minister. Secretary, Power Division is member of that Committee. Besides, representatives from Power Division participate in different phases of Rooppur NPP development. Grid system development is an important issue in nuclear project. There is a committee for Grid System development. BPDB and PGCB jointly prepared TOR for grid system study and one Russian company was engaged for that study. BPDB will purchase all power from RNPP as a single buyer. Power Purchase Agreement (PPA) will be signed between BPDB and BNPCL like Materbari coal power plant. Chief Engineer (P&D) is member of technical and financial negotiation committees.



Source: Ministry of Scenence &Technilogy, 2015

Figure 14-12 Nuclear Energy Program and Implementation Organization (NEPIO)

14.6.4 Ruppur Nuclear Power Plant Project

(1) Project outline and government Decision[68]

The nuclear power plant (Ruppur Nuclear Power Plant, RNPP) will be built at Ruppur, 200 km north-west of Dhaka, at Paksey union on the bank of the river Padma in the Ishwardi subdistrict of Pabna District, in the northwest of the country as shown in the following figure.

In February 2011, the Governments of Bangladesh and Russian Federation signed a Cooperation

[68] IAEA Country Nuclear Power Profiles, 2016 update

Agreement to build the approximately 2,400 MW with two reactors.
Due to limited resources and competencies, Bangladesh is considering building the Rooppur NPP through an Inter-Governmental arrangement (IGA). On 2 November 2011, Bangladesh signed an IGA with the Russian Federation for cooperation on construction of a NPP with two units, as well as in the establishment of necessary infrastructure to ensure the proper operation. BAEC is appointed as the customer for IGA on behalf of Bangladesh government. To implement the provisions of the IGA, a General Contract for construction of Rooppur NPP needs to be concluded.
As of September 2016, RNPP obtained site clearance approval from Bangladesh Nuclear Regulatory Commission and site preparation work is going on.



Source: JICA Survey Team

Figure 14-13 Location of RNPP

(2) Finance
Russia agreed to build the Rooppur plant in an intergovernmental agreement signed in 2011, and agreed to provide $500 million to finance preparatory work including engineering surveys.
In July 26, 2016, Bangladesh and Russia signed a credit agreement of amount 11.38 billion US $ (90% of total project cost) for RNPP construction with an interest rate of Libor plus 1.75%. Bangladesh will pay off the loan within 28 years with a 10-year grace period[69].

(3) Technical assistance from Russia[70]
The contract signed in October 2013 by NIAEP-ASE and Bangladesh Atomic Energy Commission is a technical agreement covering the design stage of the project, which forms the basis for obtaining the necessary licences and starting construction of the plant. Rooppur's two reactors will be based on a modified version of the NPP-2006 VVER (pressurized water reactor) with a proven track record. Russia and Bangladesh will sign fuel supply agreement soon for fuel supply chain. Regarding O&M, there will another agreement to be signed later on.

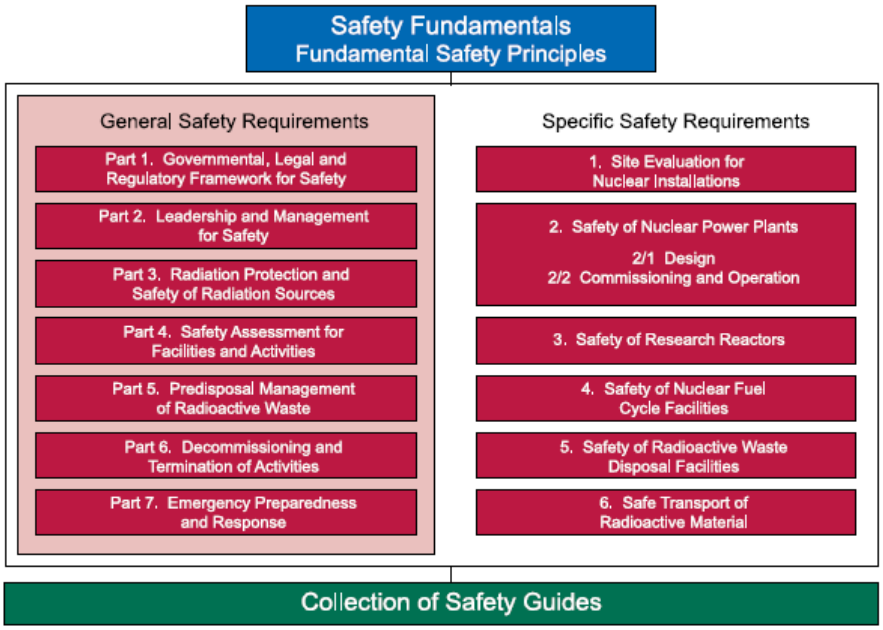
14.6.5 Challenges for Bangladesh

(1) Meeting IAEA safety standards71
Nuclear safety remains the highest priority for the nuclear sector. Regulators have a major role to play to ensure that all operations are carried out with the highest levels of safety. Safety culture must be promoted at all levels in the nuclear sector (operators and industry, including the supply chain, and regulators) and especially in newcomer countries (Nuclear energy roadmap actions and milestones,

[69] World Nuclear News, World Nuclear Association, London, December, 2015
[70] Based on information from Secretary, Ministry of Science and Technology, 2015
[71] IAEA Safety Standards homepage

IEA, 2015) like Bangladesh. Followings are major frameworks to secure the nuclear safety to be followed and utilize for Bangladsh.

Nuclear safety is a global issue. There are many instruments for achieving high level of nuclear safety on a global basis, such as IAEA safety standards, safety review services provided by the IAEA. The IAEA safety standards provide a system of safety fundamentals, Safety Requirements and Safety Guides for ensuring safety. They reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. The IAEA safety standards are applicable throughout the entire lifetime of facilities and activities existing and new utilized for peaceful purposes, and to protective actions to reduce existing radiation risks. For proceed nuclear power project, all shall follow the IAEA safety standards.



Source: IAEA Safety Standards homepage

Figure 14-14 Structure of IAEA Safety Standards

IAEA recommends some critical issue for strengthen nuclear safety

- The regulatory body should be strengthened. The draft Bangladesh Atomic Energy Regulations Act of 2011 should be promulgated as soon as possible to establish an independent regulatory body.
- Management of the nuclear infrastructure development should be strengthened. Bangladesh should commit to ensure appointment of leaders (especially in future owner and regulatory body) with appropriate training and experience for leadership and management of safety. Integrated management systems (including quality management) should be planned and implemented in both BAEC and the regulatory body that define the organizational goals and key processes in sufficient detail.

(2) Establishment of fuel cycle management[72]

Based upon the existing nature of the nuclear business worldwide, Bangladesh is considering a long-term contract and transparent suppliers' arrangements with supplier(s) through backing of the respective government in order to ensure availability of fuel for the nuclear power reactor of the country. Examples would be fuel leasing and fuel take-back offers, commercial offers to store and

[72] IAEA Country Nuclear Power Profiles, 2016 update

dispose of spent fuel, as well as commercial fuel banks. On the other hand, at present there is no international market for spent fuel disposal services except for the readiness of the Russian Federation to receive Russian supplied fuel. Storage facilities for spent fuel are in operation and are being built in several countries.

Bangladesh is considering accessing detailed technical descriptions of the nuclear fuel assemblies offered from the supplier side, including physical, thermo-hydraulic, thermodynamic and mechanical data as well as calculations for batch planning (short term and long term). The supplier shall provide the QA programme, Handling and inspection methods for new and spent fuel and Tools for fuel and control rod manipulation and the scope of supply and services. The first core as well as the first reload should be included in the scope of supply for the plant. The bidders should include the supply of further reloads as an option.

IEAE points out that the general concerns of Bangladesh about the nuclear fuel cycle are as follows.

- The owner/operator of the nuclear plant in Bangladesh needs to ensure availability of fuel for the NPP from supplier(s) covering its entire life cycle.
- The above life cycle supply assurance shall include all services related to the front end of the fuel cycle. "Fuel leasing-fuel take-back" model (full or partial) is conceivable for Bangladesh.
- Alternate sources of services and supply of the front end of fuel cycle should be identified to accommodate any unforeseen circumstances.
- Depending on the size of the nuclear power programme, efforts will be made to acquire the technology of fabrication of fuel elements based on imported raw materials and enrichment services in order to ensure security of fuel supply.
- Pending a final decision on the back-end of the fuel cycle, the NPPs will have provision for on/ off -site spent fuel storage, the size of which shall be sufficient to store the spent fuel generated over their respective life cycles.
- Sufficient security and physical protection and safety of the fuel storage on-site will be provided in accordance with the relevant provisions of the non-proliferation regime, as well as national law and regulations on nuclear safety and radiation control.

Bangladesh will consider any suitable model of nuclear fuel cycle under the responsibility of the IAEA as the guarantor of service and supplies, e.g. as administrator of a fuel bank.
Bangladesh opines that as far as assurances of supply are concerned, the proposed multilateral approaches to nuclear fuel cycle could provide the benefits of cost-effectiveness for developing countries with limited resources. Bangladesh is strongly supporting the Agency's approach of developing and implementing international supply guarantees with IAEA participation.

(3) Proper knowledge about nuclear safety and Public Acceptance
Many kinds of programmes, such as meetings and seminaars with journalists, local people, have been arranged till now, and Bangladesh has established Nuclear Industry Information Center in 2013. [73]
These kind of activities should be continued and enhanced for the public knowledge which will be the basis for public acceptance.
However, BAEC has conducted survey in 2015 on public acceptance / awareness for nuclear power project and it is found that still concrete public opinion for nuclear power generation has not yet formed in Bangladesh since accurate information of nuclear generation technology has not became widely and correctly known.
Therefore, the government has to do more supporting enlightenment activities to enhance accurate technical knowledge on nuclear generation with good point and bad point as well as safety issue.
It is also recommended to review other countries' experience of interactive communication with

[73] Presentation by MoST, "NATIONAL NUCLEAR POWER PROGRAMME OF BANGLADESH", https://www.iaea.org/NuclearPower/Downloadable/Meetings/2014/2015-02-03-02-06/D1_S2_Bangladesh_Akbar.pdf

public (citizen society) on nuclear technology and its safety, and ask for necessary cooperations.
As for emergency preparedness, several committees have been formed involving relevant stakeholders to formulate the emergency management system during the operation of Nuclear Power Plant in the territory of Bangladesh. These committees have already held several meeting with national and international experts. The Government is also very much eager to develop a standard emergency preparedness system for the densely populated country.



Source: Ministry of Science and Technology, 2015

Figure 14-15 Nuclear Industry Information Center

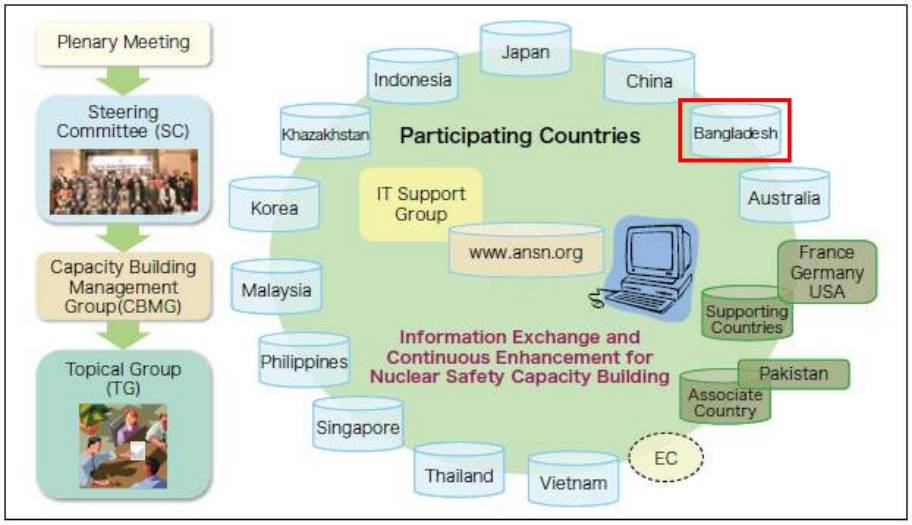
In addition, the government is preparing the Multi purpose information center around Rooppur NPP site to strengthen public communication strategy with public and media. Expected PR-program is as follows;

- Scientific workshops & round tables, discussion clubs
- Information center
- Social networks/ Social activities
- Expert opinions
- Televisions (talks shows, documentaries)
- Book "100" Facts bout Nuclear Energy
- Communication of press releases & organization of interviews
- Interaction with neighboring countries…etc

(4) Participating international framework[74]
The Asian Nuclear Safety Network (ANSN) was launched in 2002 to pool, analyze and share nuclear safety information, existing and new knowledge and practical experience among the countries. Moreover, the ANSN is expected to be a platform for facilitating sustainable regional cooperation and for creating human networks and cyber communities among the specialists of those countries. Development of a regional capacity building system composed of knowledge network, regional cooperation and human networks will serve for enhancement of nuclear safety infrastructures in the participating countries, and will serve eventually for ensuring and raising the safety levels of nuclear installations in the region. The ANSN has recently expanded to become a forum for broader safety strategy among countries in the region.
The current participating countries are **Bangladesh**, China, Indonesia, Japan, Kazakhstan, Republic of Korea, Malaysia, the Philippines, Singapore, Thailand and Vietnam. Australia, France, Germany and the USA are ANSN supporting countries. Pakistan is an associate country in activities related to the

[74] Asian Nuclear Safety Network homegage

safety of nuclear power plants and/or strengthening their regulatory frameworks.
For proceed nuclear power project, all shall work with international framework.



Source: Japan Nuclear Energy Safety Organization

Figure 14-16 Asian Nuclear Safety Network (ANSN)

(5) Ratification to the international laws and standards
Bangladesh has not ratified the following critical international laws:
- Vienna Convention on Civil Liability for Nuclear Damage
- Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage
- Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, etc.[75]

For the implementation of RNPP, these international laws and standards should be followerd.

(6) Other issues
There are many issues such as;
- Nuclear power planning integrated into the part of power & energy planning, such as alternative generation capacity in case of outage of nuclear power plant, reliability of the power supply system
- Development of science technology experience within the country
- Emergency planning
- Protection of the power plant from natural disaster (e.g. cyclone, flood, earthquake, etc) or outside human disaster (e.g. terrorist activities, etc)

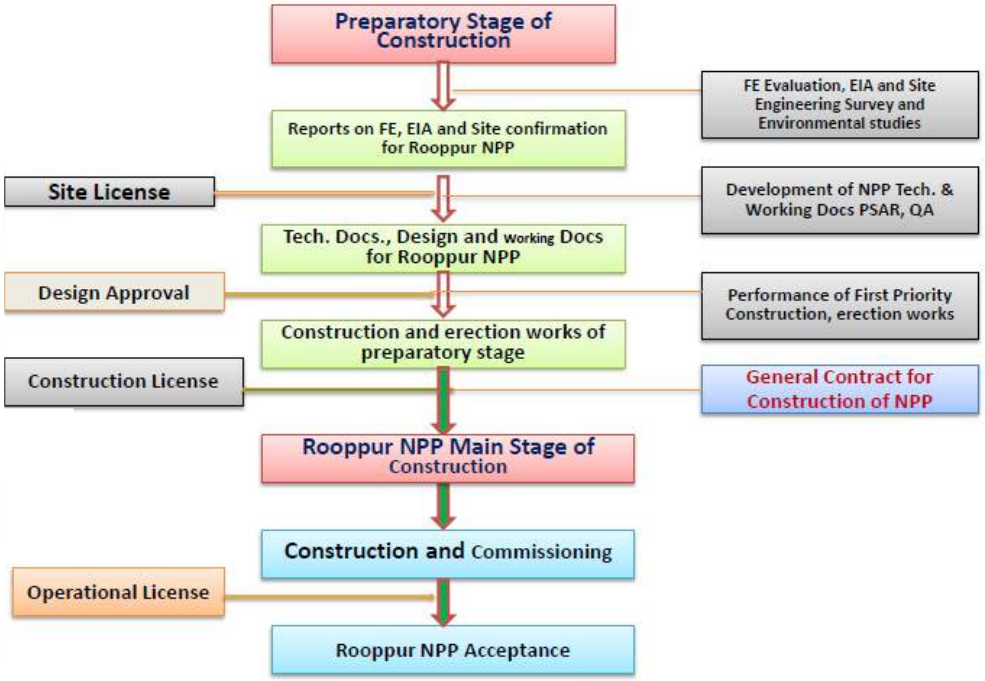
[75] IAEA factsheet: https://ola.iaea.org/ola/FactSheets/CountryDetails.asp?country=BD

14.6.6 Roadmap

(i) Construction

Consideration of the domestic legal and regulatory conditions to obtain;

- required licenses for building NPP,
- industrial base to support NPP construction,
- availability and competence of human resources for managing the NPP construction project,
- national resources as well as its social, economic and environmental condition to support NPP build.



Source: Ministry of Science and Technology, 2015

Figure 14-17 Roadmap for nuclear power development

(ii) Legal and implementation framework

All legal and implementation framework shall be established, and even be in an active before a commissioning of the first nucleare power generation as follows;

- Meeting IAEA safety standards
- Establishment of fuel cycle management
- Propoer knowledge about nuclear safety and public acceptance
- Participating international framework
- Ratification of the international law and standards

(iii) Comissioning of generation

- 2024/25: 1st and 2nd units
- 2030/31 3rd and 4th units
- 2040/41 5th and 6th units

Chapter 15 Power System Plan/ Rural Electrification (Distribution)

15.1 Power Network System Plan Tasks

The power network system planning will be examined by categorizing its phases into mid-term (2025) and long-term (2035) and reviewing PSMP2010. The required power system analysis will be carried out using PSS/E software. The Survey should take notice of the following issues.

Power Supply-Demand Imbalance among the Regions

The power interconnections with neighboring countries, the seaports for importing fuel and the mining points for domestic coal/gas will be scattered around the country, causing regional energy imbalance and requiring power trades among the regions. This trend appears to be growing and the transmission lines for regional connections will be further needed from the mid- and long-term points of view.

Power Imports and Exports via Interconnections

Power imports from the hydropower stations of neighboring countries such as India, Bhutan or Nepal are planned, in consideration of their potential for economical energy supply, due to the shortage of domestic gas supply and their role in broadening the energy sources for Bangladesh. The information regarding interconnections will be collected and the related detailed power system analysis will be carried out.

The Transmission Lines Crossing Rivers

There will be restrictions in power flow between the eastern and western sides of the country because Bangladesh has two large rivers in its center, Jamuna and Padma, with widths of 4.5km to 6km even at their narrowest points. It would entail much cost to construct power transmission lines across these large rivers.
A bridge across the Padma River was designed in detail in 2010 and the contractors that are currently under selection will also construct seven bases for towers for the 400kV transmission line connecting Khulna to Dhaka, located at its downstream side. This construction method may be applied for other river crossing transmission lines in Jamuna and Padma.

Optimal Operation Planning for Power System

Through the local power systems connecting to each other, improvement of power supply reliability and economic merit will be expected. On the other hand, new issues, such as concerns about accident impacts from weak points in the system upon the whole system and the necessity of different know-how to operate a large country-wide connection system, will be created. Countermeasures for the issues will be discussed and examined with the relevant counterparts.

15.2 Power System Plan Examination Criteria

15.2.1 Examination Methods

In this chapter, we examined a plan for a backbone power transmission and substation in Bangladesh up to 2035 based on the Bangladeshi power demand forecast, power development plan, and the power system plan for 2020 set out by PGCB.
Taking into account regional distribution of power stations and substations in the Bangladesh system, we confirmed through system analysis the validity of power flow, fault current and stability in 2025 and 2035. PSS/E software was used for system analysis.
System power demand was set based on the maximum expected demand on 132kV substations forecasted by PGCB, and on the aforementioned predicted value for system-wide maximum demand. Large-scale power stations are located in the Khulna region and in southern Chittagong, where development of seaports to expedite fuel imports is easy. Both locations are 200-300km from Dhaka, where power demand is highest. Therefore, to ensure supply reliability, we looked into consolidating power transmission routes. In addition, to reduce transmission routes and to cut costs, we looked into 765kV power transmission, alongside the 400kV system in the sections from Dhaka to Chittagong and from Dhaka to the Khulna region.
Finally, we estimated the scale of infrastructure investment for a 230kV-plus system, which will be necessary by 2035.

15.2.2 System Plan by PGCB for 2020

The system plan by PGCB for 2020 is shown in the figure on the next page. The black lines represent 400kV power lines, which are planned in a radial pattern from Dhaka toward Chittagong, Comilla, Bibiyana, Khulna, and Bogra. A ring of 400kV power lines will be constructed around the Dhaka metropolitan area, with 230kV power lines leading into the city, fed by the 400kV ring.
Table 15-1 shows a list of the on-going projects in March 2016, made by PGCB. The following are listed as projects for the installation of 400kV transmission lines and substations.

No. 1: Bibiyana-Kaliakoir 400kV transmission lines and substations and their related 230kV transmission lines
No. 4: Ghorasal-Tongi 400kV transmission lines and substations and the construction of their related 230kV and 132kV systems
No. 6: Ashuganj-Bhulta 400kV transmission lines and substations
No. 7: Aminbazar-Maowa-Mongla 400kV transmission lines and substations

The projects for expansion of the HVDC interconnection facilities to India are listed as follows.

No. 8: Expansion of Bheramara HVDC by 500MW and its related 230kV system

Nos. 2, 3, 5, 9-14 are projects for only 230kV and 132kV systems. No. 2 is the National Power System Network Development Project launched as a Yen-loan project.
Table 15-2 shows a list of the currently planned projects in April 2016, made by PGCB. The following are listed as projects for the installation of 400kV transmission lines and substations. No. 1 is the project for the installation of Matabari-Madunaghat-Meghnaghat 400kV with double circuits and Madunaghat and Meghnaghat 400kV substations.

No. 1: Matabari-Madunaghat-Meghnaghat 400kV transmission lines and substations
No. 3: Two 400kV substations in Dhaka, south of DPDC management area, and the construction of their related 230kV and 132kV systems

No. 4: One 400kV substation and 400kV transmission lines (their locations are unknown) and the construction of their related 230kV and 132kV systems
No. 5: Patuakhali-Gopalganj 400kV transmission lines and substations
No. 7: Madunaghat-Moheskhali 765kV transmission lines (initially operated at 400kV)
No. 8: Gopalgnj 400kV substation and 230kV and 132kV systems in the south regions
No. 9: Barapukuria-Bogra-Kaliakoir 400kV transmission lines
No. 11: 400kV transmission lines (including underground) and 230kV and 132kV system expansion in Chittagong
No. 12: Rooppur-Gopalganj 400kV transmission lines and substations and 230kV and 132kV system expansion
No. 13: Rooppur-Bogra 400kV transmission lines and 230kV and 132kV system expansion
No. 15: Banshkhali-Madunaghat 400kV transmission lines
No. 16: Kaliganj, Purbacha 400kV transmission lines (including underground) and substations in Dhaka, north of DESCO management area, and 230kV system.

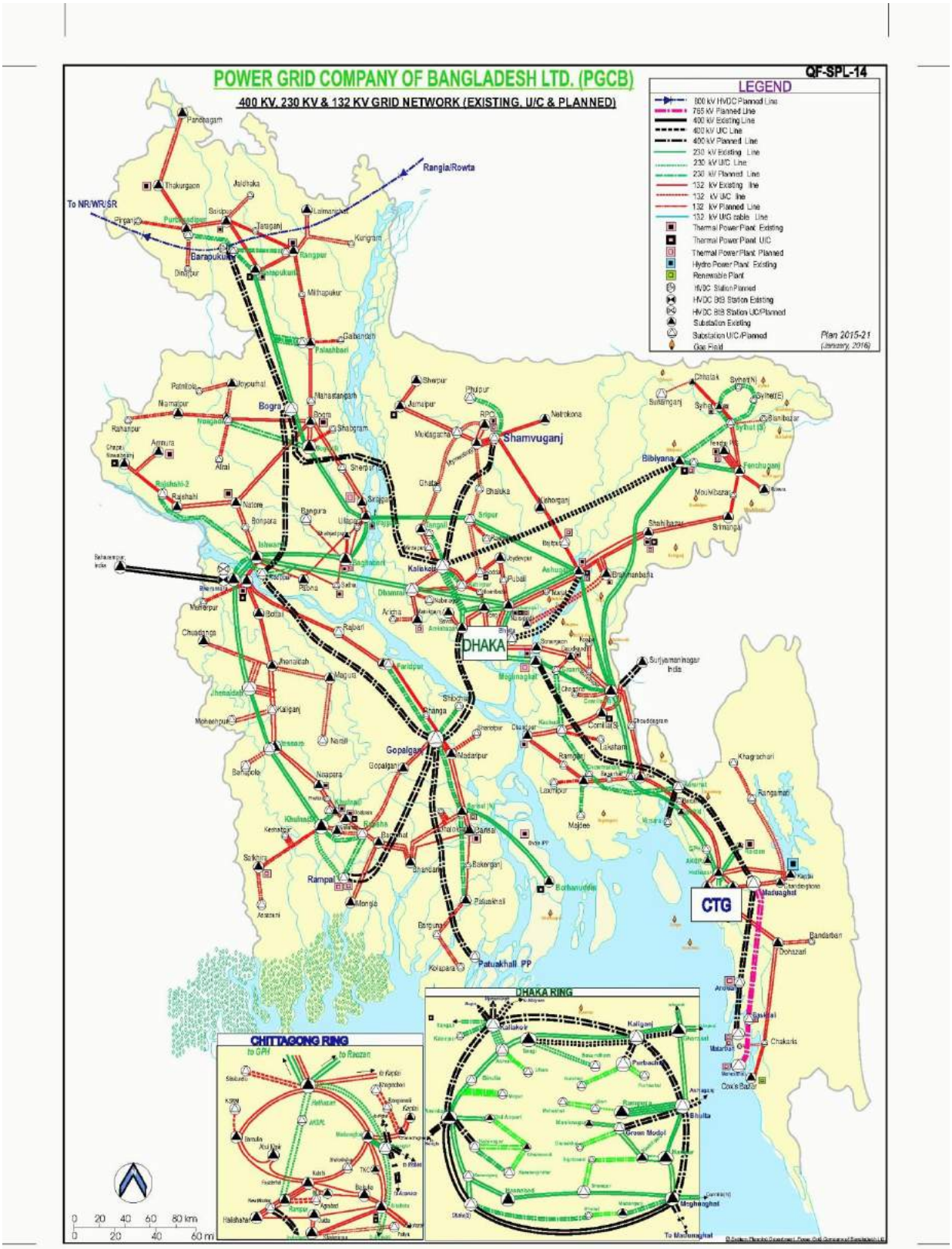
The project for the installation of the HVDC interconnection facilities to India is listed as follows.

No. 10: Barapukria 2000 MW HVDC Station

Nos. 2, 6, 5, 9 and 11-14 are projects for only 230kV and 132kV systems.
The 765kV transmission lines and substations and the 400kV underground lines included in the projects in Dhaka and Chittagong have been applied in other countries. However, they have only a shallow history of application. Thus, they should be designed with caution especially in consideration of the countermeasures for system overvoltage. Compact-scale substation facilities such as GIS or gas insulated transformers are expected to be applied in dense power demand areas such as Dhaka and Chittagong.

15.2.3 Examination of Power System Plan in this Study

The power system plan in this study is examined based on the reviews of the plan by PGCB and the discussions with them. The final results of the system plan are described in the latter half of this chapter.



Source: JICA Survey Team

Figure 15-1 Plan for Power Transmission System by PGCB

Table 15-1 On-going Projects by PGCB as of March 2016

SN	Projects Name	Scope of works	Main Objectives of the Project	Foreign Financing Status	Project Completion Year
1	**Bibiyana–Kaliakoir 400 kV and Fenchuganj–Bibiyana 230 kV Transmission Line (NG2)**	i) 168.64 km 400 kV Bibiyana–Kaliakoir Double ckt line. ii) 33.18 km Fenchuganj–Bibiyana 230 kV double ckt line iii) Installation of 400/230 kV 1x520 MVA transformer at Bibiyana. iv) 400/230 kV, 1x520 MVA & 400/132 kV, 2x325 MVA S/S at Kaliakoirv) 230/132 kV, 1x300 MVA S/S at Fenchuganj and renovation & extension of existing 132 kV substation at Fenchuganj vi) Construction of 36 km 230 kV line for turn–in and out of existing Aminbazar–Tongi230 kV line on four ckt tower at Kaliakoir. vii) Construction of 5 km 132 kV line for turn–in and out of existing Kabirpur–Tangail 132 kV line on four ckt tower at Kaliakoir. viii) Construction of16 km Kaliakoir–Dhamrai double circuit 132 kV line. ix) Construction of about 3.75 km 132 kV Four circuit transmission line on Four circuit tower from Fenchuganj SS to Fenchuganj PS	To build the power evacuation facilities for upcoming 2x450 MW CCPP at Bibiyana & to evacuate the surplus power of Sylhet area and also to supply adequate power to the northern part of Dhaka city.	**EDCF Korea & GOB**	July,2017 (Revised)
2	**National Power Transmission Network Development Project**	i) 230 kV Line: (a) 25 km Hathazari– Sikalbaha d/c TL (b) 25 km Hathazari– Rampur d/c TL (c) 5 km Hathazari– Rampur d/c u/g line ii) 132 kV Line: (a) 6 km d/c In Out u/g line of Khulshi–Halishaharline at new Rampur 132/33 kV GIS SS (b) 7 km d/c Rampur–Agrabad u/g (c) 132 kV interconnection line : 354 Ckt.km. iii) Two nos. 230/132 kV, 2×300 MVA Sub Stations at Rampur and Sikalbaha, Ctg. iv) 132/33 kV SS: 11 Sub Stations(1536 MVA) at Agrabad, Chowddagram, Benapole, Shariatpur, Ramganj, Baroirhat (Chg.), Bhaluka (Mymensingh), Barisal–(N), Mahastangarh (Bogra), Jaldhaka (Nilfamari), Rajshahi–2. v) Bay Extension:	i) To evacuate power from the proposed 225MWpower plant at Sikalbaha ii) Provide reliable power to Chittagong citythrough Rampur & Sikalbaha iii) Meet the growing load demand of the areas under the proposed new 132/33 kV substations atAgrabad (Ctg).; Chouddagram, Ramganj,Bhaluka (Myn), Baroirhat (Ctg), Benapol, Shariatpur, Barisal–(N), Mahastangarh (Bogra), Jaldhaka (Nilfamari) & Rajshahi–2	**JICA**	June, 2017
3	***132 kV Grid Network Development Project in Eastern Region***	i) 132 kV line: (a) 100 km RPCl–Tangail double circuitLine (b) 80 km Chandraghona–Rangamati–Khagrachari double circuit line (c) 55 km Brahmanbaria–Narsingdi double circuit line (d) 28 km Beanibazar–Sylhet(S) single circuit line on double circuit tower (e) 30 kmSunamganj–Chhatak single circuit line on double circuit tower ii) 132/33 kV SS: 4 nos. atRangamati, Khagrachari, Beanibazar, Sunamganj (each 82 MVA) iii) 132 kV Bay Extension : 17 nos. at Tangail (2), RPCL (2), Chandraghona (4), Brahmanbaria (2), Chhatak (1), Narsingdi (6). iv) 3 nos. of 132 kV Bay Modification at Narsingdi v) Conversion of Single Bus–bar configuration into Double Bus–bar at Narsingdi 132/33 kV S/S vi) Installation of one 132/33 kV 50/75 MVA transformer at Narsingdi S/S.	i) To increase the power supply reliability of Mymensingh area. ii) To reduce dependency on Ashuganj–Kishorganj 132kV line. iii) To evacuate the Power from the upcoming Power Plant in Mymensingh area. iv) To meet the growing demand of Rangamati, Khagrachari, Beanibazar & Sunamganj. v) To supply reliable power to Hill Tract area. vi) To minimize the accumulation of huge power at Ashuganj 132 kV bus bar. vii) To minimize the overloading of existing "Ashuganj–Ghorasal 132 kV transmission line". viii) To strengthen the power evacuation arrangement & increase power supply stability, reliability & transmission capability in Ashuganj & Ghorasal area.	**ADB**	June, 2016
4	***400/230/132 Network Development project***	(i)Construction of substations. a) 230 kV GIS Switching,Substation at Ghorasal b) 230/132 kV GIS, Substation at Ullon(2x225/300 MVA) , Basundhara (2x225/300MVA) & Shyampur(3x225/300 MVA) and 230/132 kV AIS Substation at Sripur(2x225/300MVA) c) 132/33 kV GIS, 2x80/120 MVASubstation at Ullon (d) 132/33kV SS at Rampur, Sholosahar,Sylhet(S), Kodda, Dhamrai, Kalurgaht, Kachua, Sitakunda, Rupshi, Sripur, Mirzapur. (ii) Construction of Lines. a) Construction of Ghorasal–Tongi 28 km 400 kV double circuit line. b) Construction of 132 kV line : 358 Ckt.km. c) Construction of 230 kV line : 62.6 Ckt.km. d) Re–conductoring 54 Ckt.km Ghorasal–Tongi 230kV line. e) 132/33 kV SS Renovation: Manikganj, Comilla(S), Madunaghat. f) 132 kV bay Extension : 4 g) 230 kV bay Extension : 6	i) To evacuate power from upcoming power plant at Ghorasal. (ii) To minimize the overloading of existing "Tongi–Ghorasal 230 kV transmission line". (iii) To meet up upcoming demand of Ullon and Dhanmondi area. (iv) To replace aged Ullon 132kV substation. (v) To strengthen the power supply stability, reliability & transmission capability in Ullon, Dhanmondi as well as inner of Dhaka city.(vi) To relieve the overloaded adjacent substations in different areas of the country(vii) To meet up upcoming demand of potential areas. (viii) To strengthen the power supply stability, reliability & transmission capability all over the country.	**ADB Tranche–2 Loan Package.**	June, 2017
5	***Enhancement of Capacity of Grid Substations and Transmission Line (Phase–I)***	i)Capacity Enhancement offive existing 132/33 kV S/S. ii)Construction of one new 230/132/33 kV S/S. iii) Construction of five new 132/33kV S/Ss. iv) Renovation / Upgradation of some existing transmission lines.	To meet the growing demand of respective area.	***WB***	June, 2017
6	***Ashuganj–Bhulta 400 kV Transmission line***	(i) **70 km** double ckt 400 kV line. (ii) **400/230 kV S/S at Bhulta**	To strengthing the power evacuation capability from Ashuganj to Dhaka.	***GOB & PGCB financing***	June, 2016
7	***Aminbazar–Maowa – Mongla 400 kV Transmission line***	i) 174 km 400 kV line ii) 400/230 kV 3x520 MVA at **Aminbazar**	To evacuate the Generated power of upcoming Rampal 1320 MW Coal Power Plant toDhaka & Khunla.	***ADB***	June, 2020
8	***Capacity Upgradation(500MW) of Existing Bheramara HVDC Station Project***	i.500MW BtB HVDC Station ii.Bheramara – Ishurdi 230 kV Double Circuit: 12km ii. Two 230 kV bay extension at Bheramara & Ishwardi	To import additional 500MW power from India.	***ADB***	June, 2018
9	***Western Grid Network Development Project***	i)Two no. of230/132 kV,2x225 MVA S/S at **Rajshahi & Jhenaidah** ii) 70 km Ishurdi–Rajshahi 230 kV Lines iii) 3 new 132/33 kVS/S at **Rajbaari, Mithapukur & Bangura(Pabna)** (iv) 60 km Khulna(S)–Gopalganj132 kV double ckt transmission line,	i)To meet the growing demand of Rajshahi area. ii) To enhance the power supply capacity & reliability of western Region.	***KfW***	June, 2018
10	***Barisal–Bhola–Borhanuddin 230 kV line project***	(i) 230KV Line (Double Circuit) : 61 km (ii) New 230/132 kV S/S:1 No (Barisal). 600 MVA (AIS)	To evacuate power to generated in upcomming Bhola power plant.	**PGCB Own Fund (HSBC)**	June, 2016
11	***Two New 132/33 kV Substations at Kulaura & Sherpur with***	(i)132 KV Line (Double Circuit) : 45 km (ii)New 132/33 kV S/S:2 Nos. (AIS) 1) Kulaura & 2) Sherpur (iii) 132 kV Bay Extension:4 Nos.	To meet the growing demand of the respective areas	**PGCB Own Fund**	June, 2016
12	***Goalpara–Bagerhat 132 kV Double Circuit Transmission***	(i) 45 km. 132 kV Double circuit lineand (ii) 4 nos. 132kV bay extension	To evaquite power from Goalpara Power Plant	**PGCB Own Fund**	June, 2016
13	***Mongla–Khulna (S) 230 kV Transmission Line Project***	i) 230 kV Mongla–Khulna d/c line :24km ii) Two 230kV bay extension at Khulna.	Power evacuation from coal based power plant at Mongla.	**PGCB Own Fund**	Dec, 2017
14	***Amnura 132/33 kV Grid Substation with Associated 132kV Transmission Line***	i) 132/33 kV AIS Substation, 1x35/50 MVA ii) 132kV line 15 km	To evacuate power to generated in upcomming 100MW power plant.	**Bidders Finance**	June, 2016

Source: PGCB

Table 15-2 Projects Planned by PGCB as of April 2016

SN	Projects Name	Scope of works	Main Objectives of the Project	*Foreign Financing*	Project Completio	Present Status
1	***Matarbari – Madunaghat – Meghnaghat 400 kV Transmission line (NG4)***	i) 314 km 400 kV line ii)400/230 kV, 3x520 MVA S/S at **Madunaghat & Meghnaghat** iii) 230/132 kV, 2x300 MVA S/S at **Madunaghat** iv) 230 kVLine: 16 km. v) 2 no. of 230 kV bay extension at Meghnaghat	To evacuate Generated power of upcoming CPP at Matarbari(1320MW), LNG PP at Anowara(1000MW) & transport the surplus power of Ctg area to Dhaka area.	***Expected from JICA***	2017–2021	DPP splitting into two part sent to Power Division on 14.01.2016. DPEC meeting held in Power Div on 07.02.2016. PGCB is now reviewing the DPP as per decision of DPEC meeting and will be submitted to Power Division.
2	***Energy Efficiency in Grid Based Power Supply Project***	i) Construction of 5 nos of 230/132 kV, 2x300 MVA s/s at **Purbasadipur, Naogaon, Feni, Bhulta & Biruli(Savar)**with interconnecting lines. ii) Construction of 8 nos of 132/33 kV s/s in rural areas (**Pubail, Gazaria, Ullapara, Bajitpur,Ghatail, Araihzar, Nabinagar & Rajendropur**) & interconnecting lines. iii) Renovation & upgragation of 9 nos of 132/33 kV s/s. vi) Upgradation & modification of 744 ckt-km 132 kV transmission line.	To meet the growing power demand & quality improvement of– –Dhaka City Adjacent –Greater Noakhali –Naogaon District –Saidpur District	***Expected from KfW***	June, 2019	Feasibility study report submitted. DPP under preperation
3	***Expansion and Strengthening of Power System Network Under DPDC Area***	i.400/230kV New Indoor GIS Substation :**2 nos. ,3000 MVA** ii.230/132kV New Indoor GIS Substation :**7 nos. ,7650 MVA** iii.New Transmission Line: - 400kV Line:**370 Ckt. km** - 230kV Line:**111 Ckt. Km** - 230kV Cable:96 Ckt. Km -132kV Line: **8.8 Ckt. km** iv.Bay Extension work at other Substations : **8 nos.**	To meet the growing power demand & quality improvement of– –Dhaka City & Adjacent	***Expected from EXIM Bank, China (G–G)***	December, 2020	Technical Feasibility Complete. Financial Negotiation in progress.
4	***Power Grid Network Strengthening Project under PGCB***	i.400/132kV New Substation :1 **no. ,650 MVA** ii.230/132kV New Substation :**13 nos. ,9200 MVA** iii.230/132kV Old Substation (Capacity Upgradation) :**7 nos. ,3075 MVA** iv.132/33kV New Substation :**28 nos. ,7240 MVA** v.132/33kV Old Substation (Capacity Upgradation) :**28 nos. ,3383 MVA** vi.Substation Renovation :**18 nos.** vii.New Transmission Line: - 400kV Line:**200 Ckt. km** - 230kV Line:**680 Ckt. km** - 132kV Line: **676 Ckt. km** viii.Old Transmission Line (All 132kV):6 nos. - Second Ckt. Stringing:**147 Ckt. km** - Conductor Upgradation :**312 Ckt. km**	· To meet nation–wide power demand & ensure quality improvement.	***Expected from EXIM Bank, China (G–G)***	December, 2020	Technical Feasibility Complete. Financial Negotiation in progress.
5	***Patuakhali – Gopalganj 400 kV Line & Gopalganj 400 kV Super Grid Sub–Station Project***	i) 400/230/132 kV SS: **Gopalganj** (1x520 MVA, 2x325MVA) ii) Patuakhali – Gopalganj 400 kV Double Circuit Line :165 km	· To ensure power evacuation from coal based power projects of Patuakhali area · To create a high capacity power evacuation node at Gopalganj.	**Proposed for IFC & GoB**	December, 2020	PDPP sent to planning commission 11–01–2015
6	***Enhancement & Strengthening of Power Network in Eastern Region***	i. 230/132kV GIS Substation: **2 nos (Chowmohoni, Kachua, 1750 MVA)** ii. 132/33kV Substation: **9no.(Muradnagar, Laksham, Maijdee, Paitya, Chandina, New Mooring, Basurhat, Laxmipur, Kosba, 1920 MVA)** iii. 230kV Line: **246 Ckt. km** iv. 132kV Line: **304 Ckt. km** v. 132/33kV SS Renovation: **01 no. (360 MVA)**	i. To enhance & strengthen existing grid network of Eastern Region. ii. To meet up the growing demand of Eastern Region. iii. To ensure reliable power supply to Industrial/ Commercial /Residence points of Greater Comilla, Chittagong, Greater Noakhali area.	**Expected from WB**	December, 2020	PDPP sent to Power Division on 19–08–2015 Consultant appointment for Feasibility Study in progress
7	***Madunaghat – Moheskhali 765kV Transmission line***	i) 765 kV Line: **200 Ckt. km** ii) Two 400 kV bay at Madunaghat	* To establish transmission infrastructure for evacuation of power to be generated from proposed power plants at Maheshkhali. * To provide reliable power to all over the country.	***Proposed for EDCF, Korea***	June, 2020	PDPP sent to Power Division on 30–08–2015

SN	Projects Name	Scope of works	Main Objectives of the Project	*Foreign Financing*	Project Completio	Present Status
8	***Grid Network Development Project at Southern Area***	i) 230kV Switching Station: **Korerhat, Gogalganj (400/230kV, 2x350/450 MVA)** ii) 230/132KV SS: **Mirsarai (4x350/450), Faridpur (2x350/450 MVA),** iii) 132/33 kV SS: **Phultola (2x80/120MVA) Jhalokhati, Kolapara, Barguna** (2x50/75 MVA Each) , **Kaliganj / Assasuni** (2x25/41 MVA) iv) 400 kV Line: 58 Ckt. km v) 230 kV Line: 270 Ckt. km. vi) 132 kV Line: 154 Ckt. Km.	To improve Southern Area power supply relaibility To ensure adequate and relaible power supply for Mirsarai Economic Zone	***Proposed for ADB***	June, 2020	PDPP sent to Power Division on 06-12-2015
9	***Baropukuria-Bogra-Kaliakoir 400 kV Transmission Line Project (NG-5)***	i.400 kV Line: 520 Ckt. km. ii. 400kV bay extension: 6 no's	· To ensure power evacuation from proposed Bangladesh-India eastern grid interconnection from Barapukuria.	***Proposed for Credit Loan (India)***	December, 2019	PDPP sent to planning commission on 22-01-2015
10	***North- Eastern Interconnection***	i.2000MW HVDC Station at **Barapukuria** ii.198km 800kV Bipole HVDC Line	* To connect the huge hydroelectric potential of Bhutan and Arunachal Province to India through Bangladesh territory * To draw 1000-2000MW power at Barapukuria from Cross Boarder Interconnection	**Yet to be Funded**	June, 2021	PDPP Under Preparation
11	***Expansion and Strengthening of Power System Network Under Chittagong Area***	i) 230/132/33 kV GIS SS: **Anowara, Khulshi** (2x350/450 MVA, 3x80/120 MVA) ii) 230/132kV GIS Swithing: **New Mooring** ii) 400 kV Line: 54 Ckt. km. (OH & UG) iv) 230kV U/G line: 44 Ckt. km v) 230kV bay extension: 2 no's	To improve CTG city power supply relaibility To meet growing demand of CTG City Adjacent Area	***Proposed for ADB***	June, 2020	PDPP sent to Power Division on 31.01.16
12	***Rooppur-Gopalganj 400 kV Transmission Line (NG-7)***	i) 400 kV Line: 330 Ckt. km. ii) 230 kV Line: 120 Ckt. km. iii) 132 kV Line: 40 Ckt. Km. iv) 400kV Bay extension at Rooppur S/S	· To ensure power evacuation from Rooppur NPP · To create power evacuation facilities for future NPPs at Rooppur.	***Yet to be Funded***	December, 2021	PDPP sent to planning commission 11-01-2015.
13	***Rooppur-Bogra 400kV Transmission Line Project (NG-6)***	i) 400/230 kV SS**: Bogra GIS (2x750 MVA)** ii) 400 kV Line: 200 Ckt. km. iii) 230 kV Line: 24 Ckt. km.	· To ensure power evacuation from Rooppur NPP · To create power evacuation facilities for future NPPs at Rooppur.	***Yet to be Funded***	December, 2021	PDPP sent to planning commission on 22-01-2015
14	***230 & 132 kV Transmission Network Development Project in Western Zone***	i) 230/132/33 KV SS: **Rupsha** (3x350/450, 2x80/120 MVA) ii) 132/33 kV SS: **Bhanga**, **Meherpur,Kesabpur, Mahespur** (2x50/75 MVA Each) iii) 230 kV Line: 92 Ckt. km. iv) 132 kV Line: 238 Ckt. Km. v) 132 kV Line Stringing: 82 Ckt. km. vi) 230 kV bay extension: 4 no's vii) 132 kV Bay extension : 8 No's	i)To meet the growing demand of Khulna & Barisal area. ii) To enhance the power supply capacity & reliability of Khulna & Barisal Region.	***Proposed for ADB***	June, 2020	PDPP sent to Power Division on 18.02.16
15	***Banshkhali-Madunaghat 400kV Transmission Line Project***	i) 400 kV line: 130 Ckt. km. ii) 400 kV GIS Bay Extension: 2 no's	(i) To ensure reliable transmission facilities to evacuate power from proposed coal based thermal PP project at Banshkhali (1320 MW). (ii) To meet the growing demand of the Chittagong	***Yet to be Funded***	June, 2019	PDPP sent to Power Division on 27.04.16
16	***Expansion and Strengthening of Power System Network in DESCO & its Adjacent Area (Phase-1)***	i) 400/230 kV GIS SS: **Kaliganj, Purbachal** ii) 230/132 kV GIS/GIT SS: **Gulshan, Uttara, Mirpur, Ashulia, Mohakhali, Purbachal-2** iii) 400 kV (O/H+U/G) line: 33 km iv) 230 kV (O/H+U/G) line: 74 km	To meet the growing power demand & quality improvement of--DESCO & Adjacent area	***Yet to be Funded***	December, 2021	PDPP Under Preparation

Source: PGCB

15.2.4 Maximum Power Demand Forecast

(1) Load Borne by 132kV Transformer Substations

PGCB set a plan for 132kV transformer substations up to 2040 based on data from each power distribution company and forecast the maximum power demand for each substation. The list of planned 132kV substations prepared by PGCB and the maximum power demand forecast are shown on the following pages. A whole-system model was established during this survey's examination of the system plan, based on this list of planned 132kV substations.

(2) System-Wide Demand

The maximum system-wide power demand is shown below.

Table 15-3 Maximum Power Demand used for Power System Plan

Year	2015	2025	2035
Maximum Power Demand	8,920MW	19,874MW	37,221MW

Source: JICA Survey Team

Table 15-4 List of Planned 132kV Substations and Maximum Power Demand (Bogra)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Barapukuria	46	72	104	94	104	104	Hatibandha	0	0	0	0	43	43
Bogra	186	83	76	79	91	91	Kurigram	0	49	71	93	83	83
Matidali	0	0	0	60	69	69	Kurigram-2	0	0	0	0	39	39
Sultanganj	0	0	0	88	102	102	Mahastanghar	0	58	87	84	102	102
Joypurhat	38	60	87	79	92	92	Mithapukur	0	70	82	107	108	108
Hakimpur	0	0	0	78	100	100	Palashbari	74	65	88	114	103	103
Lalmonirhat	60	46	67	88	66	66	Gobindaganj	0	0	0	0	52	52
Naogaon	105	115	121	132	153	153	Panchagarh	21	40	67	97	66	66
Dupchachia	0	0	52	68	64	64	Panchagarh-2	0	0	0	0	43	43
Natore	84	57	72	94	109	109	Purbasadipur	77	73	113	109	126	126
Atrai	0	0	55	74	85	85	Birganj	0	0	0	48	55	55
Niyamatpur	62	78	112	122	142	142	Rajshahi (N)	0	87	72	94	84	84
Chowdala	0	45	65	85	99	99	Shahjadpur	71	44	61	78	90	90
Pabna	81	70	101	89	114	114	Sherpur (Bogra)	0	64	93	98	77	77
Ataikula	0	0	0	63	73	73	Bangura	0	43	62	82	95	95
Rajshahi	108	106	96	127	113	113	Bonpara	0	40	58	74	86	86
Rajshahi-3	0	0	0	0	85	85	Bogra (New)	0	82	133	124	100	100
Rangpur	104	85	73	96	88	88	Gabtoli	0	0	0	0	62	62
Pirgacha	0	0	70	92	94	94	Dinajpur	0	58	85	103	77	77
Rangpur-2	0	0	0	0	61	61	Dinajpur-2	0	0	0	0	55	55
Saidpur	90	70	105	100	115	115	Gaibandah	0	39	56	74	84	84
Parbatipur	0	0	0	61	70	70	Paglapir	0	64	92	99	114	114
Sirajganj	69	88	82	108	125	125	Patnitola	0	77	114	112	130	130
Thakurgaon	75	66	94	86	95	95	Mahadevpur	0	0	0	85	99	99
Thakurgaon-2	0	0	0	60	66	66	Pirganj	0	61	96	87	101	101
Amnura	0	45	64	82	95	95	Puthia	0	44	64	82	95	95
Bera	0	60	87	85	100	100	Bagha	0	0	69	90	105	105
Chapai Nawabganj	82	42	61	80	93	93	Ullapara	0	40	58	74	86	86
Tanore	0	0	69	90	105	105	Belkuchi	0	0	45	58	67	67
Jaldhaka	0	54	73	90	102	102							

Source: JICA Survey Team

Table 15-5 List of Planned 132kV Substations and Maximum Power Demand (Chittagong)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Bakulia	108	97	84	110	133	133	Fatikchari	0	0	52	55	61	61
Bakulia-2	0	0	70	94	114	114	Mirsharai	0	0	0	67	90	90
Cox's Bazar	65	94	110	115	75	75	Chandraghona	33	39	58	50	55	55
Teknaf	0	0	0	47	52	52	Kalurghat	0	70	78	104	127	127
Cox's Bazar-2	0	0	0	0	70	70	Khagrachari	0	45	64	82	104	104
Dohazari	74	92	68	100	70	70	Modern Steel	18	18	30	30	30	30
Bandarban	0	0	40	59	83	83	Matarbari	0	54	51	71	78	78
Chakaria	0	0	47	69	76	76	Baskhali	0	0	49	70	77	77
Lohagara	0	0	0	0	56	56	Moheskhali	0	0	47	63	69	69
Halishahar	159	72	50	67	90	90	Rampur	0	70	79	107	92	92
Patenga	0	0	79	105	127	127	Rampur-2	0	0	0	0	126	126
Hathazari	98	97	93	85	103	103	Rangamati	0	45	64	85	94	94
Raozan	0	0	0	80	88	88	Sholoshahar	0	67	56	75	92	92
Juldah	32	38	61	69	84	84	TKC	13	13	30	30	30	30
Kaptai	9	17	27	43	48	48	Bhoalkhali	0	0	53	59	72	72
Khulshi	186	140	149	199	178	178	F.hat	0	59	86	74	98	98
Nasirabad	0	0	86	120	168	168	Batiari	0	0	0	88	108	108
Khulshi-2	0	0	0	0	88	88	Newmooring	0	68	76	101	122	122
Madunaghat	57	57	77	83	112	112	Patiya	0	53	67	91	100	100
Shahmirpur	20	37	60	56	68	68	Sikalbaha-2	0	0	0	75	91	91
Sikalbaha	40	64	44	48	58	58	KSRM	0	30	50	50	50	50
Agrabad	0	79	70	98	95	95	KYCR	0	20	20	40	40	40
Agrabad-2	0	0	68	95	91	91	Kumira	0	0	77	80	120	120
Baroaulia	106	74	76	79	106	106	Sitakundu	0	69	71	84	112	112
Baroirhat	0	68	102	82	110	110							

Source: JICA Survey Team

Table 15-6 List of Planned 132kV Substations and Maximum Power Demand (Comilla)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Ashuganj	70	43	51	75	55	55	Barlekha	0	0	0	0	67	67
Chandpur	100	93	87	107	124	124	Kachua	0	63	95	111	79	79
Chandpur-2	0	0	70	74	86	86	Kulaura	39	53	83	117	103	103
Matlob	0	0	0	52	60	60	Ramganj	0	63	100	118	112	112
Chhatak	46	39	58	78	86	86	Raipur	0	0	0	0	54	54
Chowmuhani	155	90	142	105	123	123	Srimangal	43	54	86	121	88	88
Laxmipur	0	50	80	115	98	98	Srimangal-2	0	0	0	0	70	70
Sonaimuri	0	0	0	121	133	133	Sunamganj	0	50	80	69	80	80
Senbag	0	0	0	0	68	68	Sylhet	138	88	81	111	103	103
Comilla (N)	54	73	80	110	135	135	Sylhet©	0	0	92	128	126	126
Amratali	0	0	93	112	130	130	Biswnath	0	0	67	98	113	113
Maynamoti	0	0	80	110	97	97	Tuker Bazar	0	0	0	0	70	70
Comilla (S)	165	145	78	73	98	98	Sylhet (S)	0	73	75	114	118	118
Lalmai	0	0	84	105	122	122	Chandina	0	45	56	80	70	70
Daudkandi	71	84	108	126	146	146	Nimsar	0	0	0	0	87	87
Sachar	0	0	0	0	53	53	Gazaria	0	57	98	68	79	79
Feni	100	109	67	90	105	105	Baluakandi	0	0	0	72	84	84
Shahjibazar	66	54	86	81	97	97	Laksham	0	50	51	51	59	59
Nabiganj	0	39	60	60	72	72	Muradnagar	0	66	66	88	102	102
Derai	0	0	0	53	62	62	Homna	0	0	52	60	69	69
Madovpur	0	0	0	60	71	71	Maijdee	0	57	101	156	122	122
Brahmanbaria	89	85	97	132	87	87	Subarnachar	0	0	0	0	53	53
Kosba	0	56	54	73	84	84	Sylhet (N)	0	78	81	114	91	91
Beanibazar	0	55	57	76	90	90	Sylhet (N)-2	0	0	0	0	93	93
Darbosto	0	0	50	68	80	80	Basurhat	0	62	94	104	54	54
Chauddagram	0	83	131	125	145	145	Companiganj	0	0	0	62	72	72
Miarbazar	0	0	0	90	104	104	Feni-2	0	0	51	67	78	78
Fenchuganj	36	45	70	97	100	100	Feni-3	0	0	76	102	118	118
Moulvibazar	0	45	76	105	116	116							

Source: JICA Survey Team

Table 15-7 List of Planned 132kV Substations and Maximum Power Demand (DESCO and DPDC)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Cantonment	106	141	96	91	111	111	English Road	0	93	130	133	147	147
Gulshan	138	86	145	131	171	171	Goran	0	73	92	142	164	164
Gulshan-2	0	70	129	156	141	141	Green Model	0	56	99	171	130	130
Mirpur	106	125	139	133	162	162	Shyampur	161	161	160	214	163	163
Pallabi	0	0	0	108	133	133	Pagla	0	0	111	149	122	122
Aftabnagar	0	84	130	150	138	138	Farashganj	0	0	0	154	170	170
Banani	0	148	150	120	154	154	Ullon	79	88	94	125	145	145
Mohakhali	0	0	0	130	166	166	Niketon	0	0	136	151	192	192
Sainik Club	0	0	0	0	90	90	Old Airport	79	109	139	95	115	115
Bashundhara	174	81	100	152	179	179	Old Airport-2	0	0	0	93	114	114
Basundhara-2	0	0	75	114	126	126	Fatullah	0	130	168	209	213	213
Kalachandpur	0	0	0	104	132	132	Chasara	0	0	145	158	175	175
Badda	0	0	0	98	90	90	Kazla	0	82	144	113	103	103
Dumni	0	76	88	141	163	163	Lalbagh	86	72	106	149	165	165
Basundhara-3	0	0	0	0	137	137	BUET	0	0	0	0	119	119
Purbachal	0	52	73	152	145	145	Madertek	60	71	94	149	173	173
Purbachal-2	0	0	52	107	133	133	Motijheel	0	100	99	148	189	189
Purbachal-3	0	0	0	0	109	109	Panthapath	0	0	109	154	150	150
New Tongi	112	128	171	120	145	145	Postagola	0	114	155	217	165	165
Uttara	117	57	80	92	117	117	Shyampur-2	0	0	0	0	110	110
Uttara-3rd	0	89	179	115	161	161	Muradpur	0	0	0	0	194	194
Uttara-3rd-2	0	0	0	100	141	141	Satmasjid	72	53	94	143	158	158
Uttara-VI	0	0	0	126	179	179	Mohammadpur	0	0	48	73	113	113
Airport	0	75	127	97	124	124	Siddhirganj	142	67	78	91	141	141
Baunia	0	0	95	121	147	147	Sign Board	0	89	159	147	147	147
Mirpur-II	0	79	101	96	117	117	Adamjee	0	0	55	70	89	89
United City	0	58	89	143	166	166	Konapra	0	0	0	129	97	97
Satarkul	0	0	0	0	118	118	Rayerbagh	0	0	0	0	99	99
Uttarkhan	0	61	103	104	133	133	Sitalakhya	112	105	132	170	172	172
Dakshinkhan	0	0	0	89	113	113	Sitalakhya-2	0	0	0	172	204	204
Ashian City	0	0	0	85	113	113	Zigatola	0	98	104	154	171	171
Bangabhaban	51	42	56	69	76	76	Charsaidpur	0	96	146	118	150	150
Dhanmondi	157	125	118	159	136	136	Charsaidpur-2	0	0	0	126	161	161
Kakrail	0	0	94	151	199	199	New Ramna	0	120	113	158	169	169
DU	0	0	0	0	125	125	Bandar	0	44	66	79	101	101
Kallayanpur	124	127	103	131	159	159	Basila	0	46	62	113	158	158
Kallayanpur-2	0	0	80	102	124	124	Hazaribagh	0	0	120	129	175	175
Kamrangirchar	65	69	106	150	166	166	Rayerbazar	0	0	0	130	144	144
Azimpur	0	0	102	151	133	133	Ctg Road	0	0	0	80	74	74
Madanganj	89	59	99	95	127	127	Demra	0	0	0	0	112	112
Maniknagar	102	67	112	140	179	179	Near Balu River	0	0	0	0	91	91
Matuail	72	50	55	76	102	102	Amulia	0	0	0	0	106	106
Matuail Ext.	0	50	101	172	230	230	Khanpur	0	0	0	0	185	185
Godnail	0	0	0	86	115	115	Khilgaon Taltola	0	0	88	124	144	144
Moghbazar	160	125	124	182	153	153	Tejgaon	0	125	140	206	141	141
Railway Colony	0	0	0	0	138	138	Tejgaon-2	0	0	0	0	164	164
Narinda	103	116	139	150	191	191	Sarulia	0	0	0	0	90	90

Source: JICA Survey Team

Table 15-8 List of Planned 132kV Substations and Maximum Power Demand (Dhaka)

Unit: MW

132kV S/S	2015	2020	2025	2030	2035	2040	132kV S/S	2015	2020	2025	2030	2035	2040
Nabinagar	0	0	74	89	99	99	Kishoreganj-2	0	0	0	0	76	76
Ghorasal	91	92	78	104	134	134	Madan	0	0	0	0	49	49
Shibpur	0	0	48	66	61	61	Kodda	0	136	121	159	194	194
Haripur	68	63	84	103	123	123	Mirjapur	0	88	80	107	130	130
Rahim Steel	18	35	35	35	50	50	Narsingdi	77	67	65	90	92	92
Hasnabad	183	85	126	107	141	141	Pachdona	0	0	75	103	108	108
Hasnabad-2	0	0	0	101	134	134	Rupshi	0	122	86	117	149	149
Ishwardi	38	57	56	73	85	85	Rupshi-2	0	0	101	136	173	173
Jamalpur	81	109	126	126	90	90	Nabinagar Housing	0	40	95	152	167	167
Bakshiganj	0	0	64	88	95	95	Sherpur	45	73	75	103	81	81
Jamalpur-2	0	0	0	0	79	79	Nandigram	0	0	0	0	56	56
Sherpur-2	0	0	0	0	64	64	Sonargaon	50	59	97	74	95	95
Kabirpur	189	81	73	101	84	84	Sonargaon-2	0	0	0	84	108	108
Shafipur	0	0	100	138	147	147	Sreenagar	0	68	80	110	134	134
Keraniganj	0	79	118	117	105	105	Sreepur	0	108	94	91	111	111
Ruhitpur	0	0	0	0	100	100	Sreepur-2	0	0	110	112	136	136
Manikganj	88	65	97	95	76	76	Shakhipur	0	0	79	106	134	134
Manikganj-2	0	0	0	0	90	90	Barmibazar	0	0	0	74	99	99
Munshiganj	101	108	117	161	125	125	New Tongi-2	0	0	0	105	128	128
Tongibari	0	0	66	91	98	98	Akrain	0	0	0	103	108	108
Munshiganj-2	0	0	0	0	90	90	Araihazar	0	57	63	85	109	109
Mymensingh	161	116	109	146	123	123	Aricha	0	45	69	82	83	83
Ishwarganj	0	0	77	104	119	119	Ashulia	0	66	99	72	46	46
Trishal	0	0	75	100	99	99	Ashulia-2	0	0	0	0	79	79
Mymensingh-2	0	0	0	0	107	107	Bajitpur	0	57	82	110	83	83
Nawabganj	0	68	101	135	141	141	Monohordi	0	0	0	0	97	97
Netrokona	60	90	76	102	79	79	Shibchar	0	0	0	51	62	62
Purbadhala	0	0	45	60	69	69	Boardbazar	0	62	72	99	132	132
Savar	92	53	79	70	88	88	Sataish	0	0	74	99	115	115
Singair	0	0	0	84	86	86	Dhaka EPZ	0	68	101	75	66	66
Tangail	128	92	60	82	105	105	Dendabor	0	0	0	103	106	106
Deldwar	0	0	52	70	81	81	Ghatail	0	45	69	94	120	120
Tongi	84	59	50	68	90	90	Dhanbari	0	0	0	74	77	77
Bhaluka	0	97	100	133	109	109	Hemayetpur	0	45	72	100	73	73
Gaforgaon	0	0	0	0	60	60	Hemayetpur-2	0	0	0	0	54	54
Bhulta	149	78	70	94	121	121	Madobdi	0	65	97	131	168	168
Kanchan	0	0	80	108	138	138	Marjal	0	62	67	92	94	94
Dhamrai	0	83	126	128	83	83	Mukhtagacha	0	64	99	105	121	121
Dhamrai-2	0	0	0	0	79	79	Nabinagar	0	57	85	49	63	63
Joydevpur	143	88	44	61	33	33	Sarail	0	0	0	0	97	97
BRRI	0	0	79	111	113	113	Phulpur	0	37	55	74	85	85
Shimulia	0	0	0	0	105	105	Pubail	0	61	68	94	126	126
Gazipur	0	0	0	0	81	81	Rajendrapur	0	70	95	68	91	91
Abdullahpur	0	48	72	99	119	119	Kapasia	0	0	0	62	83	83
Kishoreganj	61	74	77	103	86	86							

Source: JICA Survey Team

15.2.5 Power Generation Plan

Based on the power system plan noted in the previous chapters, generators were modeled using systems analysis data. The capacities of the generators as modeled by the systems analysis data are shown in the table below.

Table 15-9 Capacities of Generators as Modeled by Systems Analysis Data

Unit: MW

Bus Name	2025	2030	Bus Name	2025	2030	Bus Name	2025	2030
JMLPR DC	0	500	KAPTAI	230	230	DCBERM	1000	1000
JMLPR DC	0	500	ANOWARA	0	250	DCBERM	1000	1000
HARIPUR	400	400	ANOWARA	0	250	BHOLA	220	220
MUNSIGANJ	522	522	ANOWARA	300	300	KHULNA (S)	630	630
LALBAG	163	163	MATABARI	1104	1104	KHULNA (S)	1214	1214
ASHUGANJ	361	361	MATABARI	0	1200	ROOPPUR	1200	1200
SIDDHIRGANJ	328	328	MATABARI	0	1200	ROOPPUR	1200	1200
DHAKAG	635	635	PYRA	0	600	ROOPPUR	0	1200
GHORASAL	168	0	PYRA	0	600	ROOPPUR	0	1200
SIDDHIRGANJ	138	0	MOHESIKHALI	0	1200	PAYRA	1214	1214
SIDDHIRGANJ)	206	0	MOHESIKHALI	0	800	FARIDPUR	52	0
MYMENSHING	202	0	MOHESIKHALI	0	800	GOPALGONJ	107	0
HARIPUR	360	0	MOHESIKHALI	0	800	KATAKHALI	49	0
MEGHNAGHAT	450	0	MOHESIKHALI	0	800	NOAPARA	40	0
GHORASAL	108	0	MOHESIKHALI	0	500	SATKHIRA	50	0
ASHUGANJ	195	0	SHIKALBAHA	147	0	BHERAMARA	402	402
GAZIPUR	51	0	HATHAZARI	96	0	KHULNA (S)	221	221
SANTAHAR	49	0	DOHAZARI	99	0	KHULNA (S)	196	196
GOGNAGAR	102	0	RAOJAN	25	0	PYRA	0	800
BARAKA	50	0	POTIYA	108	0	PYRA	0	800
JANGALIA	52	0	PATIYA	100	0	PYRA	0	800
MUNSHIGONJ	51	0	JULDA	100	0	PYRA	0	250
KODDA	147	0	KAPTAIPSPP	0	100	PYRA	0	250
KERANIGONJ	100	0	SIKALBAHA	218	218	PYRA	0	500
KERANIGONJ	108	0	SALAM	612	612	BHOLA	189	189
JAMALPUR	95	0	SALAM	612	612	Khulna	8984	14486
MADANGONJ	55	0	Chittagong	3751	12176			
MANIKGONJ	50	0				DC BRPK	1000	1000
KAMALAGHAT	55	0	CHANDPUR	158	158	DC BRPK	0	500
NABABGONJ	55	0	SYLHET	221	221	DC BRPK	0	500
BHAIRAB	50	0	PSPP	0	1000	DC BRPK	0	500
ASHUGANJ	51	0	COM_INDA	500	500	BAGHABARI	102	102
ASHUGANJ	44	0	FENCHUGONJ	50	0	SIRAJGANJ	204	204
GHORASAL	352	352	DOUDKANDI	51	0	BARAPUKURIA	182	182
ASHUGANJ	218	218	BIBIYANA	341	341	BARAPUKURIA	252	252
ASHUGANJ	370	370	BIBIYANA	388	388	BAGHABARI	51	0
MEGHNAGHAT	305	305	SHAHJIBAZAR	98	98	BERA	70	0
GHORASAL	776	776	BIBIYANA	372	372	NATORE	52	0
Dhaka	7422	5430	SHAHJIBAZAR	322	322	CHAPAI	102	0
			Comilla	2501	3400	BARISAL	110	0
						SIRAJGANJ	414	414
						SIRAJGANJ	216	216
						SIRAJGANJ	216	216
						Bogra	2971	4086

Source: JICA Survey Team

15.2.6 Power Supply and Demand Balance by Region

Power supply and demand balances by region were calculated through system analysis, and the results are shown in the next table.
In 2025, at time of maximum demand, power supply in the Dhaka region will be 7,422MW, but demand will be 12,564MW, and because system loss will be 127MW there will be a total power shortage of 5,269MW. Furthermore, there will also be a shortage in the Comilla region of 696MW, and a shortage in the Bogra region of 171MW. However, the Khulna region has many large-scale power resources, including DC interconnection from Bheramara, 2,400MW from nuclear power, 1,214MW from Pyra, and others, with 4,905MW of excess power. In addition, the Chittagong region has large-scale power resources, including 1,104MW from Matarbari and 1,224MW from S. Alam, with 1,232MW of excess power. This excess power will be sent to Dhaka, Comilla, and Bogra to make up for the deficits in those areas.

Table 15-10 Power Supply and Demand Balance by Region in 2025 at Maximum Power Demand

Unit: MW

Area	Generation	Load	Loss	Interchange
Dhaka	7,422	12,564	127	-5,269
Chittagong	3,751	2,478	41	1,232
Comilla	2,273	2,929	40	-696
Khulna	7,984	3,007	73	4,905
Bogra	2,971	3,040	103	-171
Total	24,401	24,017	384	0

Source: JICA Survey Team

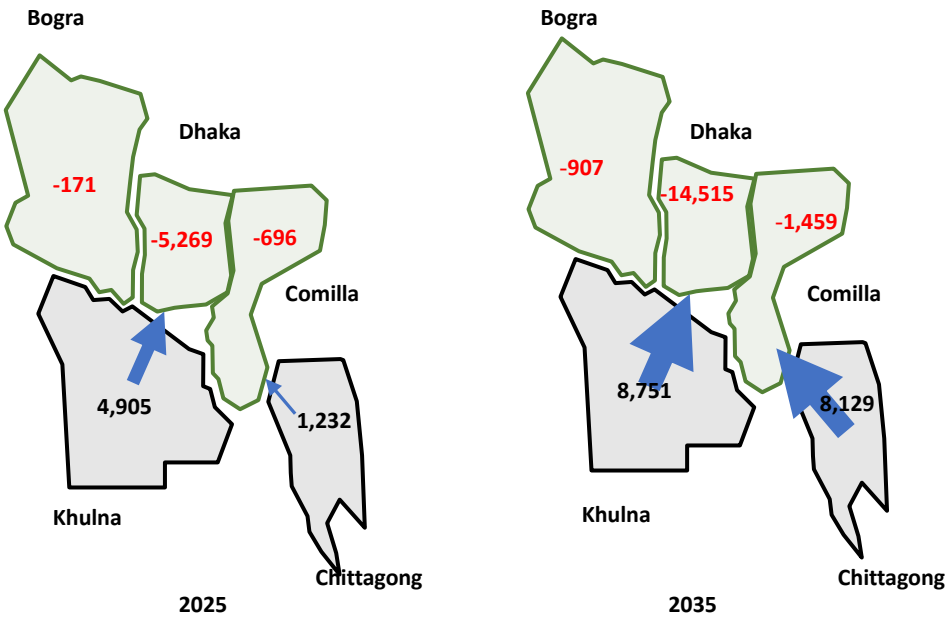
Table 15-11 Power Supply and Demand Balance by Region in 2035 at Maximum Power Demand

Unit: MW

Area	Generation	Load	Loss	Interchange
Dhaka	5,430	19,608	336	-14,515
Chittagong	12,176	3,867	180	8,129
Comilla	3,233	4,571	121	-1,459
Khulna	13,486	4,599	136	8,751
Bogra	4,086	4,744	249	-907
Total	38,411	37,389	1,022	0

Source: JICA Survey Team

The regional excesses and deficits listed in the table above are shown in the schematic maps below. Major power plants are clustered in Khulna and Chittagong, where development of seaports for fuel import is easy. However, the Bogra, Dhaka, and Comilla regions have power deficits, and will receive power supplies from Khulna and Chittagong.
In 2025, at time of maximum demand, 4,905MW will be sent from Khulna, and 1,232MW will be sent from Chittagong to make up for the power deficits in other areas. In 2035, at time of maximum demand, 8,751MW will be sent from Khulna, and 8,129MW will be sent from Chittagong to make up for the power deficits in other areas.



Source: JICA Survey Team

Figure 15-2 Power Supply and Demand Balance by Region

15.3 Setting Plans for 2025 and 2035

Based on the previously mentioned plan, expected power flow and the results of discussions with PGCB, the power network system plans for 2025 and 2035 have been set as shown below.

15.3.1 The Plan for 2025

Figure 15-3 and Figure 15-4 show the nation-wide 400kV system in 2025 and its expected power flow. The required facilities in the 400kV system up to 2025 are by the main regions described as follows. Some circuit breakers in a portion of the 230kV system in Dhaka and Chittagong are assumed to be operated in an open position in order to suppress the fault current levels.

(1) Dhaka area (Figure 15-5)

The 400kV substations of Meghnaghat, Bhulta, Green Model, Bashundara, Kaliakoir, Aminbazar, Gabtoli and Dhaka South are constructed. The 400kV transmission lines are constructed surrounding Dhaka city.

(2) Chittagong area (Figure 15-6)

The construction of 400kV Matabari-Madunaghat-Meghnaghat transmission lines with double circuits and 400kV Madunaghat and Meghnaghat substations will be launched as a yen-loan project. In addition, 400kV S. Alam-Matabari and S. Alam-Madunaghat transmission lines with double circuits will be constructed in accordance with the start of operations of S. Alam thermal power plant. The 400kV Mirsharai substation will also be constructed.

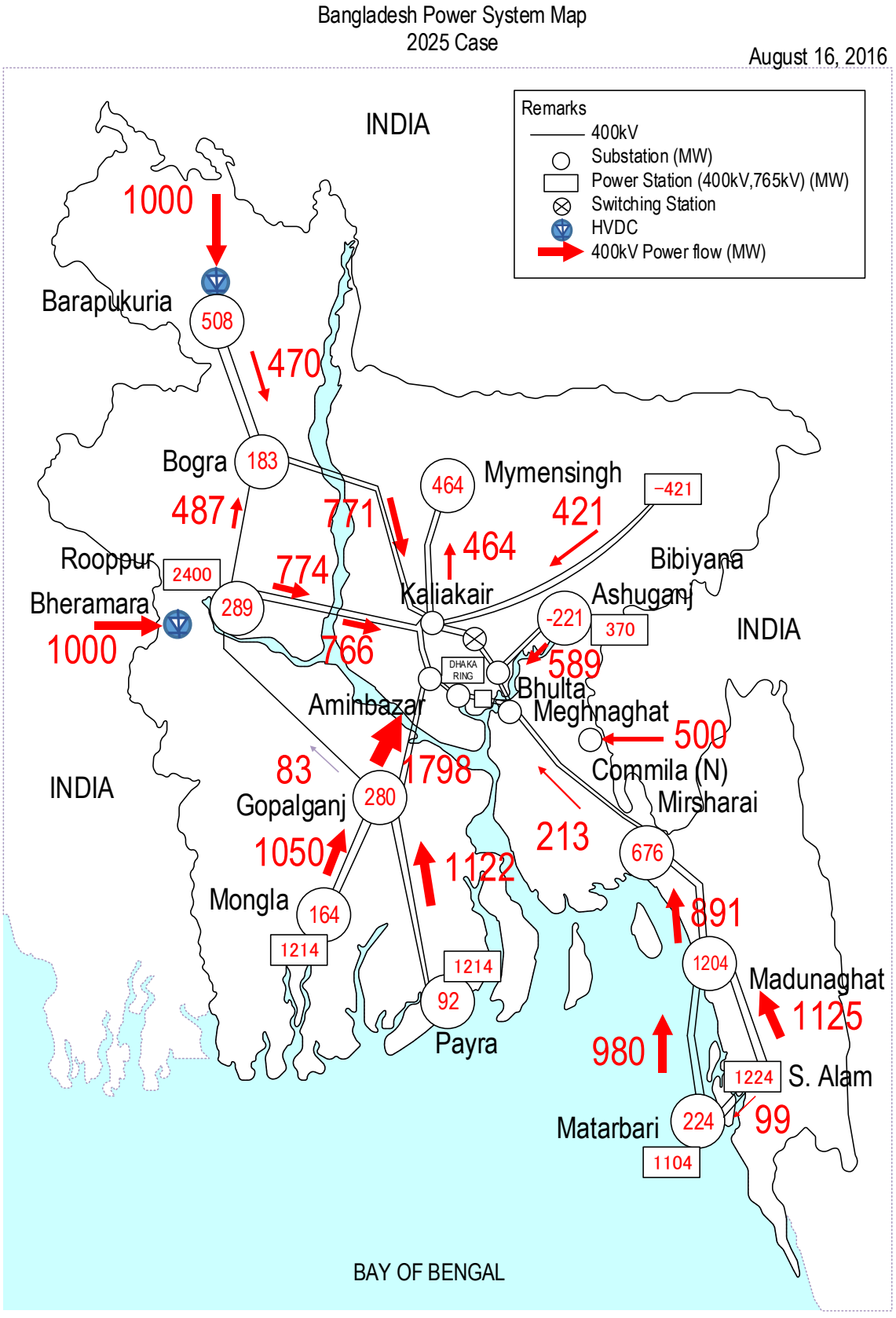
(3) Khulna area (Figure 15-7)

- Power Transmission for Rooppur Nuclear Power Station

400kV Rooppur-Kaliakoir and Rooppur-Aminbazar transmission lines with a single circuit will be constructed in accordance with the start of operations of Rooppur Nuclear Power Station. Single circuits of both Rooppur-Kaliakoir and Rooppur-Aminbazar are co-mounted on the same towers from Rooppur to a point near Dhaka city. The four circuits of the transmission lines will be derived from Rooppur to enhance the system reliability for power transmission from the nuclear power plant even if the Rooppur-Kaliakoir and Rooppur-Aminbazar towers collapse.

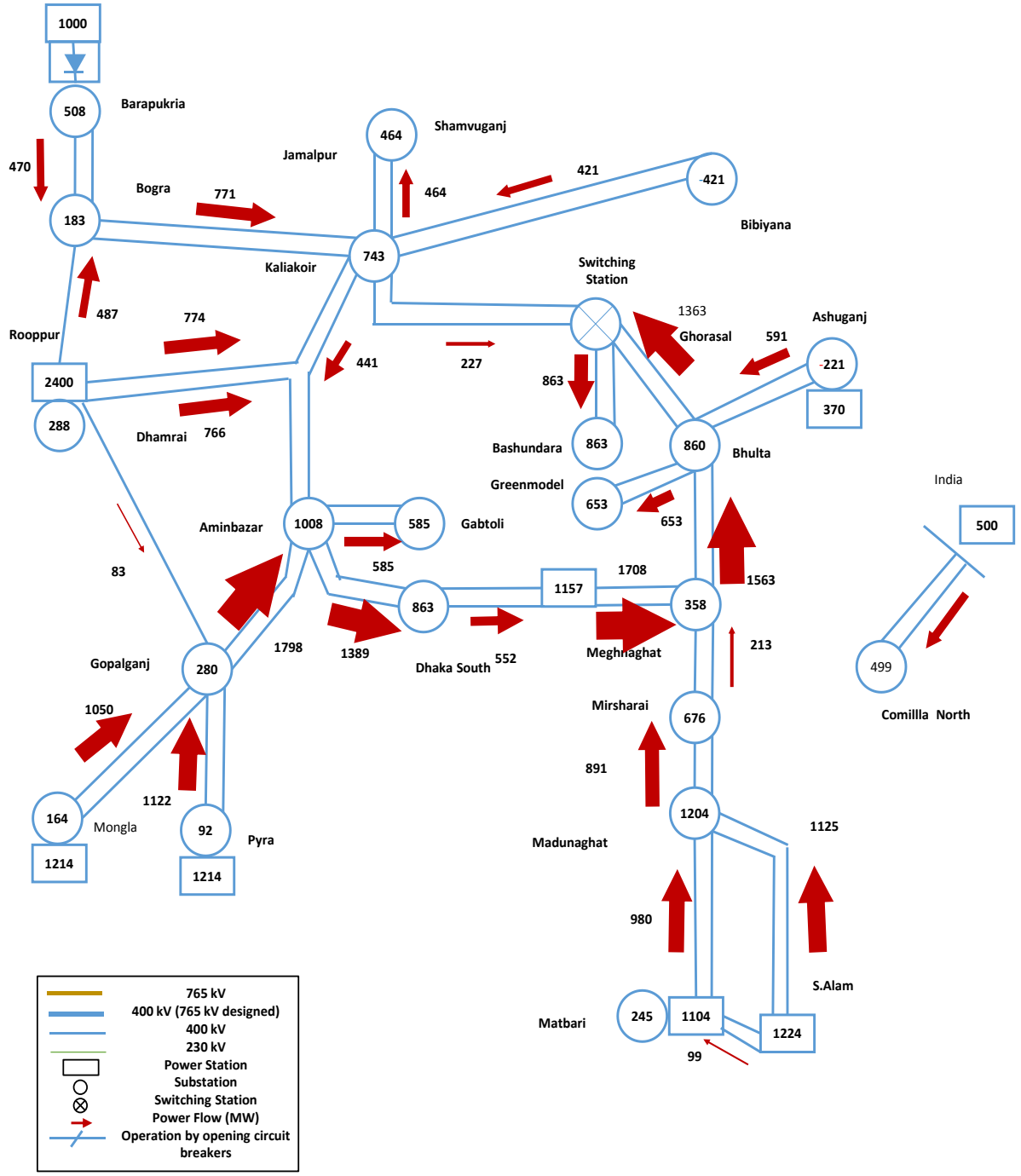
- Power Transmission for Mongla and Pyra (Patuakhali) Thermal Power Plants

400kV Mongla-Gopalganj, Pyra-Gopalganj and Gopalganj-Aminbazar with double circuits will be constructed in accordance with the installation of Mongla and Pyra (Patuakhali) thermal power plants.



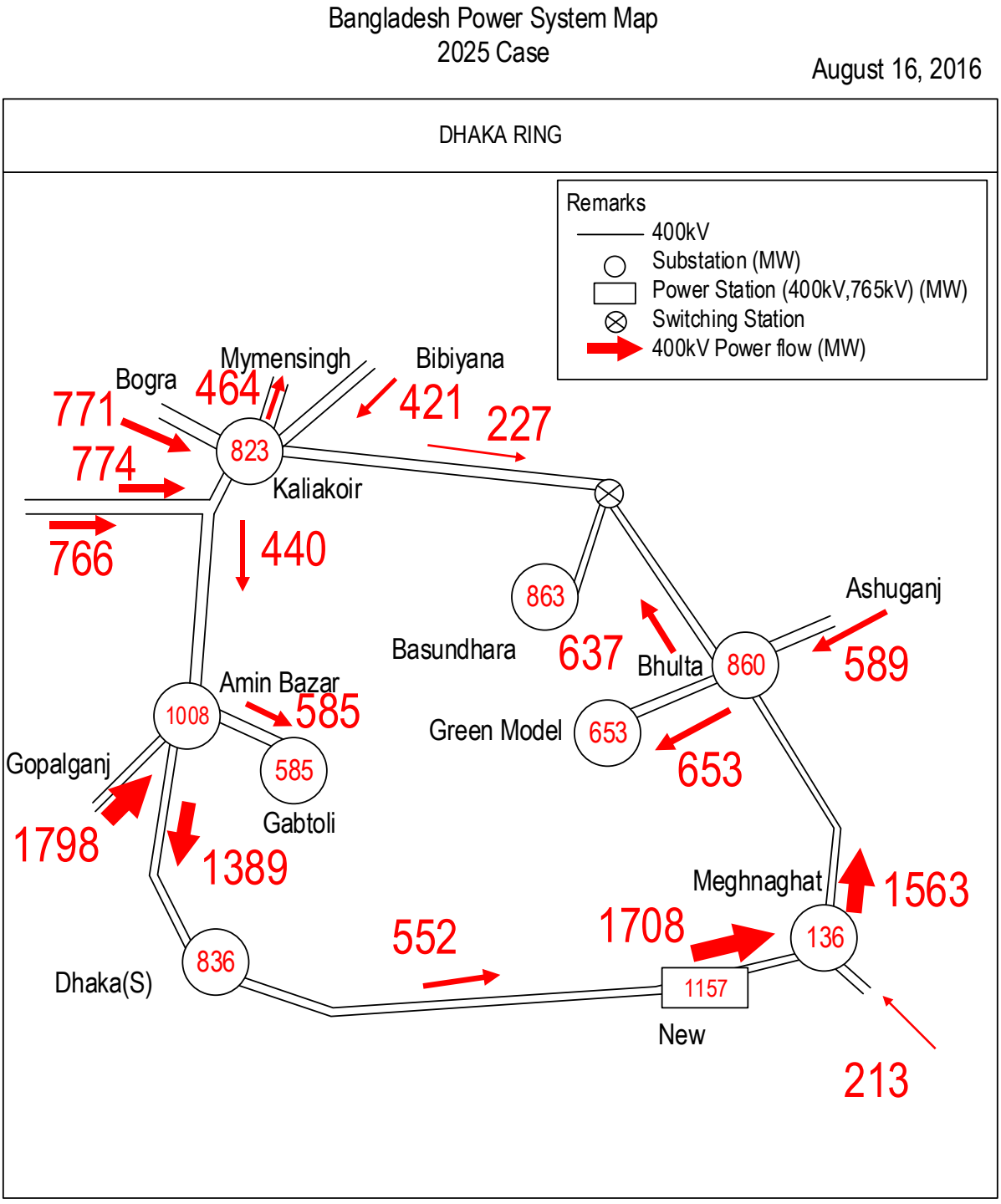
Source: JICA Survey Team

Figure 15-3 Map of Bangladesh System with Expected Power Flow in 2025 (Nation-wide)



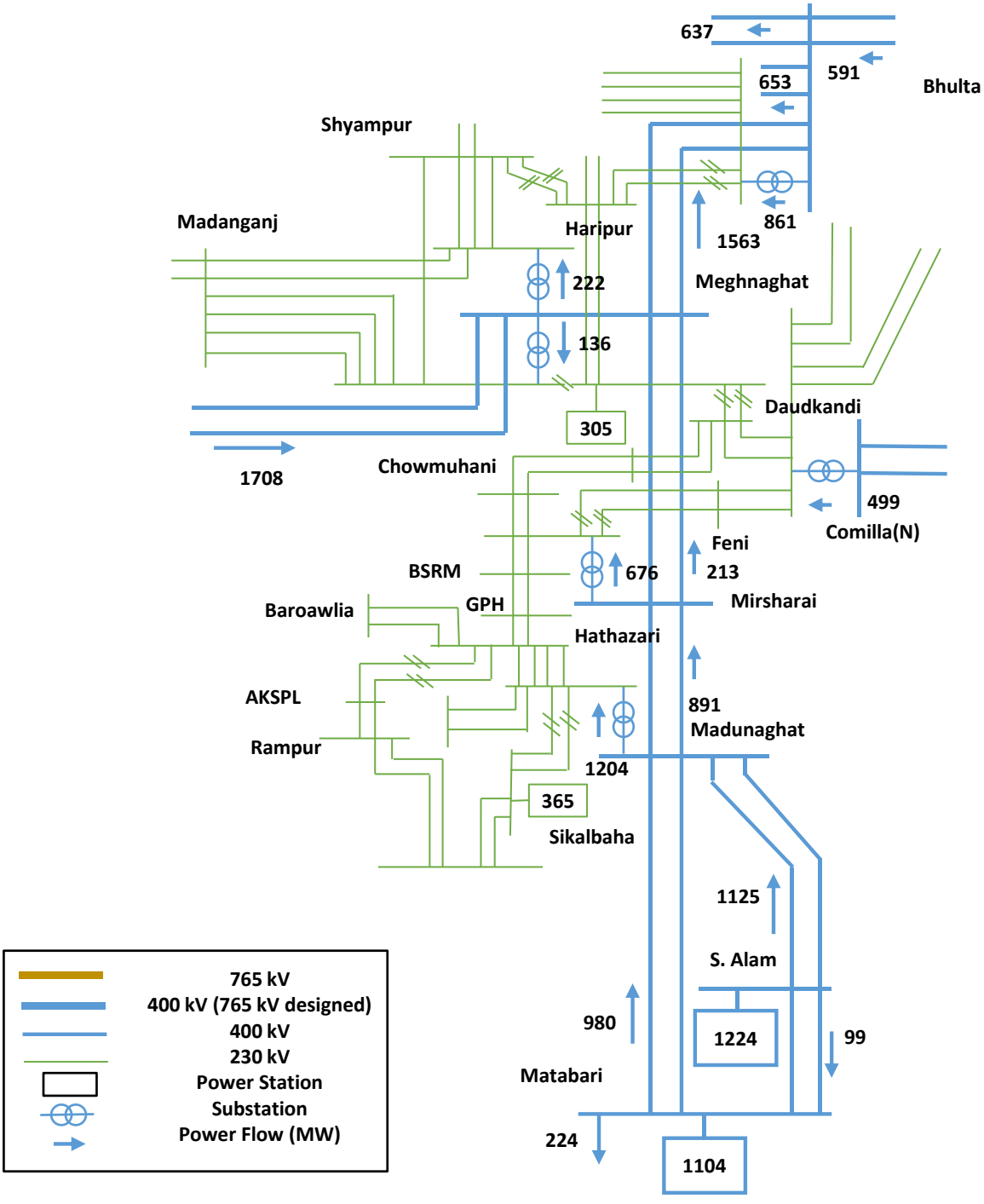
Source: JICA Survey Team

Figure 15-4 400kV System Diagram for Bangladesh with Expected Power Flow in 2025



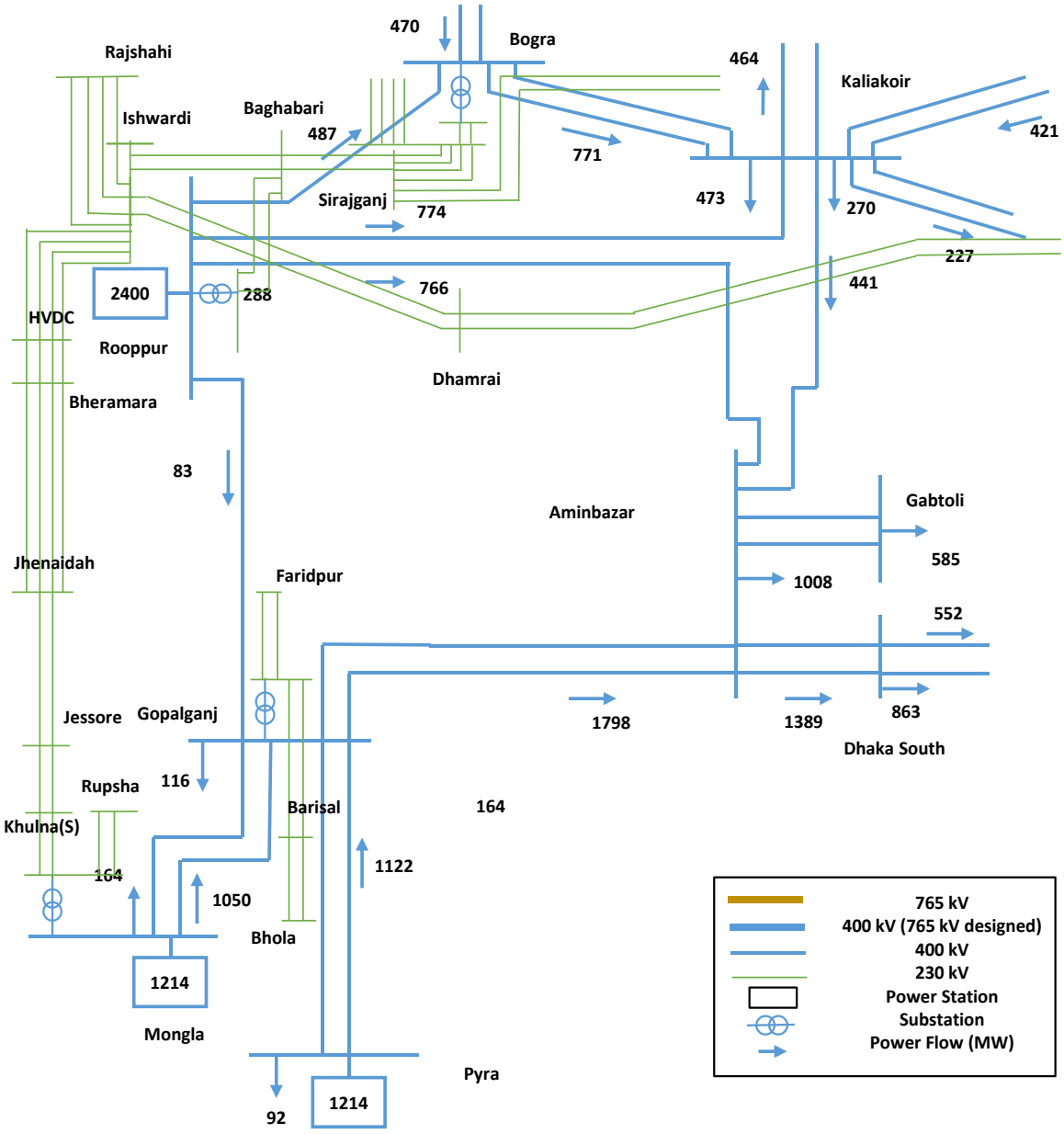
Source: JICA Survey Team

Figure 15-5 Map of Bangladesh System with Expected Power Flow in 2035 (Dhaka Area)



Source: JICA Survey Team

Figure 15-6 400kV System Diagram for Chittagong with Expected Power Flow in 2025



Source: JICA Survey Team

Figure 15-7 400kV System Diagram for Khulna with Expected Power Flow in 2025

15.3.2 The Plan for 2035

Figure 15-8 and Figure 15-9 show the nation-wide 400kV system in 2035 and its expected power flow. The required facilities in the 400kV system up to 2035 are described by the main regions as follows. Some circuit breakers in a portion of the 400kV and 230kV systems in Dhaka and Chittagong are assumed to be operated with opening in order to suppress the fault current levels.

(1) Dhaka area (Figure 15-10)

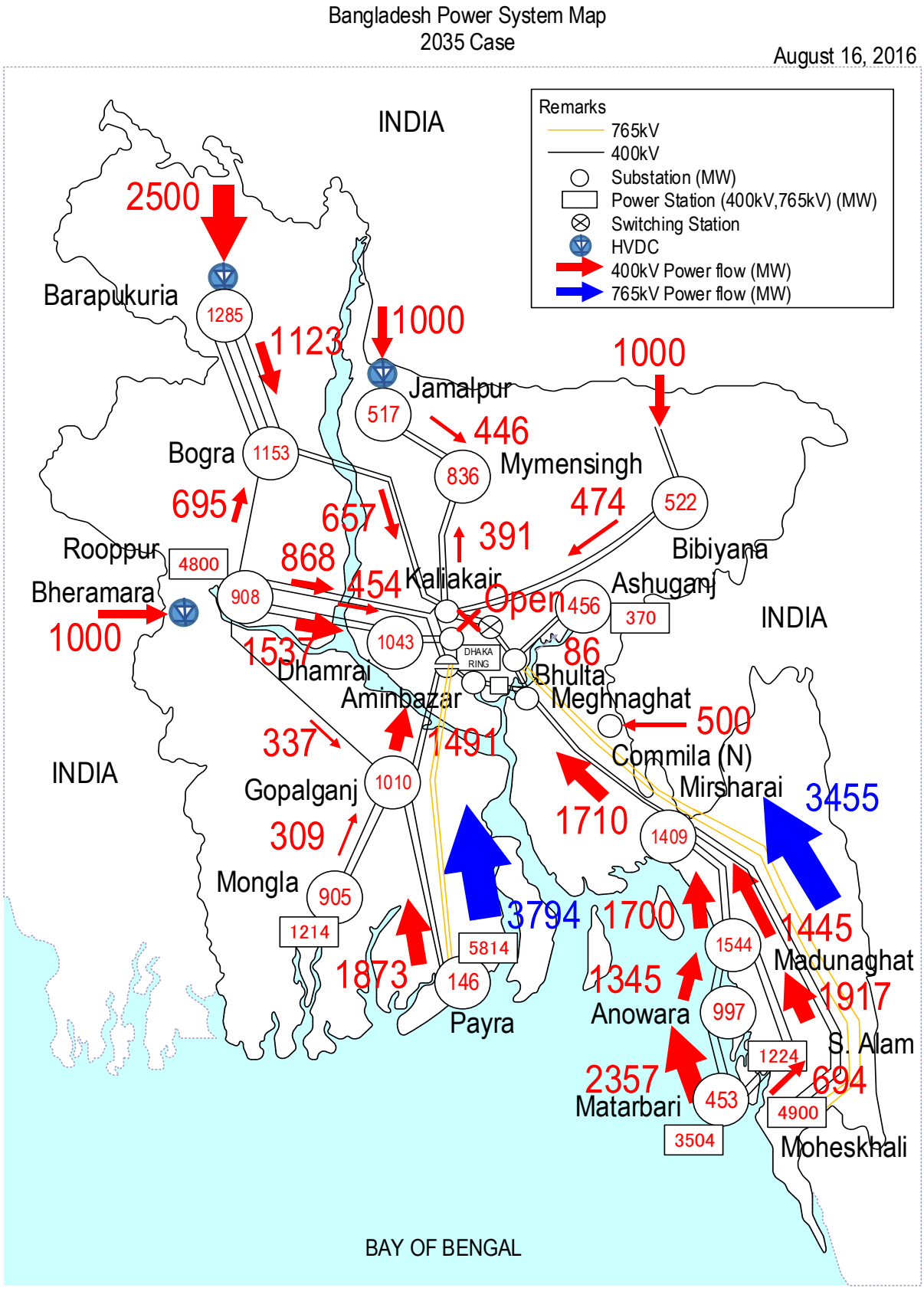
400kV Ghorsal, Tongi and Birlia substations will be constructed between 2025 and 2035.

(2) Chittagong area (Figure 15-11)

A 765kV Mohesikali-Bhulta transmission line with double circuits will be constructed between 2025 and 2035 in accordance with the start of operations of Mohesikali thermal power plant. The 765kV-designed Mohesikali-Mirsharai transmission line, operated at 400kV with double circuits, will be constructed. Some units of Mohesikali power plant will be connected directly to 765kV through their step-up transformers.

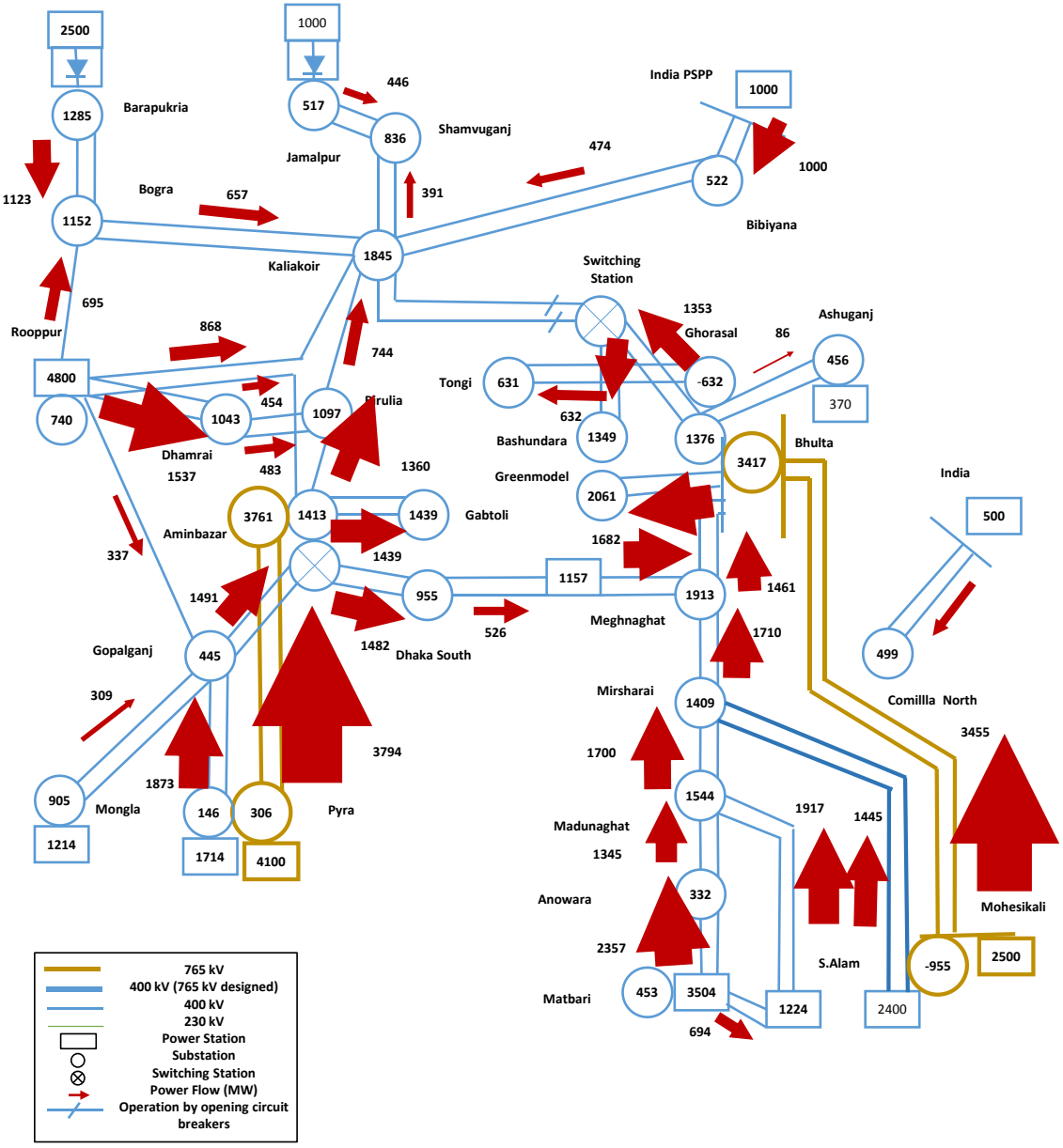
(3) Khulna area (Figure 15-12)

The 400kV Rooppur-Dhamrai-Birulia with double circuits will be constructed between 2025 and 2035.
A 765kV Pyra-Aminbazar transmission line with double circuits will be constructed in accordance with the additional installation of the Pyra (Patuakhali) units.



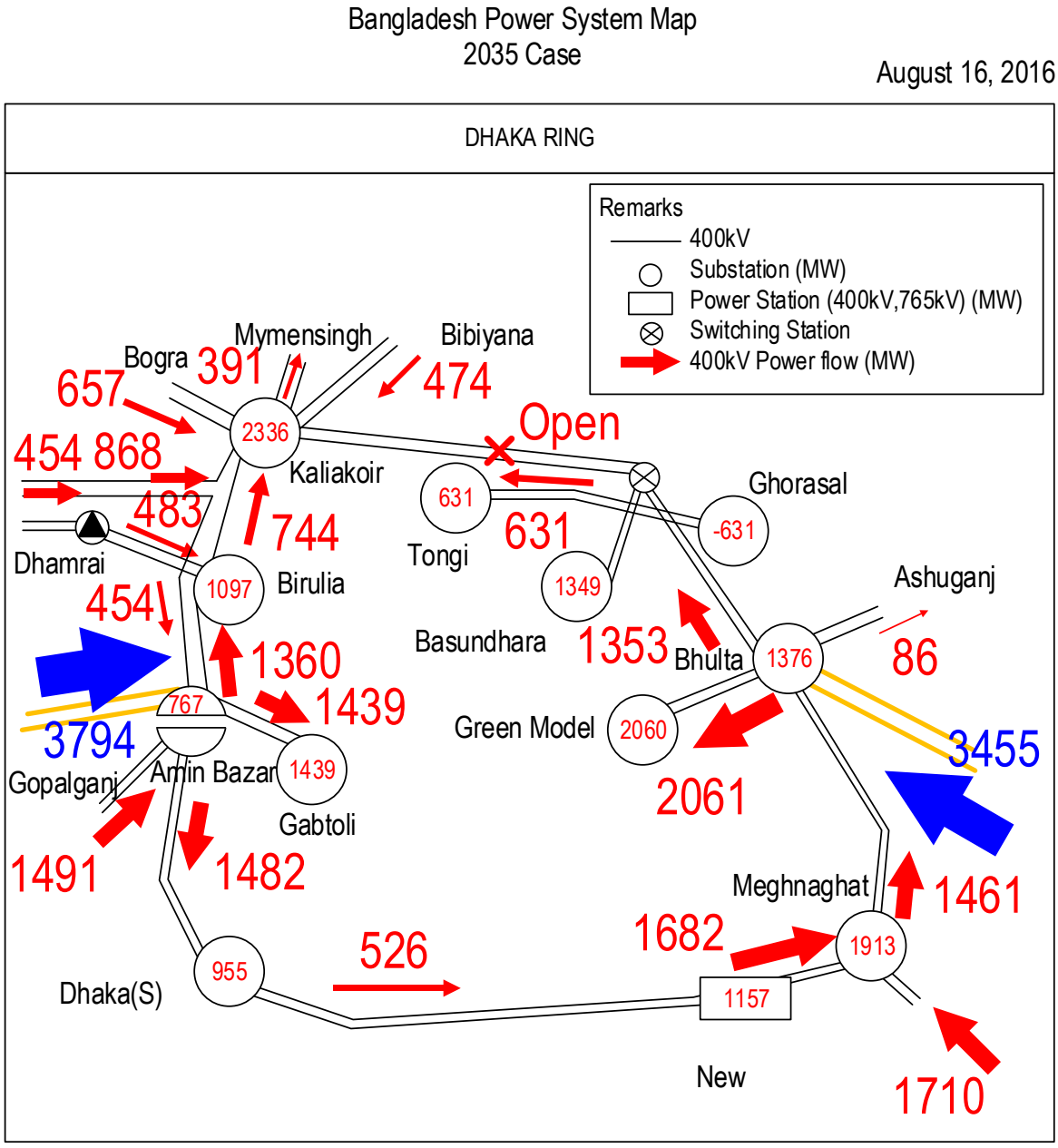
Source: JICA Survey Team

Figure 15-8 Map of Bangladesh System with Expected Power Flow in 2035 (Nation-wide)



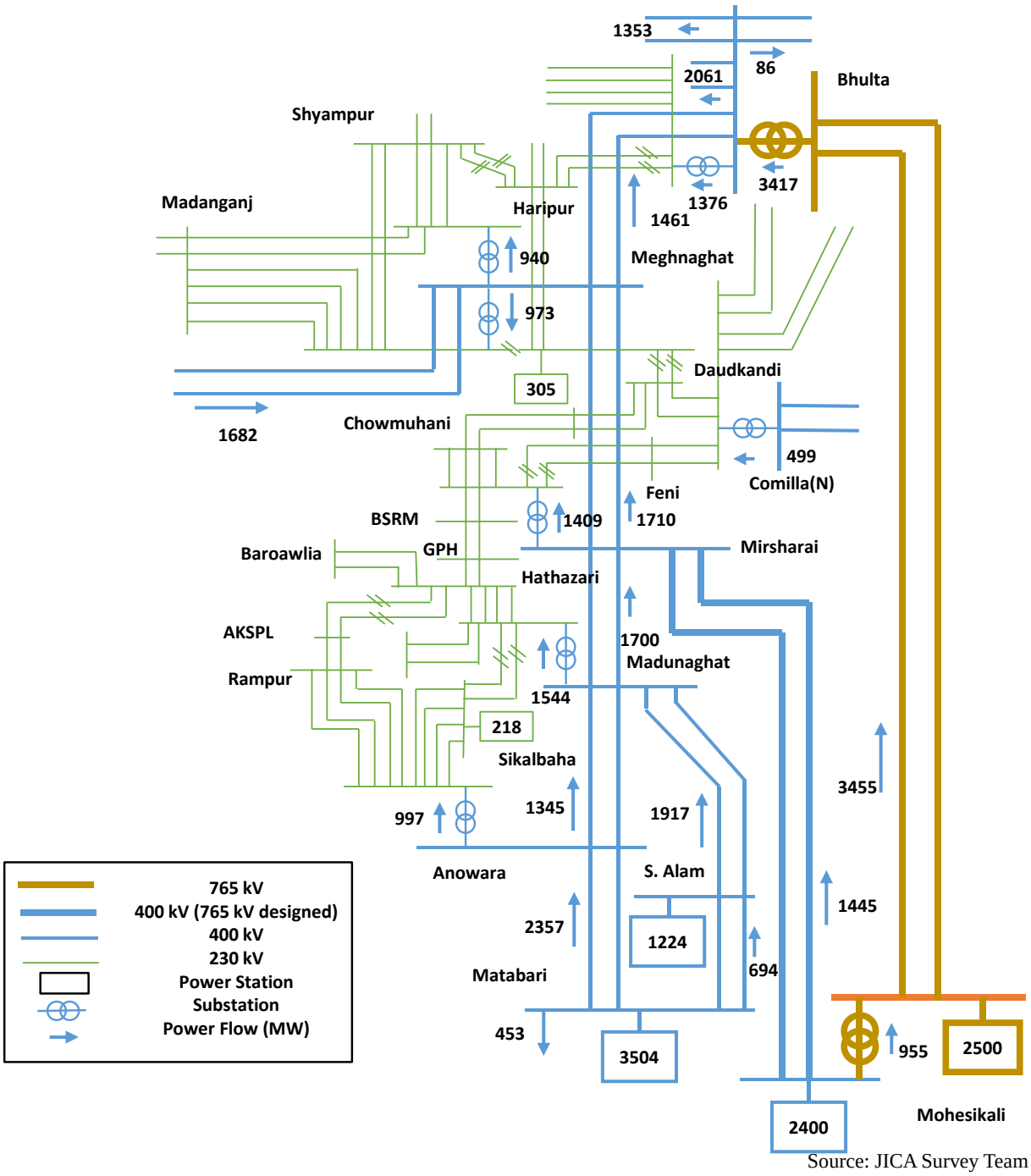
Source: JICA Survey Team

Figure 15-9 400kV System Diagram for Bangladesh with Expected Power Flow in 2035



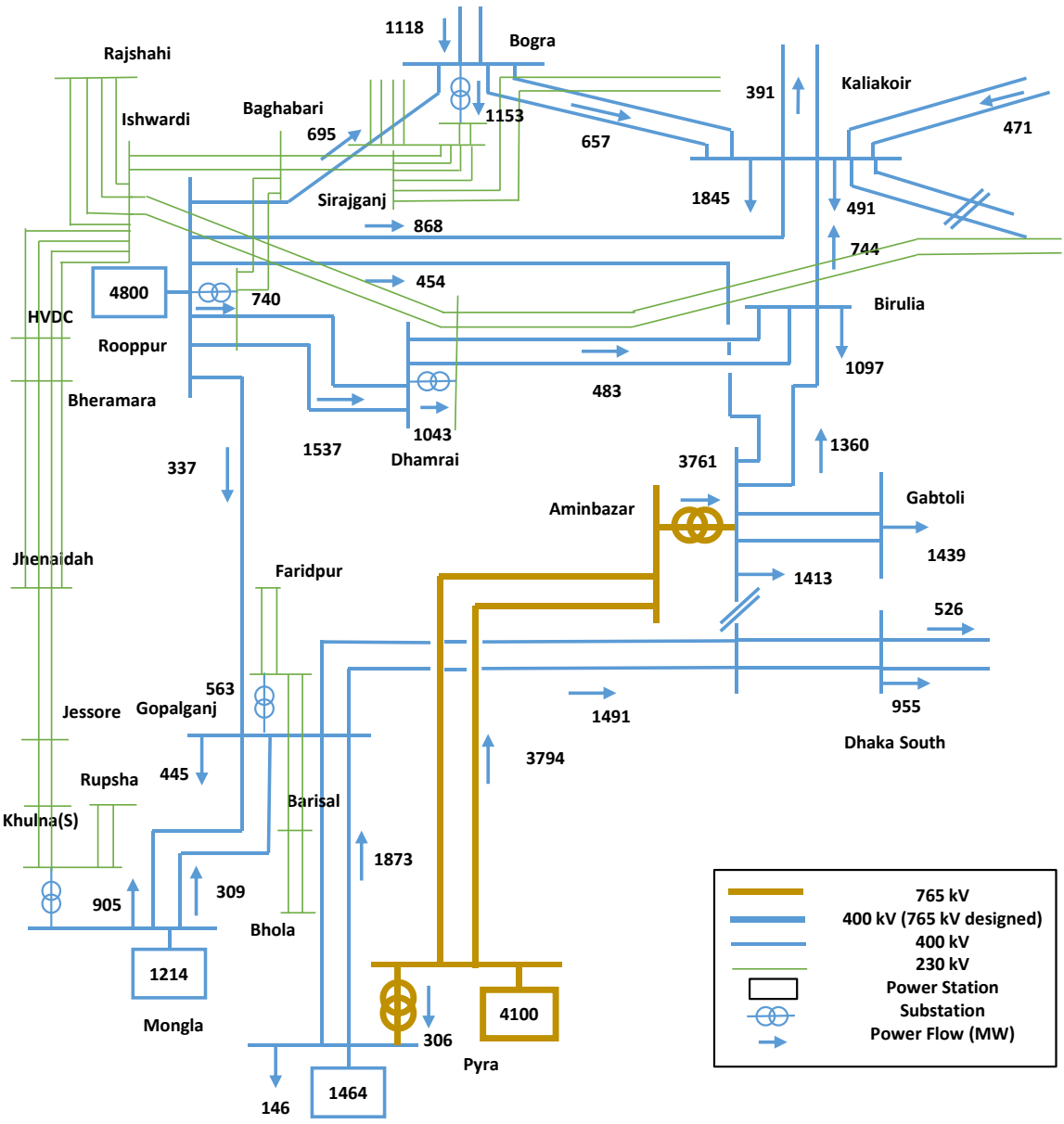
Source: JICA Survey Team

Figure 15-10 Map of Bangladesh System with Expected Power Flow in 2035 (Dhaka Area)



Source: JICA Survey Team

Figure 15-11 400kV System Diagram for Chittagong with Expected Power Flow in 2035



Source: JICA Survey Team

Figure 15-12 400kV System Diagram for Khulna with Expected Power Flow in 2035

15.4 Power System Analysis for 2025 and 2035

15.4.1 System Analysis Criteria

Based on the power demand forecast and power system plan detailed in the previous section, the following criteria were used to analyze power flow, fault current, and stability for the entire Bangladesh power system for 2025 and 2035.

(1) Generator Model

A model with fixed terminal voltage and active current output was used to calculate power flow.
Stability is calculated by applying the salient-pole model (hydropower generators), round-rotor model (thermal power generators), and exciter model, as listed below. A portion of the generators was assumed to be equipped with a power system stabilizer (PSS). A direct current model was considered for grid connections with India.

Thermal Generator (Round-rotor model)

T'do	T"do	T'qo	T"qo	H	D	Xd	Xq	X'd	X'q	X"d = X"q	Xl	S(1.0)	S(1.2)
8.73	0.045	0.97	0.068	2.607	0	2.26	2.2	0.275	0.405	0.214	0.1	0.12	0.6

Hydropower Generator (salient-pole model)

T'do	T"do	T"qo	H	D	Xd	Xq	X'd	X"d = X"q	X1	S(1.0)	S(1.2)
5	0.05	0.06	5.084	1	1.5	1.2	0.4	0.2	0.12	0.03	0.25

Exciter Model

TA/TB	TB	K	TE	EMIN	EMAX
0.1	10	100	0.1	0	5

Power System Stabilizer

T1	T2	T3	T4	T5	T6	KS	LSMAX	LSMIN
0.06	0.18	0.06	0.18	5	1.5	-0.75	0.1	-0.1

(2) Load Model

A constant power model was used as the load model for calculating power flow.
A model with constant current for active current and constant impedance for reactive power was used to calculate stability.
In addition, the loads of 132kV substations to be newly installed in the future were modeled at the 132kV substations that would be expected in the vicinity up to 2020. As necessary, the 132kV transmission lines were assumed and incorporated into the completed model.
Load factors at 132kV buses are assumed as 0.9.

(3) Power Transmission Line Model

The values listed below were used for the line constants for power lines to be newly installed in the near future.

Line Impedance for New Power Transmission Lines (Unit: p.u./km (100 MVA base))

	R	X	Y
765kV (6 x ACSR 480)	0.0000018095	0.0000471520	0.0243821390
400kV (4 x Finch)	0.000008554	0.000151229	0.007651757
230kV (Mallard)	0.00015	0.00077	0.001488

(4) Substation Model

The values listed below were used for the main specifications of substations to be newly installed in the near future.

Transformers	Unit Capacity	Primary-Secondary Impedance
765/4000kV	2,250 MVA	13.5%
400/230kV	750 MVA	12.5%
230/132kV	300 MVA	12.5%
Generator Step-up Transformer (Thermal, Hydro)		12.5%
Generator Step-up Transformer (Nuclear) *)		15%

*) Because fault currents around Nuclear Power Stations in the Bangladesh system are high, high-impedance transformers were assumed.

(5) HVDC Model

HVDC model is used for the HVDC interconnection to India.

(6) Capacitor and Reactor Model

Shunt reactors to compensate for the line charge of the 765kV transmission lines and the long distance 400kV lines are installed at some intervals.
The shunt capacitors are assumed to be installed at the areas of the system where voltage drops are observed.

(7) Planning Criteria

- Power Flow

Even when a unit of transformers or a single circuit breaks down, the power flow should be below the capacity of the remaining facilities.
However, for the double circuit lines leading from a nuclear power plant, when the double circuits break down the power flow should be below the capacity of the remaining circuits.

- Fault Current

Fault current was calculated using the IEC60909 method. The fault current levels for the 400kV and 230kV systems were evaluated as symmetric components of the fault current 100ms after fault occurrence.
The allowable fault current levels should be less than 50kA at buses of 765kV, 400kV and 230kV.

- Stability

A three-phase short circuit fault at the near end of the bus was assumed. After fault clearance, convergence of fluctuations in the generator angles was checked and stability was determined.

15.4.2 Power Flow Calculation

It is confirmed that the power flow in the 765kV, 400kV and 230kV systems meets the criteria for every case in 2025 and 2035.

15.4.3 Fault Current Calculation

Three phase short circuit currents are analyzed at the buses of substations with nominal voltages of 400kV and 230kV on the condition that operating generators and power network configuration are set as shown in the previous sections.
Although a fault current due to a single phase grounding near the generators might sometimes be larger than a three phase short circuit current, single phase grounding fault currents are not calculated in this study because of a lack of data about zero sequence impedances. Single phase grounding currents should be analyzed in future.
The three phase short circuit currents at all the busses of 400kV and 230kV are below 50kV in 2025. The following table shows the buses with their three phase short circuit currents over 40kA in 2025.

Table 15-12 Three Phase Short Circuit Currents of 400kV and 230kV Buses in 2025 (Over 40kA)

Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)	Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)
MEGHNAGHAT	400	47.0	MEGHNAGHAT	230	41.0
ORION	400	47.0	KALIAKOIR	230	41.0
BHULTA	400	45.1	MADANGANJ	230	40.7
KALIAKOIR	400	41.5			

Source: JICA Survey Team

The following table shows the buses with their three phase short circuit currents over 40kA in 2035. The 400kV bus of Rooppur nuclear power plant has its three phase short circuit at over 50kA.

Table 15-13 Three Phase Short Circuit Currents of 400kV and 230kV Buses in 2035 (Over 40kA)

Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)	Name of Bus	Voltage (kV)	Three Phase Short Circuit Current (kA)
ROOPPUR	400	52.6	GABTOLI	230	45.0
MEGHNAGHAT	400	47.3	DHANMONDI	230	44.7
ORION	400	47.3	AMINBAZAR	230	44.0
BHULTA	400	44.4	KCHAR	230	44.0
BIRULIA	400	43.0	KALIAKOIR	230	43.6
AMINBAZAR	400	42.1	OLDAIRPORT	230	43.3
PYRA	400	40.4	ANOWARA	230	42.6
			BSRM	230	41.7
			ROOPPUR	230	40.4
			DHAMRAI	230	40.4

Source: JICA Survey Team

Many circuits of the transmission lines will be derived from the nuclear power station in order to maintain the power system reliability. Four units of generators will start to be operated up to 2035. Thus, a huge fault current would be observed at the 400kV buses of Rooppur nuclear power station and this may become larger than 50kA in 2035 if no change to the system configuration is made.
The three phase short circuit currents at some buses in Dhaka city are close to 50kA and the fault currents of those buses may become greater than 50kA because the single circuit grounding fault current may be larger than the three phase short circuit current near generators.
Countermeasures for large fault current would be required for the places where the fault current is expected to exceed 50kA. General countermeasures are considered as follows.

- Countermeasures against large fault current

① Split of buses or network connection
② Application of high impedance transformers
③ Application of 63kA circuit breakers fulfilling the necessary conditions (securing mechanical strength of facilities at power transmission lines and substations or electro-magnetic induced current)

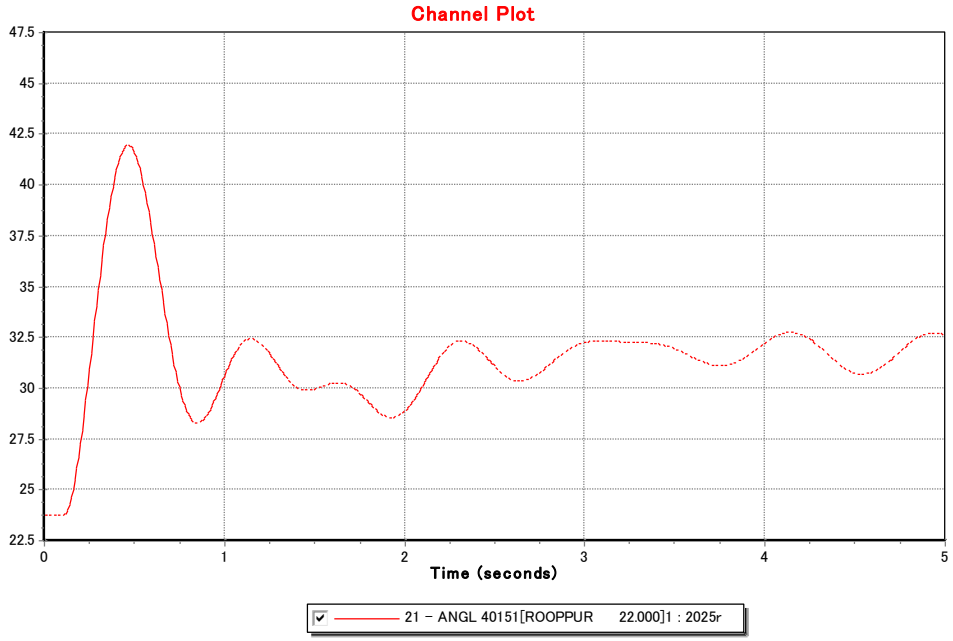
Countermeasure ③ "Application of 63kA circuit breakers fulfilling the necessary conditions" should be considered as the countermeasure for the 400kV bus of Rooppur nuclear power station because ① "Split of buses or network connection" and ② "Application of high impedance transformers" tend to weaken stability of the generators with long distance power transmission.
On the other hand, for the Dhaka system, ① "Split of buses or network connection" or ② "Application of high impedance transformers" can be recommended as the countermeasure against large fault current because the areas to be improved against increase in their fault current levels are widely spread out and the countermeasure seems inefficient.
The system models for 2025 and 2035 set in this study assume that some circuit breakers of the transmission lines and substation buses in the system around Dhaka are operated in an open position to reduce the fault current.

15.4.4 System Stability Calculation

System stability is calculated for cases of faults at the transmission lines from the main power stations located in Chittagong and Khulna. The power outputs of the targeted power generators are set to be operated at their maximum values for each case. It is found that the system can be kept stable for each case.

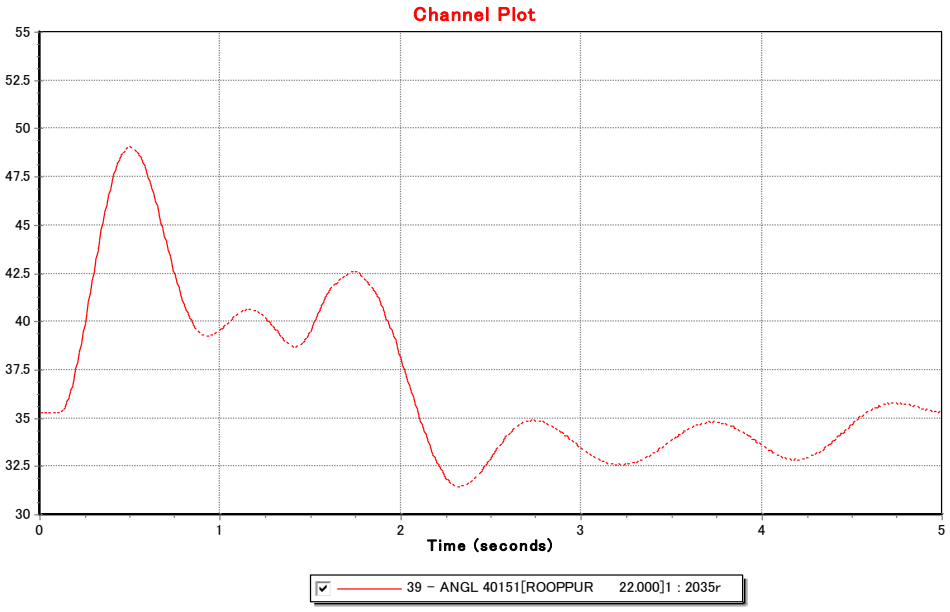
(1) Power transmission from Rooppur nuclear power station

The case of fault clearance by opening the circuit breakers of the transmission lines of Rooppur-Kaliakoir and Rooppur-Aminbazar after occurrence of a short circuit fault around the Rooppur 400kV bus, in 2025 and 2035, is simulated as a double circuit fault around the nuclear power station. The results of the simulation show that the system can be kept stable.
The following figure shows the power angle oscillation of a Rooppur nuclear power generator in this case.



Source: JICA Survey Team

Figure 15-13 Power Angle Oscillation of a Rooppur Nuclear Power Generator in Case of Double Circuit Fault at 400kV Transmission Lines of Rooppur-Kaliakoir and Rooppur-Aminbazar (2025)



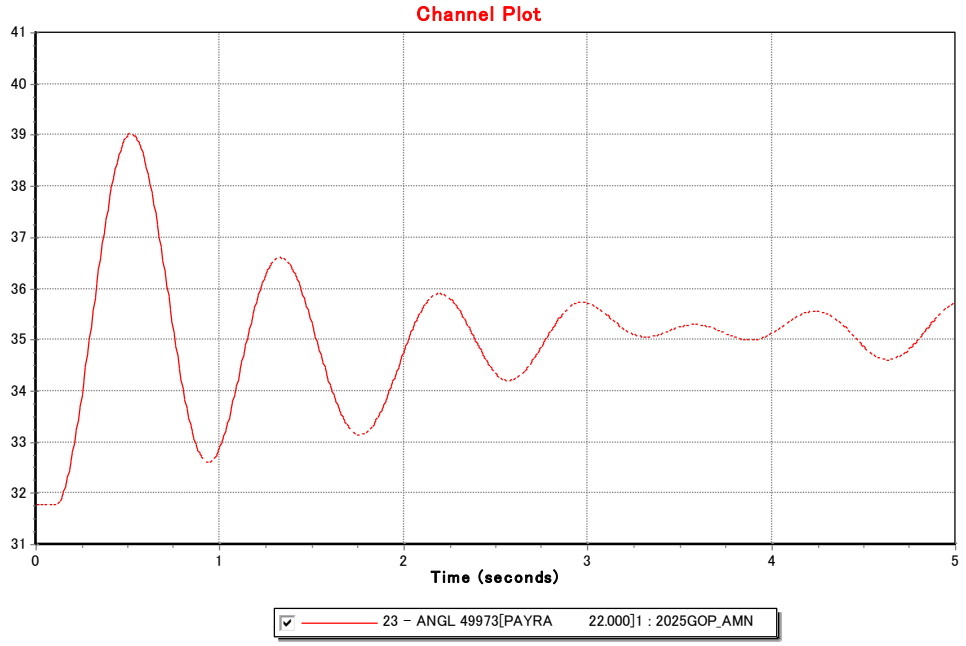
Source: JICA Survey Team

Figure 15-14 Power Angle Oscillation of a Rooppur Nuclear Power Generator in Case of Double Circuit Fault at 400kV Transmission Lines of Rooppur-Kaliakoir and Rooppur-Aminbazar

(2035)

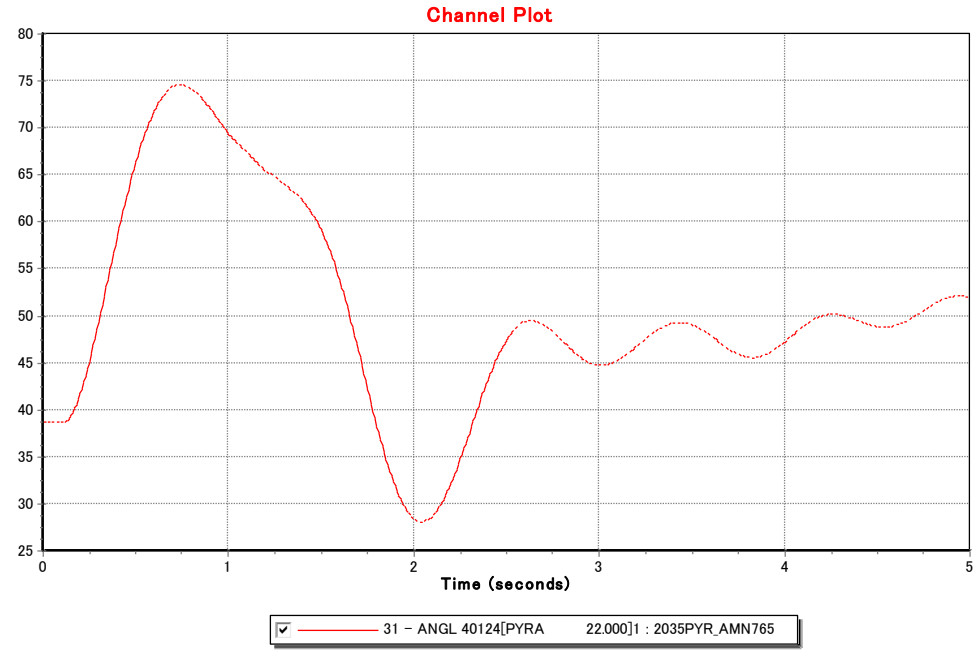
(2) Power transmission from Mongla and Pyra (Patuakhali) thermal power stations

System stabilities in the cases of single circuit faults at the 400kV transmission lines of Gopalganj-Aminbazar in 2025, and the 765kV transmission lines of Pyra-Aminbazar in 2035, are simulated respectively. The results of the simulation show that the system can be kept stable. The following figures show the power angle oscillation of a Pyra thermal power generator in these cases.



Source: JICA Survey Team

Figure 15-15 Power Angle Oscillation of a Pyra Thermal Power Generator in Case of Single Circuit Fault at 400kV Transmission Line of Gopalganj-Aminbazar (2025)

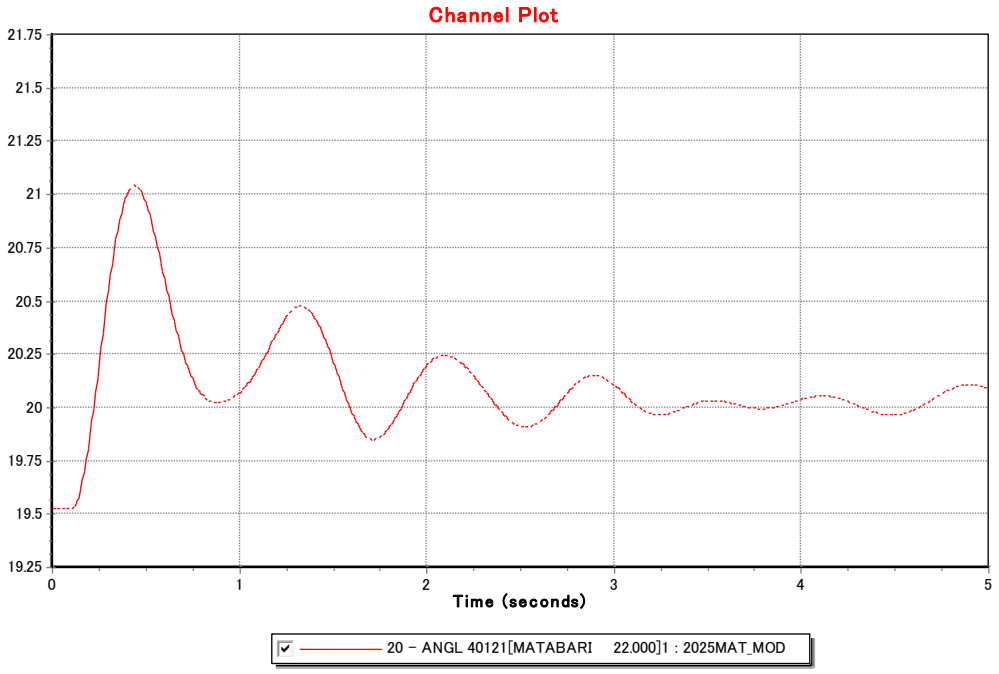


Source: JICA Survey Team

Figure 15-16 Power Angle Oscillation of a Pyra Thermal Power Generator in Case of Single Circuit Fault at 765kV Transmission Line of Pyra-Aminbazar (2035)

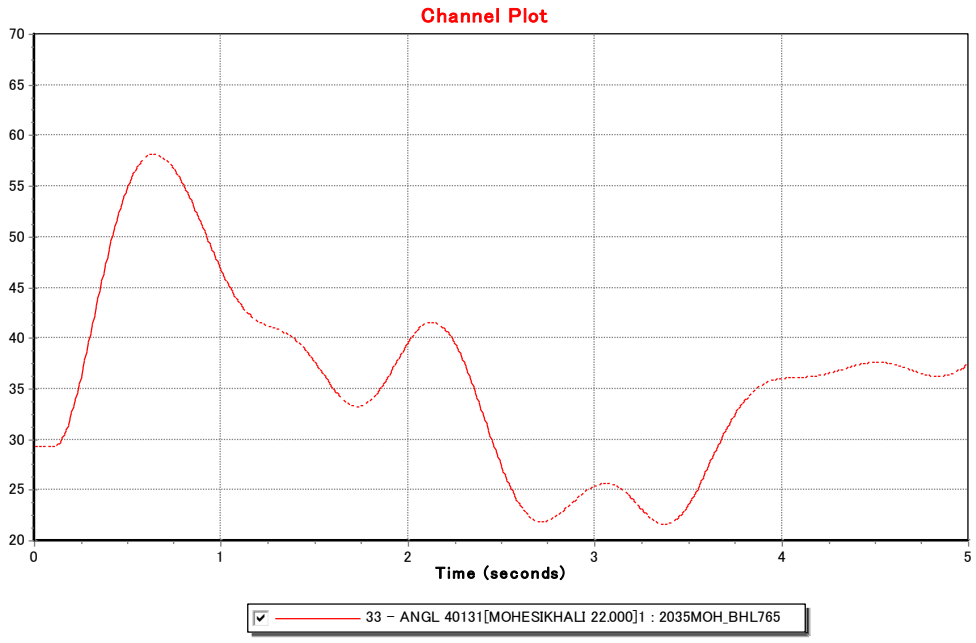
(3) Power Transmission from the thermal power stations located in Chittagong area

System stabilities in the cases of single circuit faults at the 400kV transmission lines of Matabari-Madunaghat in 2025, and the 765kV transmission lines of Mohesikali-Bhulta in 2035, are simulated respectively. The results of the simulation show that the system can be kept stable. The following figures show the power angle oscillations of a Matabari thermal power generator and a Mohesikali thermal power generator in these cases.



Source: JICA Survey Team

Figure 15-17 Power Angle Oscillation of a Matabari Thermal Power Generator in Case of Single Circuit Fault at 400kV Transmission Line of Matabari-Madunaghat (2025)



Source: JICA Survey Team

Figure 15-18 Power Angle Oscillation of Mohesikali Thermal Power Generator in Case of Single Circuit Fault at 765kV Transmission Line of Mohesikali-Bhulta (2035)

15.5 Recommendations Regarding Power System Network Plan

The following is recommended with regard to the power network system plan.

- 765kV transmission lines and substations and 400kV underground transmission lines are applied in some countries. However, because of their technically shallow histories, their design should be carefully studied, especially with regard to countermeasures for over voltage.
- The application of compact type facilities such as GIS and Gas Insulated Transformers or underground substations should be studied for the Dhaka and Chittagong systems, where high demand density is observed.
- A sufficient amount of shunt capacitors should be installed to improve the system voltage at the 230kV and 132kV substations in systems such as Dhaka, where large voltage drops are observed.
- The multi circuits of the 400kV transmission lines are derived from Rooppur nuclear power station. Thus, the fault current levels may exceed 50kA at the 400kV bus of the nuclear power station. In order to solve this issue, upgrading the ability of the fault breaking current to 63kA at the 400kV bus of Rooppur nuclear power station should be studied.
- The fault current may exceed 50kA in dense power transmission systems such as Dhaka and Chittagong. In order to solve this issue, split operation of buses or transmission lines in and around Dhaka and Chittagong, and the application of high impedance transformers, should be studied.
- Feasibility studies on the individual projects confirmed in this master plan for 2025 and 2035 should be carried out.

15.6 Cost Estimation Assumptions

The cost estimation was carried out based on the following assumptions, which were confirmed between PGCB and the JICA Survey Team:

- The unit costs were set as per Table 15-14, determined by PGCB and the JICA Study Team's experience.
- For the transmission lines inside the Dhaka 400kV transmission line circle, underground cables were applied. The others were overhead lines.
- Major river crossing lengths (5km and over) for transmission lines are: 400kV transmission line between Aminbazar and Gopalganj (6km), and 400kV transmission line between Kaliakoir and Bogra (5km).
- For all the substations, including 765/400kV, 400/230kV and 230/132kV substations, GIS was applied rather than AIS.
- The locations of substations and transmission lines were based on the rough assumptions in the Study.
- 132kV substations, transmission lines, and shunt capacitors were left out of the development cost estimation because including realistic 132kV substations in the long term planning is difficult and a vast amount of analysis time is needed if an analysis including 132kV substations is to be carried out.
- From FY2036 to FY2041, the development cost is calculated approximately by using the average annual construction costs from FY2031 to FY2035, rather than conducting detailed planning.

Table 15-14 Unit Cost Table

Equipment		Construction cost	
Overhead Line	230kV D/C (Twin Conductor)	0.63	mil. USD/km/2cct
	400kV D/C (Quad Conductor)	0.87	mil. USD/km/2cct
	765kV D/C (Hexa Conductor)	1.8	mil. USD/km/2cct
Underground Cable	230kV	2	mil. USD/km/1cct
	400kV	4	mil. USD/km/1cct
River Crossing OHL	400kV	34.8	mil. USD/km/2cct
Substation	230/132kV(2x300MW, GIS)	17	mil. USD/station
	400/230kV(3x750MW, GIS)	80.2	mil. USD/station
	765/400kV(2x2,250MW, GIS)	165	mil. USD/station
	765/400kV(4x2,250MW, GIS)	247	mil. USD/station
Static Capacitor	230kV	0.029	mil. USD/MVar
	400kV	0.051	mil. USD/MVar
	765kV	0.1	mil. USD/MVar

Source: PGCB and JICA Survey Team

15.7 Power System Expansion

15.7.1 Amount of equipment expansion from FY2016 to FY2025

(1) Transmission lines

The 230kV and 400kV transmission lines for which construction is necessary from FY2016 to FY2025 are shown in Table 15-15 and Table 15-16.

Table 15-15 230kV transmission lines required from FY2016 to FY2025

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
FARIDPUR-GOPALGANJ	2	60	37.8
JOYDEPUR-KABIRPUR	2	15	9.5
SYLHET-SYLHET (N)	2	12	7.6
SYLHET-BIBIYANA	2	33	20.8
KABIRPUR-KALIAKOIR	4	15	18.9
MOGBAZAR-RAMPURA (cable)	2	6	24.0
BASUNDHARA 2-ULLON (cable)	2	7	28.0
BAROAWLIA-HATHAZARI	2	10	6.3
BAGHABARI-ROOPPUR	2	55	34.7
BARAPUKURIA-PURBASADIPUR	4	45	56.7
BARAPUKURIA-RANGPUR	4	45	56.7
GHORASAL-TONGI	2	28	17.6
HARIPUR-SIDDHIRGANJ (cable)	1	2	4.0
HARIPUR-SIGNBORD (cable)	2	6	25.2
HASNABAD-KERANIGANJ	2	8	5.0
HATHAZARI-MADUNAGHAT	2	15	9.5
ISHURDI-HVDC	2	10	6.3
ISHURDI-RAJSHAJHI	4	70	88.2

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
HATHAZARI-AKSPL	2	10	6.3
OLDAIRPORT-DHANMONDI (cable)	2	6	24.0
RAMPURA-ULLON (cable)	2	4	16.0
SIRAJGANJ-BOGRA (S)	2	72	45.4
TONGI-KALIAKOIR	2	22	13.5
TONGI-BASUNDHARA (cable)	4	10	78.4
AKSPL-RAMPUR	2	8	5.0
BARISAL (N)-GOPALGANJ	2	65	41.0
BHULTA-JALLSHIRI	2	11	6.7
BOGRA (S)-NAOGAON	4	45	56.7
BSRM-MIRSARAI	2	1	0.6
MIRSARAI-FENI	2	1	0.6
MIRSARAI-CHOWMUHAN	2	30	18.9
KALIAKOIR-BIRULIA	2	20	12.6
KERANIGANJ-DHAKA (S) (cable)	4	6	48.0
KHULNA (S)-MONGLA	2	24	15.1
MADUNAGHAT-SIKALBAHA	2	25	15.8
MADUNAGHAT-MADUNAGHAT (O)	2	8	5.0
CHANDPUR-CHOWMUHAN	2	50	31.5
CHANDPUR-DAUDKANDI	2	35	22.1
NAOGAON-JOYPURHAT	2	45	28.4
RAMPUR-ANOWARA	2	15	9.5
SHAMPUR-SIGNBORD (cable)	2	4	15.2
SHAMPUR-MEGHNAGHAT	4	17	20.8
SIKALBAHA-ANOWARA	2	12	7.6
ULLON-GREENMODEL (cable)	2	10	38.8
DHAMRAI-ROOPPUR	2	110	69.3
DHANMONDI-GABTOLI (cable)	2	7	28.8
MADANGANJ-BHOLAIL (cable)	2	7	28.0
MADANGANJ-MEGHNAGHAT	6	10	18.9
MONGLA-RUPSHA	2	20	12.6
GREENMODEL-DHOLAIKHAL (cable)	2	6	24.4
DHAKA (S)-BHOLAIL	2	20	12.8
Total			1234.8

Source: JICA Survey Team

Table 15-16 400kV transmission lines required from FY2016 to FY2025

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
BHULTA-MEGHNAGHAT	2	20	17.4
BHULTA-GREENMODEL (cable)	2	13	104.8
BIRULIA-AMINBAZAR	1	10	4.4
BIRULIA-KALIAKOIR	1	40	17.4
KALIGANJ-BASUNDHARA 2	2	20	17.4
KALIGANJ-BHULTA	2	31	27.0
KALIGANJ-KALIAKOIR	2	40	34.8
MIRERSHARAI-MADUNAGHAT	2	70	60.9
MIRERSHARAI-FENI	2	21	18.3
AMINBAZAR-ROOPPUR	1	167	72.6
AMINBAZAR-GABTOLI	2	3	2.6
ASHUGANJ-BHULTA	2	70	60.9
BIBIYANA-KALIAKOIR	2	168	146.2
KALIAKOIR-ROOPPUR	1	137	59.6
KALIAKOIR-MYMENSINGH	2	95	82.4
KALIAKOIR-BOGRA	2	133	285.4
MADUNAGHAT-ANOWARA	2	38	33.1
MADUNAGHAT-SALAM	2	90	78.3
MEGHNAGHAT-ORION	2	1	0.9
MEGHNAGHAT-FENI	2	123	107.0
ANOWARA-MATABARI	2	62	53.9
GOPALGANJ-MONGLA	2	85	74.0
GOPALGANJ-ROOPPUR	1	165	71.8
AMINBAZAR-GOPALGANJ	2	85	277.5
GOPALGANJ-PYRA	2	163	141.8
MATABARI-SALAM	2	35	30.5
ROOPPUR-BOGRA	1	100	43.5
AMINBAZAR-DHAKA (S)	2	15	13.1
ORION DHAKA (S)	2	40	34.8
COMILLA (N)-COM_INDA	2	100	87.0
BARAPUKURIA-BOGRA	2	116	100.9
Total			2159.9

Source: JICA Survey Team

(2) Substations

The 230kV/132kV and 400kV/230kV substations for which construction is necessary from FY2016 to FY2025 are shown in Table 15-17 and Table 15-18, where the number of 230kV/132kV substations assumes that two transformers are installed in one substation.

Table 15-17 230kV/132kV substations required from FY2016 to FY2025

Location required for 230/132kV SS	No. of Tr	Cost [Million USD]
FARIDPUR	2	17.0
BHULTA	1	8.5
DHAMRAI	3	25.5
JOYDEPUR	2	17.0
SYLHET	2	17.0
SYLHET (N)	2	17.0
KABIRPUR	4	34.0
MOGBAZAR	2	17.0
BASUNDHARA	5	42.5
BAROAWLIA	3	25.5
AMINBAZAR	3	25.5
ASHUGANJ	2	17.0
BAGHABARI	1	8.5
BARAPUKURIA	1	8.5
BARISAL (N)	3	25.5
BHERAMARA	2	17.0
BOGRA (S)	3	25.5
CHANDPUR	2	17.0
CHOWMUHAN	3	25.5
COMILLA (N)	1	8.5
DAUDKANDI	2	17.0
DHANMONDI	3	25.5
GHORASAL	3	25.5
HASNABAD	1	8.5
JOYPURHAT	3	25.5
KHULNA (S)	1	8.5
MADANGANJ	5	42.5
MADUNAGHAT	3	25.5
MANIKNAGAR	1	8.5
MONGLA	2	17.0
NAOGAON	2	17.0
OLDAIRPORT	1	8.5
RAMPURA	2	17.0
RANGPUR	3	25.5
DHOLAIKHAL	3	25.5

Location required for 230/132kV SS	No. of Tr	Cost [Million USD]
SHAMPUR	3	25.5
GREENMODEL	5	42.5
SIKALBAHA	3	25.5
TONGI	2	17.0
ULLON	4	34.0
BASUNDHARA	5	42.5
FENCHUGANJ	2	17.0
JESSORE	3	25.5
JHENAIDAH	3	25.5
KERANIGANJ	3	25.5
RAJSHAJHI	3	25.5
RAJSHAJHI	3	25.5
RAMPUR	3	25.5
SIDDHIRGANJ	2	17.0
SRIPUR	3	25.5
BIRULIA	1	8.5
GOPALGANJ	1	8.5
RUPSHA	3	25.5
FENI	4	34.0
BHOLA	1	8.5
GABTOLI	2	17.0
SIGNBORD	1	8.5
BHOLAIL	4	34.0
MADOBDI	3	25.5
Total		1,266.5

Source: JICA Survey Team

Table 15-18 400kV/230kV, 132kV Substations Required from FY2016 to FY2025

Substation	Cost [Million USD]
PYRA	80.2
BHULTA	80.2
BASUNDHARA	80.2
MIRSARAI	80.2
ASHUGANJ	80.2
BARAPUKURIA	80.2
COMILLA (N)	80.2
GHORASAL	80.2
MYMENSINGH	80.2
KALIAKOIR 400/132kV	80.2
KALIAKOIR 400/230kV	80.2
MATABARI	80.2
GOPALGANJ 400/132kV	80.2

Substation	Cost [Million USD]
GOPALGANJ 400/230kV	80.2
AMINBAZAR	80.2
BIBIYANA	80.2
MEGHNAGHAT	106.9
HVDC	80.2
MADUNAGHAT	80.2
MONGLA	80.2
ROOPPUR	80.2
GREENMODEL	80.2
DHAKA (S)	80.2
GABTOLI	80.2
BOGRA	80.2
Total	2,031.7

Source: JICA Survey Team

(3) Capacitors

The capacitors for which construction is necessary from FY2016 to FY2025 are shown in Table 15-19.

Table 15-19 Capacitors required from FY2016 to FY 2025

Substation	Capacity [MVar]	Cost [Million USD]
400kV GOPALGANJ	100	5.1
400kV GOPALGANJ	100	5.1
400kV BARAPUKURIA	800	40.8
230kV RAMPURA	37.5	1.1
Total		52.1

Source: JICA Survey Team

15.7.2 Amount of equipment expansion from FY2026 to FY2035

(1) Transmission lines

The 230kV, 400kV and 765kV transmission lines for which construction is necessary from FY2026 to FY2035 are shown in Table 15-20 to Table 15-22.

Table 15-20 230kV transmission lines required from FY2026 to FY2035

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
SYLHET-BIBIYANA	2	33	20.8
KCHAR-DHANMONDI (cable)	2	3	13.2
KCHAR-GABTOLI (cable)	2	7	26.0
GHORASAL-DHAMRAI	2	70	44.1
HATHAZARI-MADUNAGHAT	2	15	9.5
TONGI-KALIAKOIR	2	43	27.1
BOGRA (S)-BOGRA	2	21	13.4
MIRSARAI-CHOWMUHAN	2	30	18.9
HVDC-JHENAIDAH	2	75	47.3

RAMPUR-ANOWARA	2	15	9.5
SIKALBAHA-ANOWARA	2	12	7.6
Total			237.1

Source: JICA Survey Team

Table 15-21 400kV transmission lines required from FY2026 to FY2035

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
DHAMRAI-BIRULIA	2	20	17.4
DHAMRAI-ROOPPUR	2	110	95.7
BIBIYANA-PSPP	2	100	87.0
GHORASAL-TONGI	2	28	24.4
MYMENSINGH-JAMALPUR	2	62	53.9
Total			278.4

Source: JICA Survey Team

Table 15-22 765kV transmission lines required from FY2026 to FY2035

Route	No. of circuits	Route length [km]	Construction cost [Million USD]
PYRA-AMINBAZAR	2	248	446.4
MOHESIKHALI-BHULTA	2	335	603.0
MIRERSHARAI-MOHESIKHALI	2	170	306.0
Total			1355.4

Source: JICA Survey Team

(2) Substations

The 230kV/132kV, 400kV/230kV and 765kV/400kV substations for which construction is necessary from FY2031 to FY2035 are shown in Table 15-23 to Table 15-25, where the number of 230kV/132kV substations assumes that two transformers are installed in one substation.

Table 15-23 230kV/132kV substations required from FY2026 to FY2035

Location required for 230/132kV SS	No. of Tr	Cost [Million USD]
FARIDPUR	1	8.5
DHAMRAI	2	17.0
SYLHET	1	8.5
SYLHET (N)	1	8.5
BHERAMARA	1	8.5
CHOWMUHAN	1	8.5
COMILLA (N)	3	25.5
ISHURDI	1	8.5
KAMRANGIRCHAR	4	34.0
RANGPUR	1	8.5
SIKALBAHA	2	17.0
RAMPUR	2	17.0
BIRULIA	2	17.0
Total		187.0

Source: JICA Survey Team

Table 15-24 400kV/230kV, 132kV substations required from FY2026 to FY2035

Substation	Cost [Million USD]
DHAMRAI	80.2
BIRULIA	80.2
MIRERSHARAI	80.2
JAMALPUR	80.2
MYMENSINGH (upgrading)	26.7
KALIAKOIR (upgrading)	26.7
TONGI	80.2
HVDC (upgrading)	26.7
ANOWARA	80.2
GREENMODEL (Upgrading)	26.7
Total	588.1

Source: JICA Survey Team

Table 15-25 765kV/400kV substations required from FY2026 to FY2035

Substation	Cost [Million USD]
PYRA	247.0
BHULTA	247.0
MOHESIKHALI	165.0
AMINBAZAR	165.0
Total	824.0

Source: JICA Survey Team

(3) Capacitors

The capacitors for which construction is necessary from FY2026 to FY2035 are shown in Table 15-26.

Table 15-26 Capacitors required from FY2026 to FY2035

Substation	Capacity [MVar]	Cost [Million USD]
230kV AMINBAZAR	400	11.6
400kV JAMALPUR	400	20.4
400kV JAMALPUR	400	20.4
400kV BARAPUKURIA	400	20.4
400kV BARAPUKURIA	100	5.1
230kV BASUNDHARA 2	350	10.2
230kV BOGRA (S)	12.5	0.4
230kV PURBASADIPUR	50	1.5
230kV BASUNDHARA	200	5.8
Total		95.7

Source: JICA Survey Team

15.8 Development Costs Summary

The development costs for FY2016-25, FY2026-35 and FY2036-41, which are calculated in the above sections, are summarized in Table 15-27.

Table 15-27 Cost estimation summary

Unit: Million USD

FY2016-25	FY2026-35	FY2036-41
6,737	3,566	2,139

Source: JICA Survey Team

15.9 Rural Electrification

15.9.1 Government policy and definition

While the government has established the "Electricity for all" by 2021[76], in its Vision Statement, there is no single internationally-established definition for electricity access. IEA uses in its analysis "electricity access at the household level, that is, the number of people who have electricity in their home. It comprises electricity sold commercially, both on-grid and off-grid. It also includes self-generated electricity for those countries where access to electricity has been assessed through surveys by government or government agencies. The data does not capture unauthorized connections. The national, urban and rural electrification rates shown indicate the number of people with electricity access as a percentage of the total population" [77].

In Bangladesh, there exist in fact four different definitions and figures for "electrification rate" by four governmental institutions, though the government adopts the Power Division figure.

- Power Division (Power Cell) Definition

  As of December 2015, Power Division recognizes the electrification rate of Bangladesh is 77%. In the government policy statement such as 7th Five Year Plan, the Power Division's figure is adopted. Their equation is as follows:

$$Access\ to\ Electricity\ (\%) = \frac{On-grid\ Electrified\ Polulation + Off-grid\ Electrified\ Population}{Total\ Polulatoin}$$

$$= \frac{\sum\left(Nunber\ of\ Residential\ Customer\ of\ each\ Distribution\ Entity \times Family\ member\ parameter\right) + SHS\ customer}{Total\ Polulatoin}$$

This equation indicates that the electrification rate improvement has two paths; one is on-grid connection, the other is off-grid connection (e.g. SHS). The detail of Power Division's calculation is as follows:

[76] In the 7th Five Year Plan adopted in December 2015, the target by 2020 is set as "electricity coverage to be increased to 96 percent with uninterrupted supply to industries".

[77] https://www.iea.org/media/weowebsite/energydevelopment/Poverty_Methodology.pdf

Table 15-28 Electrification Rate Calculation Detail by Power Division

	BPDB	REB	DPDC	DESCO	WZPDCL	SHS
No. of Domestic (Residential) customer	2,721,205	12,223,002	910,336	641,978	728,453	4,000,000
Family member parameter	5.5	6.5	4.5	4.5	5.5	4.0
No. of people with electricity access	14,966,628	79,449,513	4,096,512	2,888,901	4,006,492	16,000,000
Total No. of population with electricity access	121,408,045					
Total population of Bangladesh	157.8 million					
Access to Electricity	77%					

Source: Power Cell, Power Division

- BPDB Definition

Electrification rate adopted by BPDB is ratio of number of access and all population. Access to Electricity is calculated by the below equation.

$$Access\ to\ Electricity\ (\%) = \frac{Number\ of\ \ Electrified\ Customer \times 7^{*1} + Number\ of\ \ SHS \times 4^{*2}}{Total\ \ Population}$$

Source: BPDB System Planning Division

*1 It assumes that the number of people per grid connection (per household) is 7. Household: Husband, wife, children x 2, father, mother + 1. There are big customers such as hospitals, so 1 is added.

*2 It assumes that the number of people per off-grid connection (renewable) is 4 (-2014) or 5 (2013-). This is based on the assumption that a household using SHS, has smaller of family members than the grid-connected household.

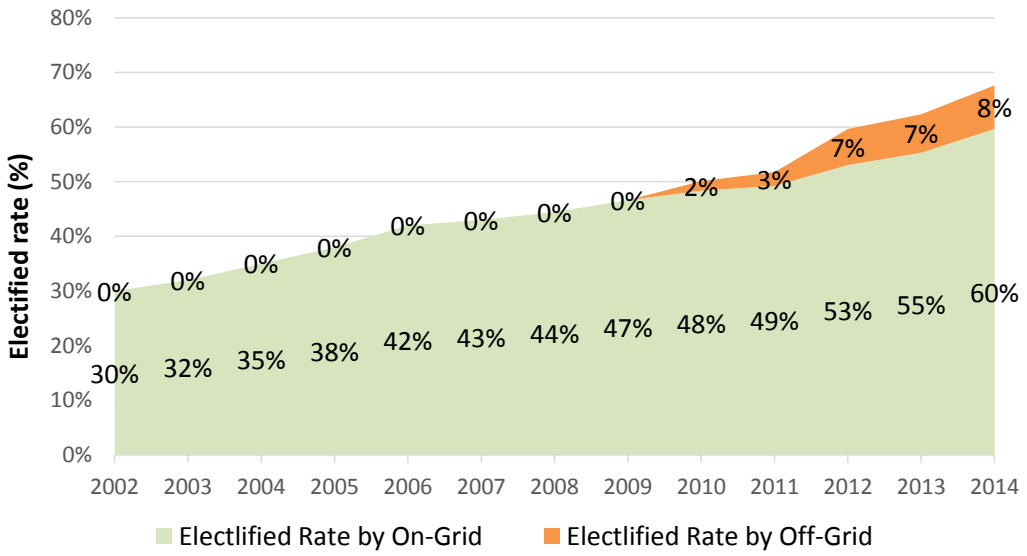
This BPDB definition indicates that the electrification rate improvement has two paths; one is on-grid connection, the other is off-grid connection (e.g. SHS).

Table 15-29 and Figure 15-19 shows the Access to Electricity provided by BPDB. According to Figure 15-19, 60% of population was electrified by grid connection; 8% of population was electrified by SHS installation. In total 68% were electrified in 2014 in Bangladesh.

Table 15-29 Annual Status of Power Sector (2005-2014)

Item (FY)	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Installed Capacity (MW)	4995	5245	5202	5305	5719	5823	7264	8716	9151	10416
Generation Capacity (derated), MW)	4364	4614	4623	4776	5166	5271	6639	8100	8537	9821
Maximum Generation (MW)	3721	3782	3718	4130	4162	4606	4890	6066	6434	7356
Net Energy Generation (MkWh)										
(a) Public Sector	13223	14456	14539	15167	15449	16072	14673	15201	17994	19644
(b) IPP & Mixed	7939	8286	8244	9138	10173	11398	14811	18196	18488	18386
(c) Power Import										2265
(d) REB	246	236	484	641	911	1777	1871	1721	1747	1899
Total Net Energy Generation (MkWh)	21408	22978	23267	24946	26533	29247	31355	35118	38229	42195
Transmission Line (400, 230 &132kV)(Ckt. Km.)	6759 (ckt.km)	6844 (ckt.km)	7044 (ckt.km)	7848 (ckt.km)	8330 (ckt.km)	8465 (ckt.km)	8616 (ckt.km)	8949 (ckt.km)	9322 (ckt.km)	9536 (ckt.km)
Distribution Line (K.M)	244104	264891	271142	256143	259963	269877	274347	281123	288787	302760
Total Consumer Number (lacs)	88.47	97.33	104.2	107.9	115.05	119.88	123.51	135.427	142.32	154.41
Agricultural Consumer (lacs)	1.78	2.16	2.26	2.34	2.82	2.7	2.76	2.95	2.97	2.98
No. of Village Electrified	47612	49435	50360	50724	52334	53837	53925	54216	54638	56312
Population in Million	137	138.8	140.6	142.4	144.2	146	148	151.6	153.6	155.8
Access to Electricity (%) (Grid)	38	42	43	44.43	46.63	48.36	49.23	53.04	55.31	59.66
Access to Electricity (%) (Renewable)								7	7	8
Access to Electricity (%)	38	42	43	44.43	46.63	48.36	49.23	60.04	62.31	67.66
Per Capita Generation (kWh) (Grid)	158	165	165	175	184	200	212	232	249	271
Per Capita Generation (kWh) (Captive)				47	55	64	68	68	72	77
Per Capita Generatio (kWh)	158	165	165	222	239	264	280	300	321	348
Per Capita Consumption (kWh) (Grid)		131	134	143	152	168	180	198	213	233
Distribution Loss (%)		18.89	15.52	14.72	14.57	13.49	12.66	12.10	11.88	11.8
System Loss (Tr. & Dist) (%)	22.79	21.3	19.3	18.16	17.25	15.9	15.21	14.65	14.36	14.13

Source: BPDB



Source: JICA Survey Team, based on the data provided by BPDB

Figure 15-19 Development of Access to Electricity (BPDB definition)

- BREB

BREB defines the electrification rate as below:

Rural Electrification Rate = Current Distribution Line Distance (km) / Targeted Distribution Line Distance (km)

As of February 2016, the current distance 300,000km / Targeted distance 440,000km = 68% (the 300,000km is the total distance of 33kV line, 11kV line and lower voltage lines). BREB does not use the BPDB's definition of rural electrification (the electrification rates of both organizations happen to be the same).

- Bangladesh Bureau of Statistics (BBS)

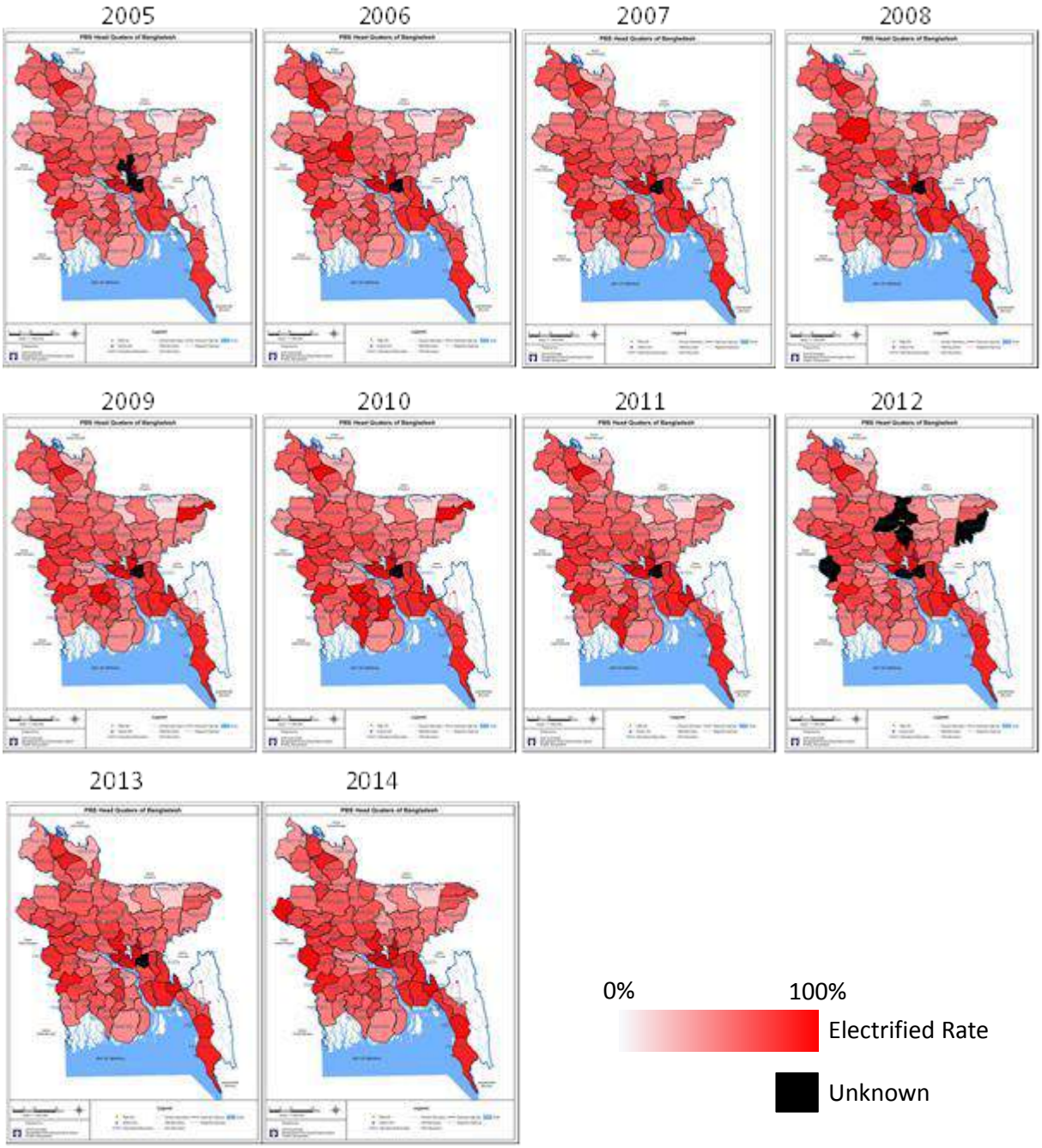
As discussed in the previous Chapter 6, BBS adopts the electrification 86.4%. However, the definition of this figure is unclear and it might be over evaluated.

15.9.2 Power distribution entities in Bangladesh

Refer to "Power Sector Overview" in Chapter 2.

15.9.3 On-grid electrification (distribution line extension)

The following figures show the progress of electrification (approximately 300,000km). According to the BREB, if all of projects are completed, on-grid electrification will be 100%.



Source: JICA Survey Team based on the BREB information

Figure 15-20 BREB's Distribution Line Extension Progress

According to BREB, another 140,000km lines are required for the completion of on-grid extension, which means the total 440,000km is needed for the on-grid electrification by 2021. For the financial needs to materialize this target, BREB is optimistic since several development partners indicate their interest to finance projects.

In addition, BREB has plan to expand its grid after 2022 (when the on-grid electrification is supposed to be completed), as exhibited in the next Table.

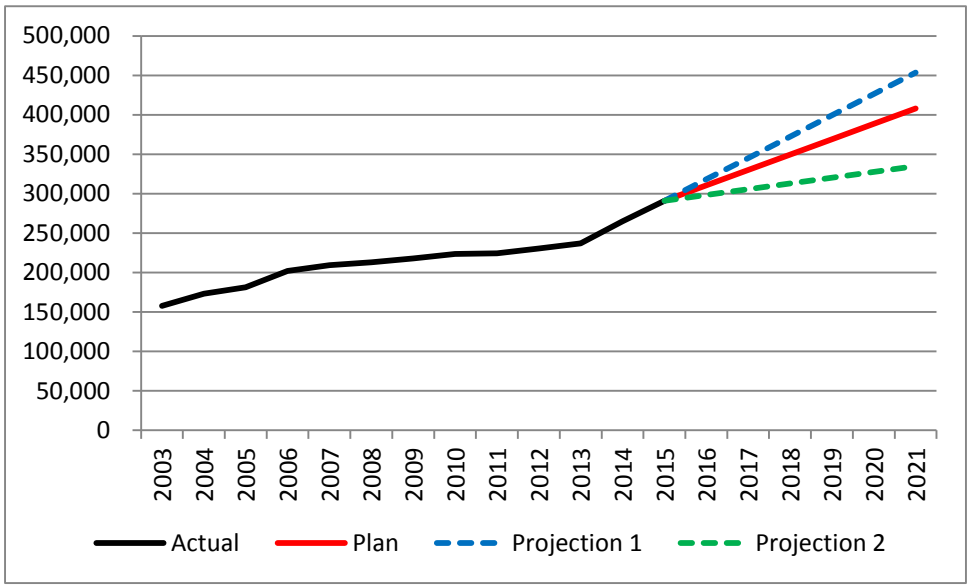
Table 15-30 Rural Electrification Plan up to 2041

SL. No.	Description	December, 2021	December, 2030	December, 2041
1	No. of Consumers (Crore)	2	3	3
2	Quantity of Distribution Line (km)	440,000	500,000	550,000
3	33/11 KV Substations (MVA)	15,100	23,000	30,000
4	Electricity Peak Demand (MW)	9	15,000	20,000

Source: BREB

The below Figure shows the BREB's grid extension projections by 2021, compared with the actual trend in the past up to 2015. The solid black line shows the actual implementation, and red solid line indicates the sum of the individual grid extension projects (as of February 2016).

It should be noted that BREB made a great improvement on grid extension implementation between 2014 and 2015, when BREB substantially increased the grid extension speed compared with the past (between 2003 and 2013). The dotted blue line (Projection 1 in the Figure) means, if BREB keeps the implementation speed as fast as between 2014 and 2015, it will in theory reach 100% on-grid extension (in other words 440,000km distribution line development) by 2021 (it should be also noted, however, that there is a technical issue for on-grid extension, as described later). On the other hand, if BREB loses its grid extension implementation speed as slow as between 2003 and 2013, it would end up far below its target (green dotted line, projection 2 in the Figure).



Source: JICA Survey Team

Figure 15-21 BREB On-grid Extension Plan Comparison

Here is a technical issue of BREB grid extension: according to BREB, the rest 10% of 140,000km (which is 14,000km) are population-scarce or river-crossing areas and thus low economic viability for grid extension. Furthermore these areas do not have PGCB transmission lines nearby, and transmission line expansion is the prerequisite for distribution line expansion.

For these difficult areas, BREB could extend their 33kV lines but not technically recommendable (huge voltage decline could occur). Otherwise, off-grid technologies such as SHS are required for electrification.

In this sense, a good communication and coordination between BREB and IDCOL is required;

however, it is observed that such communication or coordination is not taking place. IDCOL is communicating to BPDB for project planning, but BPDB seems not liaising with BREB properly. If the Government seriously pursue the achievement of "Electrification for All" by 2021, the good communication and coordination between BREB and IDCOL must be taken, and both parties (and BPDB as a coordinator too) need to improve in this area.

The following table shows the forecasts of Access to Electricity estimated by BPDB. According to the below Table, Access to Electricity reaches 90% by line extension by 2021.

Table 15-31 Power Utility Plan by Year

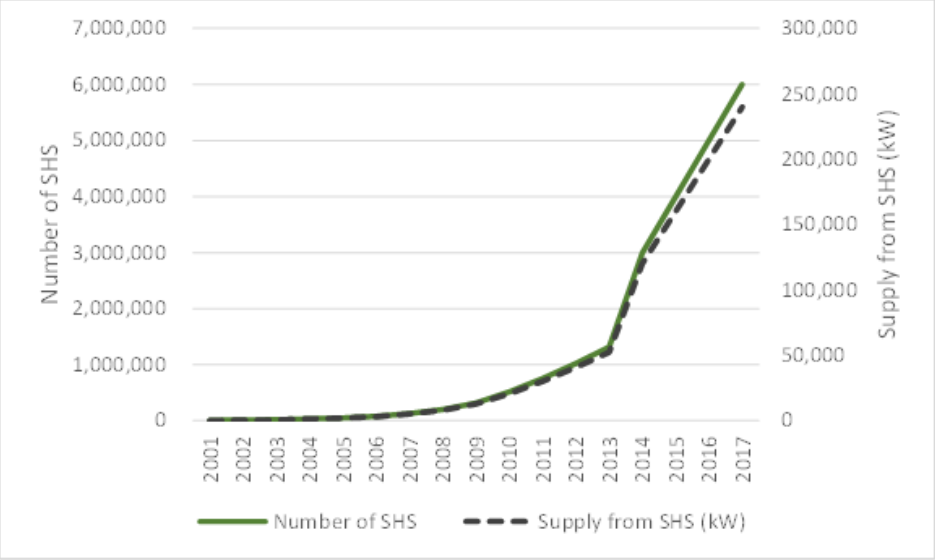
ITEM (FY)	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
GENERATION CAPACITY (DERATED), MW)	9631	12185	13640	15161	17111	18571	22571	24000
NET ENERGY GENERATION (MKWH) *	48713	54047	59945	66457	73658	81610	90950	99838
NET ENERGY GENERATION (MKWH) (REVISED)	42195	46200	51200	56200	62382	68620.2	75482.22	83030.44
TOTAL POPULATION IN MILLION	155.8	157.6	159.6	161.6	163.6	165.6	167.6	169.6
TOTAL DOMESTIC CONSUMER (IN MILLION)	13.28	14.2	15.1	16.2	17.6	18.9	20.3	21.8
ACCESS TO ELECTRICITY (%) (GRID)	60%	63%	66%	70%	75%	80%	85%	90%
PER CAPITA GENERATION (KWH) (GRID)	313	343	376	411	450	493	543	589
PER CAPITA GENERATION (KWH) (GRID) (REVISED)	271	293	321	348	381	414	450	490
PER CAPITA CONSUMPTION (KWH) (GRID)	269	295	324	356	391	429	473	514
PER CAPITA CONSUMPTION (KWH) (GRID) (REVISED)	233	254	279	304	336	367	401	441

* as per PSMP 2010
Source: BPDB

15.9.4 Off-grid electrification

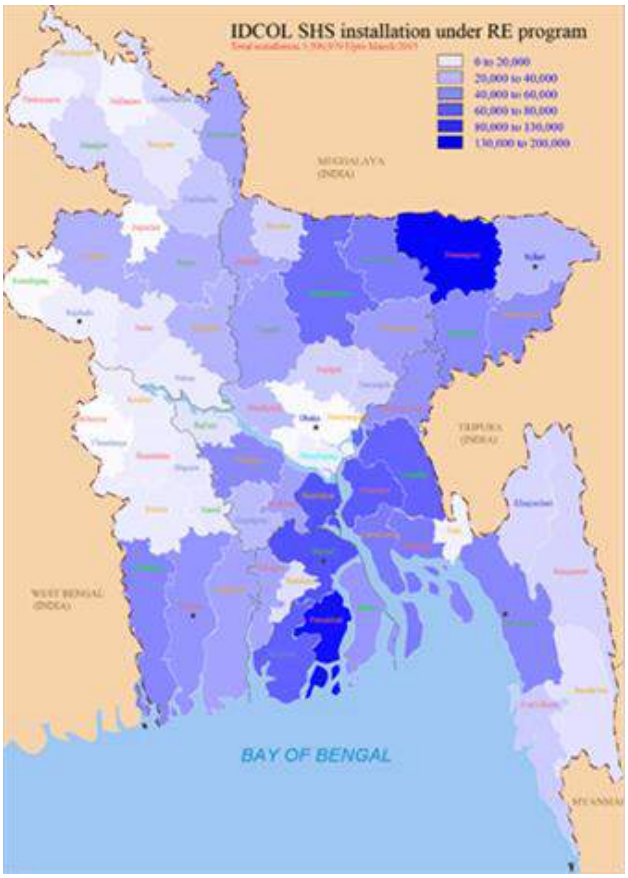
As discussed in the previous section, BREB's on-grid extension has technical limit. In order to achieve the electrification policy by 2021, off-grid technology needs to be employed to complement the on-grid extension.

The SHS installment has been implemented by IDCOL and the progress is world renowned pace (as seen in the below figure). IDCOL has a 6 million target by 2017. For solar micro-grid, IDCOL submits a plan to Power Division for project approval. On the other hand, the each installment for a household is selected by PO (refer to the Chapter 13) and the coordination between BREB is not working effectively as described in the previous section. In order to achieve 100% electrification by 2021, more efficiency (including inter-institution coordination) is required for SHS implementation.



Source: JICA Survey Team

Figure 15-22 Number of SHS under IDCOL Program

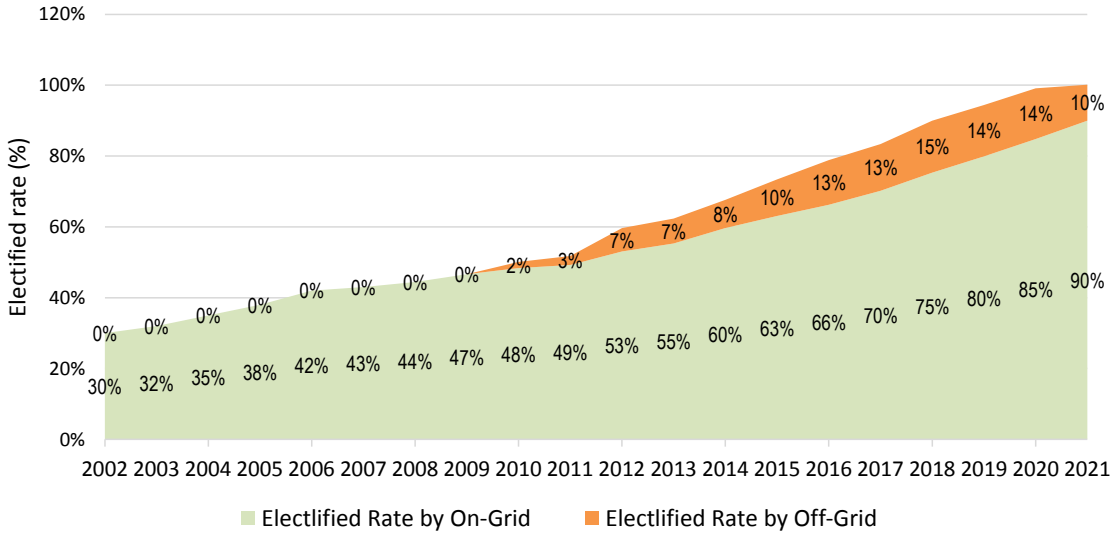


Source: IDCOL homepage

Figure 15-23 Status of SHS Installation

15.9.5 Approach for "Electricity for All"

Based on the estimation of Access to Electricity by BPDB (on-grid extension plans provided by BREB) and SHS installation by IDCOL (Off-Grid), JICA Survey Team estimates the pace of "Electrification for All". It is assumed that the Access to Electricity becomes 100% in 2021. Figure below shows the path to achieve the target.



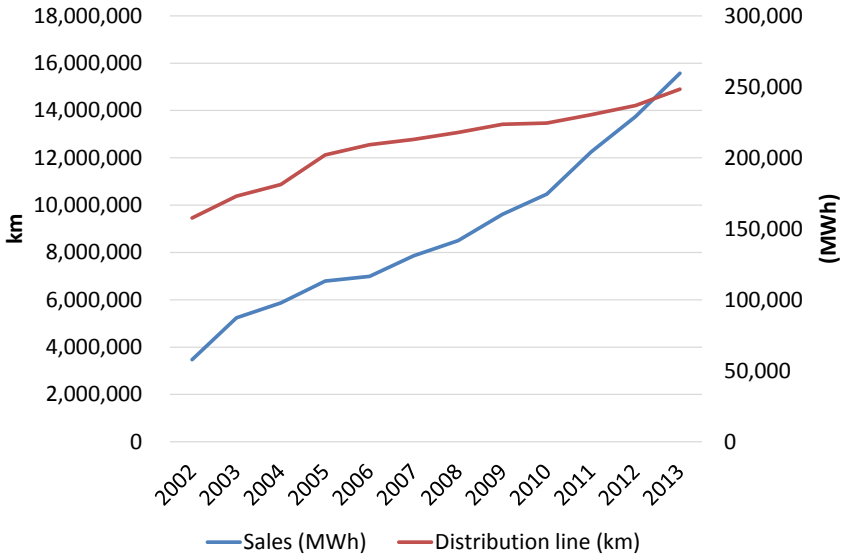
Source: JICA Survey Team

Figure 15-24 Projection of Access to Electricity (On-grid + Off-grid SHS)

It should be noted, however, that there are two issues to materialize the on-grid electrification by 2021. First of all, as pointed out earlier, BREB needs to keep its implementation speed as fast as between 2014 and 2015. Secondly, BREB needs to accommodate with a geological issue. According to the interview with BREB, 10% of future electrification area is not economically viable due to the scarce population density or river-crossing areas. Because transmission lines are not extended to these area, if PGCB does not extend the transmission line, it is difficult to extend the line to these areas. From the view point of the information from BREB, there will be off-grid electrification areas at the first period of the 100% electrification.

15.9.6 Demand estimation from electrification

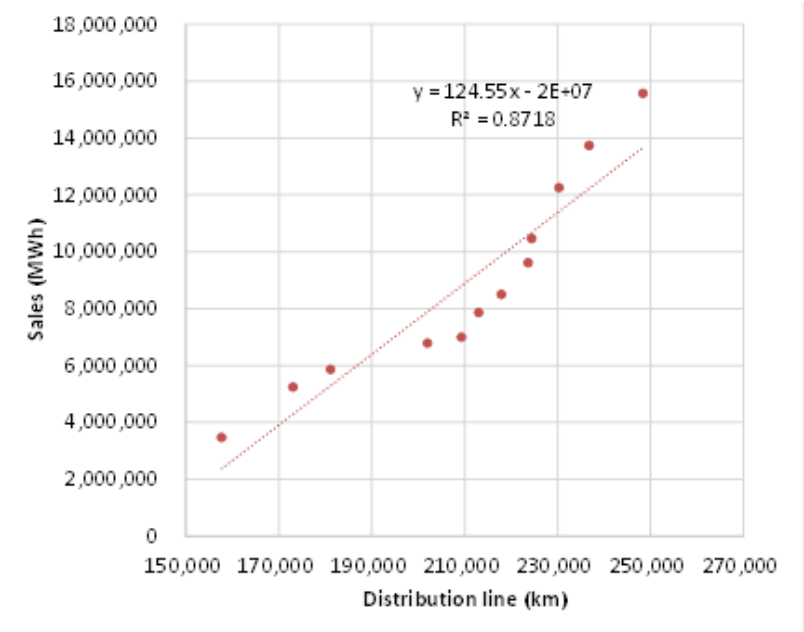
The below figure shows the pace of the grid line extension and the sales growth at BREB in the past 10 years.



Source: JICA Survey Team

Figure 15-25 Line Extension and Sales Growth

As shown in the below Figure, there is a correlation between line extension and sales growth.



Source: JICA Survey Team

Figure 15-26 Relation between Line Extension and Sales Grows

According to regression line, sales of 123.55MWh are increased by 1km distribution line extension. Therefore demand when electrification is completed is calculated by the below equation.

140,000 (km) x 124.55 (MWh/km) = 17,437 (GWh)

When load factor is 80%, maximum demand is estimated by the below equation.

17,437 (GWh) / 8760 (h) / 80% (LF) = 2,488 (MW)

According to the hearing from BREB, yearly average consumption per one customer (of residence customer type and non-residence customer type) is 372(kWh/person/year). According to the BBS statistics, because average number in one family is 4.6, consumption of one family is 1,71(kWh/contract/year). (371kWh/person*4.6person/contract=1.711kWh/contract/year) On the other hand, BSS statics estimates the contract will increase from 14.2 million to 24.0 million[78]. The consumption is calculated by the below equation based on the contract increment.

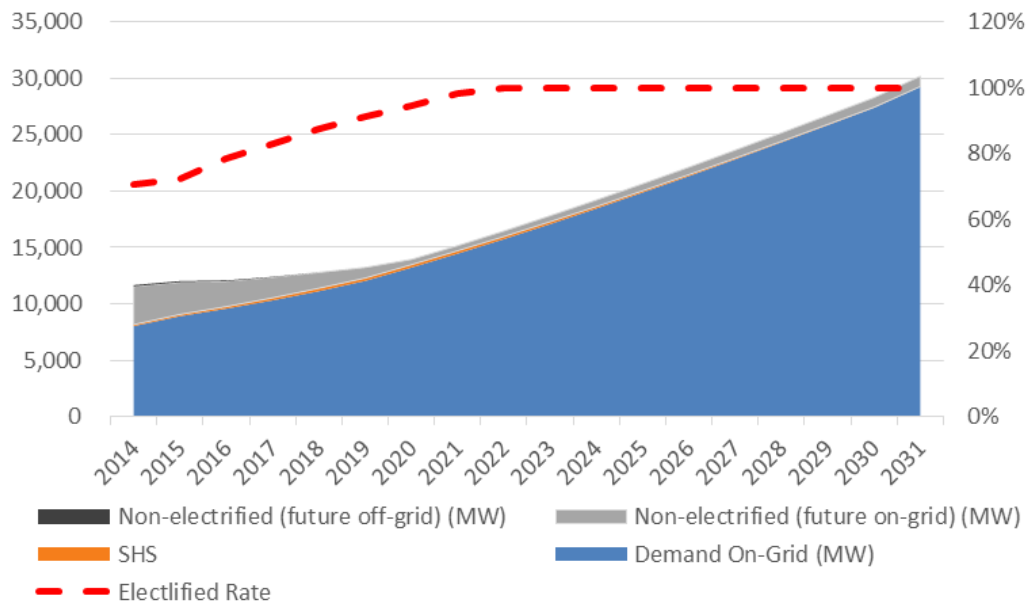
1,711 (kWh / contract / year) x (2,400(contract) - 1,420(contract)) = 16,770 (GWh)

Demand is calculated by the following equation, when load factor is 80%.

16,770 (GWh) / 8760 (h) / 80% (LF) = 2,417 (MW)

Because these two demands are similar, approximately 2,400 – 2,500MW demand will be increased when electrification rate becomes 100%.

Figure 15-27 shows the projection of the improvement of non-electrified capacity.



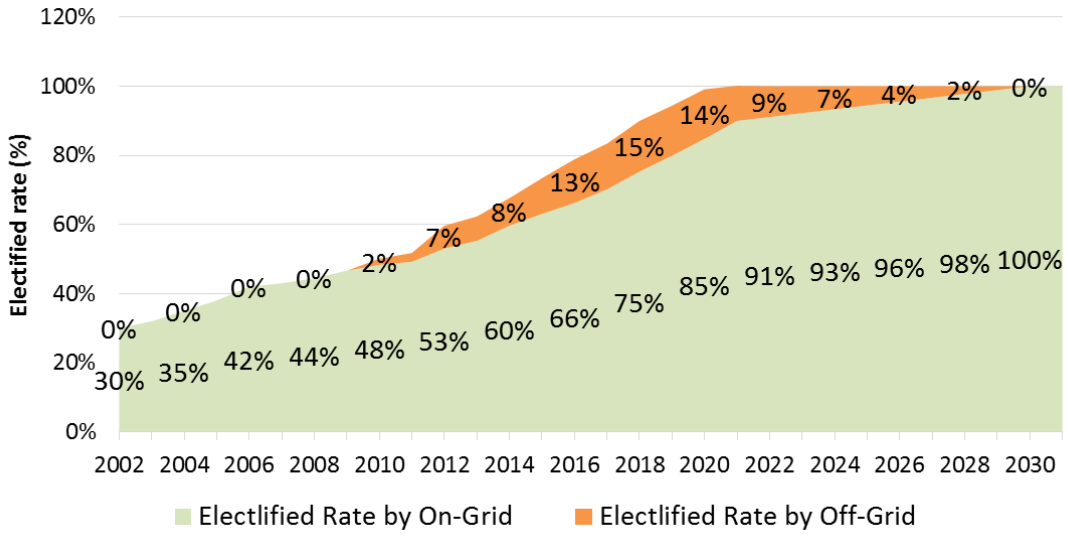
Source: JICA Survey Team

Figure 15-27 Relation between Non Electrified Energy and Demand

15.9.7 Future grid connection

If two issues described earlier can be cleared, electrification rate will be 100%. When distribution line extended to the area where SHSs were already installed, customer, which already installed SHS, will connect to the distribution line, because customer gets the merit according to the cost and limitation by the connection to the grid. When electrification rate extends by the growth rate shown in Figure 15-24, almost all of the customer will be connected to the grid by 2031 as shown in Figure 15-28.

[78] Based on the PSMP2016 Survey Team interview with BBS, February 2016.



Source: JICA Survey Team

Figure 15-28 Estimation of Progress of Grid Connection

15.9.8 Concerns on future wastes from SHSs

Once the stable power supply from grid is achieved, millions of SHSs would be disposed. Most of SHS substances are recyclable (e.g. glass and iron), but the popular SHS batteries in Bangladesh are inexpensive plumbic acid batteries, where lead and lead compounds are used for electrodes and dilute sulfuric acid are used for electrolyte.

Lead and lead compounds can have impacts to organs and nerve systems. Dilute sulfuric acid can cause respiratory disease if absorbed and chemical burn if contacted through skin. If the soil and ground water are contaminated with these substances, agricultural products and ecosystem in-taking these products (including human) would be affected. These substances will not be released to the environment as far as the battery is under usage; however, once a used battery is improperly treated the risk of substance release to the environment could occur. In addition, cadmium, extremely harmful to human body, can be contained in a small amount in a solar panel. It is also a risk of environmental contamination, if the used panel is improperly treated.

There is a report claiming the risk of these harmful substances in the solar generation system in India and China. In these countries, the handling of harmful substances is not very efficient nor well monitored. Such situation causes the loss of these harmful substances within manufacturing and recycling process, and may indicate the inappropriate exposure of these substances into the environment, resulting health risks of people living there[79]. Such loss is not necessarily caused by the illegal dumping or improper recycling of these substances; however, these cases have good implications to Bangladesh, for the importance of appropriate management of these substances.

IDCOL recognized the issues of future SHS wastes and health and environmental risks and implements countermeasures[80]

- Used battery collection process by POs,
- Incentive for POs to bring batteries to a designated recycling facility,

[79] Gottesfeld, Perry and Christopher R. Cherry (2011): Lead emissions from solar photovoltaic energy systems in China and India, Energy Policy, 39(9), pp. 4939-4946

[80]

- Acquisition of ISO14001:2004 and OHSAS 18001:2007 by all domestic battery manufactures (most of SHS batteries are domestically manufactured)
- Incentive for users (households) to comply with SHS battery recycling

15.9.9 Future issues to address

- Only one definition of electrification rate should be selected. Also, the national census tells the average family member size is 4.6, while 7 adopted by BPDB.
- Grid extension in the next 5 years requires the same implementation speed as seen between 2014 and 2015, or twice faster than the historical pace (average between 2003 and 2015).
- BREB and IDCOL coordination and communication should be improved for efficient planning and implementation. BPDB's current role as "coordinator" could be reconsidered.
- SHS waste recycling needs will drastically increase after early 2020s. It should be confirmed whether the current scheme is proven effective and scalable.

Chapter 16 Power Quality

16.1 Fundamentals of Electricity Demand/supply Operation Process

"Demand/supply Operation" is the coordination of various kinds of power sources with demand in order to realize the most economical dispatch under the conditions of maintaining power system reliability or quality, such as system frequency and voltage.

To conduct appropriate demand/supply operation, work starts with the planning and development of adequate power plants and transmission facilities based on the correct demand forecast for a long range of 10 to 20 years. Then, this is seamlessly improved with detailed information on demand forecast or planned/unplanned outages by year-ahead, month-ahead, week-ahead, day-ahead and day plans.

The following is a brief explanation of demand/supply operation planning in Japan.

16.1.1 Demand/supply operation planning

(1) Yearly plan

In this phase, the combination of various kinds of power sources such as hydro, thermal and nuclear power plants is optimized so that economical dispatching is realized for the demand forecasted throughout the year. Development plans for power plants, periodic maintenance plans for thermal and nuclear power plants, fuel operation plans for oil or gas and water operation plans for reservoirs are taken into consideration.

(2) Monthly plan

In this phase, fuel operation plans and maintenance plans for generation facilities are expected to become firm, and the yearly plan is revised with these detailed plans.

(3) Weekly plan

Weekly start-and-stop plans for the thermal power plants and generating plans for hydro power plants (reservoir, pondage and pumped-storage type) are formulated because the accuracy of the demand forecast will be improved and maintenance plans for generation facilities are expected to be finalized in this phase.

(4) Day-ahead plan

Daily start-and-stop schedule for thermal power units, generating plans for hydro power units, and economical load dispatching plans are formulated and final demand/supply operation plans are fixed because the accuracy of the demand forecast is highly improved.

16.1.2 Real-time operation

(1) Economical load dispatching control (EDC)

EDC is the operation of the output of generators every ten or so minutes in order to realize an economically optimal allocation based on past records.

In the case of a power system connected with a large amount and various kinds of generating units,

and in the case where the system load is greatly changing, EDC is largely dependent on automatic calculation and online instruction via computers, and instructions by phone in manual operations by shift engineers are performed only when unforeseeable events occur, such as enormous changes in weather or temperature, or sudden shut-off of generators.

(2) Load frequency control (LFC)

LFC is the control of generating output on a cycle in the range of several minutes to several tens of minutes in order to keep the system frequency constant.

LFC is almost completely dependent on automatic and centralized control by computer systems in the national (central) dispatching center. It is an essential condition for realizing power frequency quality in developed countries (0.2-0.3Hz or less).

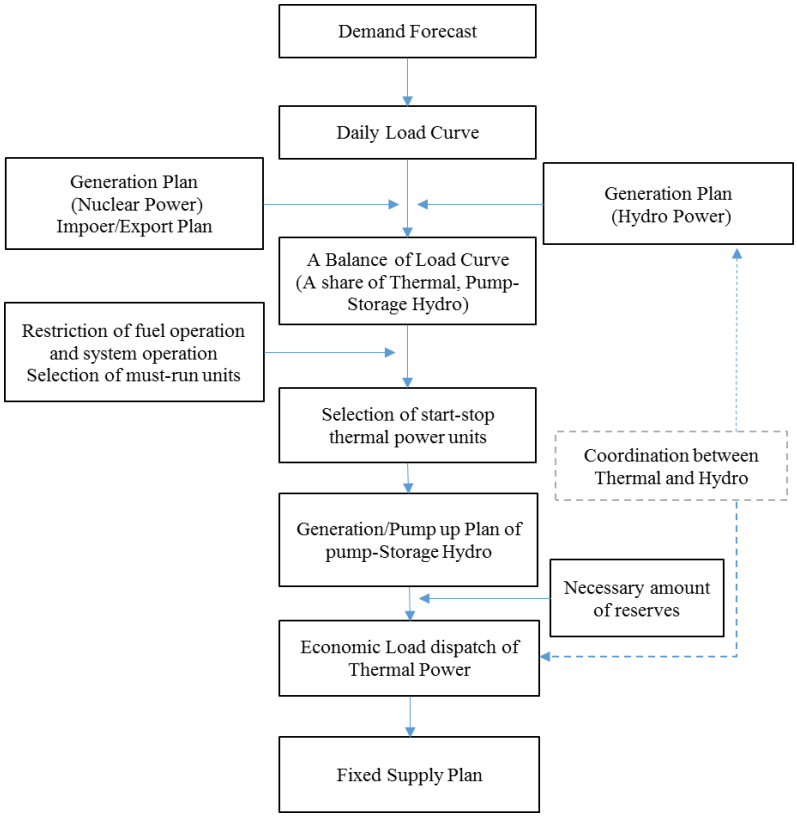
(3) Free governor mode operation (FGMO)

With more frequent load fluctuations ranging from several tens of seconds to several minutes, free governor mode operation by generators is effective for absorbing these.

FGMO is a kind of distributed control system, which can be performed by each unit independently. It is also an essential item for power quality.

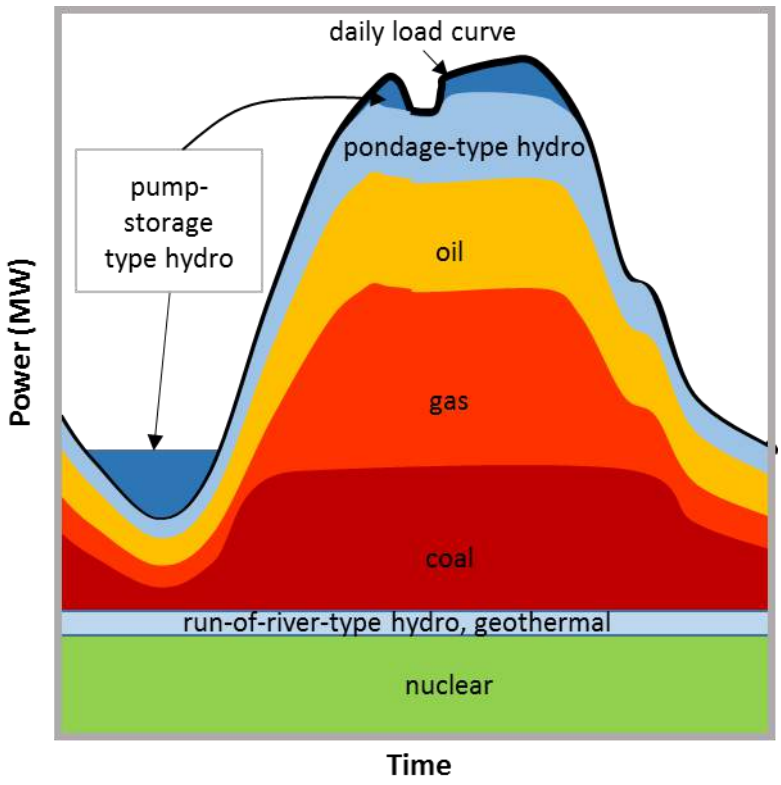
(4) Self-regulating characteristics of load

For more fine fluctuations of several tens of seconds or less, it is impossible to control these artificially because of the delay or dead band in a control system, such as LFC. Fortunately, these fine fluctuations can be absorbed by the inherent frequency-load characteristics or inertia of generators.



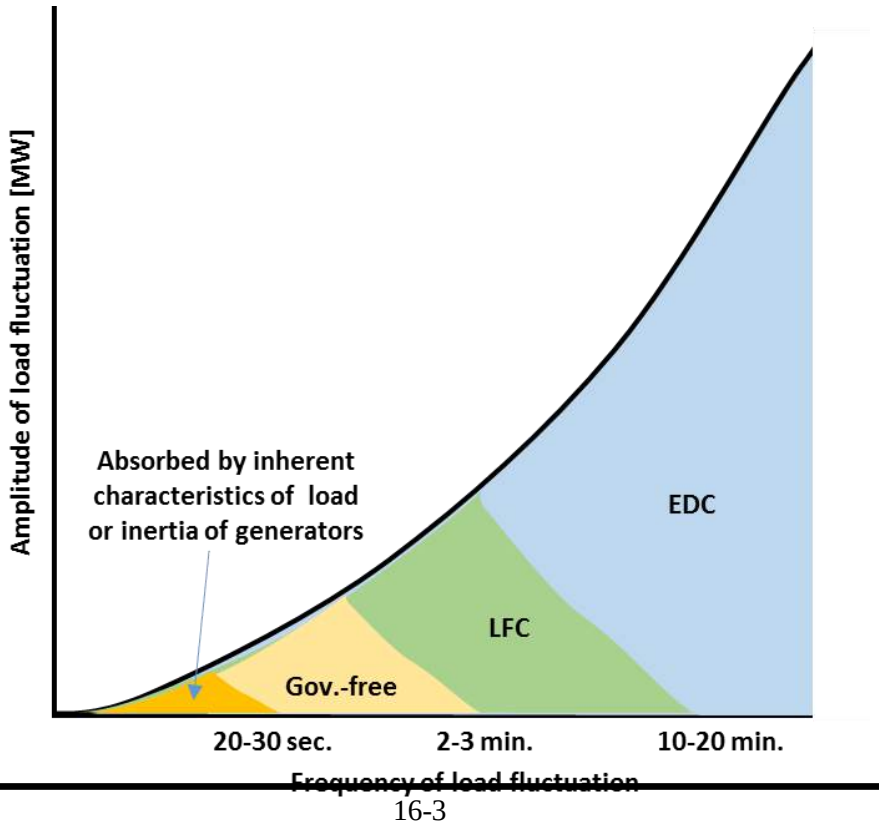
Source: JICA Survey Team

Figure 16-1 Flow Diagram of Day-ahead Demand/supply Planning Process



Source: JICA Survey Team

Figure 16-2 Example of Typical Daily Load Curve and Allocation of Power Sources in Japan



Source: JICA Survey Team

Figure 16-3 Conceptual Diagram of Role Sharing for Each Control Method

16.2 Present Status and Necessity of Improving Power Frequency Quality in Bangladesh

16.2.1 Electricity demand-supply operation in Bangladesh

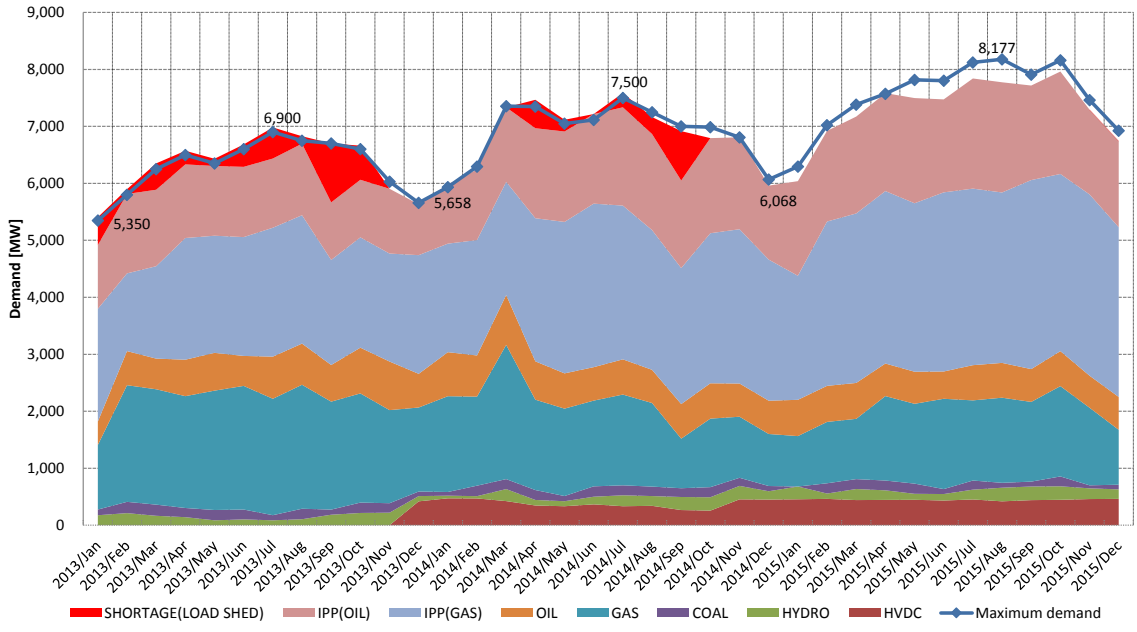
(1) Long-term planning

As shown in Fugure 16-4, load-shedding operations used to be conducted throughout the year in the past. However, it has gradually been limited to the peak load period and, in 2015, it was reduced to several days per year. (The graph in Fugure 16-4 shows supply-demand balance for the day of maximum peak load for every month. Therefore, if load-shedding operations were performed on other days, they are not illustrated in this graph.)

From the results of interviews with key persons, it is found that the following conditions only were good at supply-demand balancing operations, and they are short-lived situations:

- Commencement of operation of newly installed generators
- Commencement of electricity imports from India via HVDC interconnection
- Falling short of forecast demand

Therefore, a load-shedding scheme is still one of the major solutions for a deficiency in power sources.



Source: Created based on daily reports in NLDC

Figure 16-4 Monthly Trend of Peak Load Power Sources in Bangladesh

(2) Short-term planning

The results of the site investigations give us a glimpse of how serious the situation concerning short-term supply/demand balance planning is. In the process of settling the short-term plan, NLDC,

primarily, should have authority to gather necessary information, to integrate this for finalizing plans and to instruct according to the plans. As a matter of fact, BPDB or generating companies finalize the generation plan, and NLDC has no authority to coordinate plans.

Variety of the Term of Planning

- A day plan and a day-ahead plan is formulated in NLDC. Weekly, monthly, yearly or longer term plans are not dealt with.

Integration of the Generation Plans (Maintenance Outage Plans)

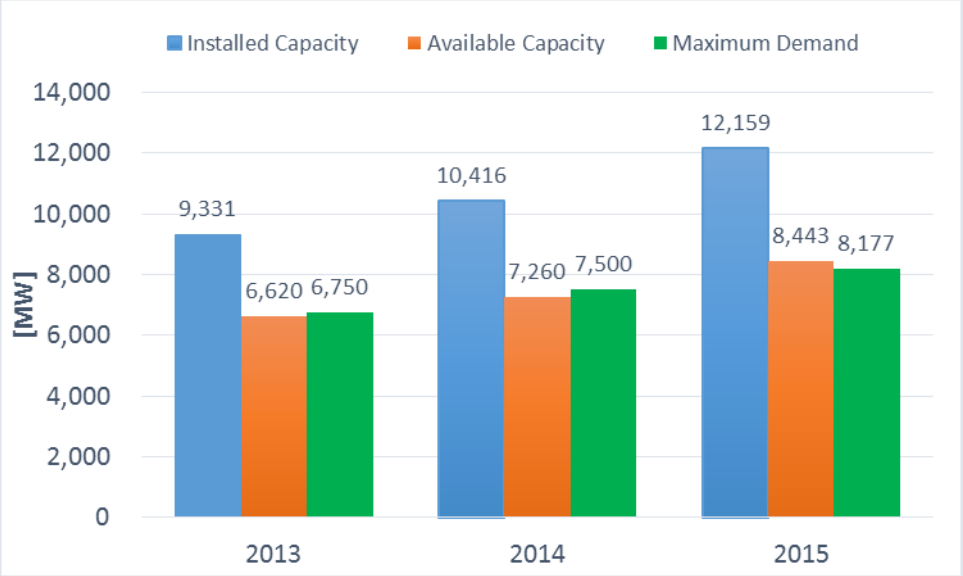
- Generation plans are not provided to NLDC until the previous day of actual operation.
- Coordination of the maintenance outage plans is performed by BPDB, and NLDC can't take part in the decision making process for the plan.

Plans of Demand-supply balancing and Unit Commitment

- The day-ahead plan is formulated at the timing of two peak hours in daytime and night-time.
- The day plan is formulated on an hourly basis from 16:00 to 15:00 of the next day.

(3) The actual condition of existing generation plants

According to the Daily Report of the Bangladeshi NLDC, the installed capacity of generators has been gradually increased corresponding to the demand rise, Figure 16-5 shows the situation of the supply-demand balance on the day of maximum peak demand from 2013 to 2015.



Source: Created based on daily reports in NLDC

Figure 16-5 Situation of Supply/Demand Balance on the Day of Maximum Peak Demand (from 2013 to 2015)

The installed capacity rate has been adequately secured at more than 130% every year. In reality, however, the available capacity is chronically insufficient due to decreases in the output and thermal efficiency and failures of power generators mainly due to insufficient periodic maintenance, which results in a decrease of around 30% in installed capacity. Until 2014, in particular, load shedding had been performed due to the shortage of power sources.
In 2015, load shedding could be prevented because the available capacity barely exceeded the maximum demand.

However, the rate of capacity decrease is remaining unchanged and the risk of load shedding is still high. Therefore, drastic measures for securing power sources are urgently required to be taken.

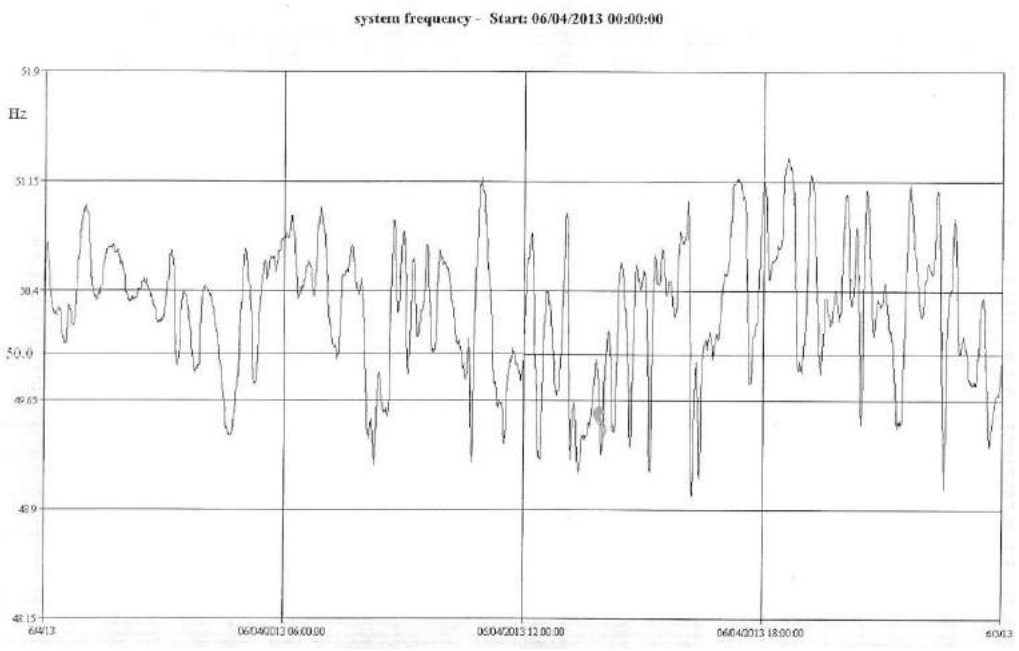
(4) Necessary actions for improving demand/supply balance

While steady development of power sources and repair of the existing power sources based on an appropriate demand forecast is hoped for in the mid to long terms, in the short term, eliminating the causes that obstruct efficient demand-supply operations, such as gaps between the demand forecast and actual demand, gaps between generating plans and actual operation, an increase in the loss of power transmission and electricity stealing, is important.

16.2.2 The Actual Situation regarding Power Frequency Quality

(1) The actual condition of power frequency control

At present, adjustment of the output of generators is instructed by phone (online instructions from SCADA are not issued). As shown in Figure 16-6, system frequency deviation from 50 Hz often exceeds ±1.0 Hz even in the normal operating condition (Grid Code stipulates that the system frequency shall be controlled within 50Hz±1.0Hz under normal conditions.)



Source: Provided by NLDC

Figure 16-6 Actual Situation of Frequency Adjustments in Bangladesh

PGCB kindly provided us with the following opinions in relation to the actual situation:

- Installation of a nuclear power station is currently planned for 2024, but it will be difficult to keep generating operation stable with the existing quality of frequency. An enhancement of frequency quality is eagerly desired.
- Before the unbundling of the electricity industry in 1996, the fluctuation in frequency was smaller than the present situation because about 50% of generators could offer reserves for frequency control, including generators in Kaptai hydro power station. However, since the unbundling, the number of generators which can offer the reserves has gradually decreased.
- PGCB estimates the following 2 causes of degradation of the frequency quality.

1. There is almost no remaining power which can be offered for frequency control due to a significant deficiency in power sources. That is, all generators have no other choice except to keep their outputs at the maximum of available capacity.
2. The electricity industry was unbundled without rules and authorities for demand-supply control.

BPDB and Siddhirganj power station also gave us the following comments on the problems at present:

- It may be possible to operate in AGC (Automatic Generation Control) mode with the necessary modifications and testing conducted by the manufacturer (GE), yet the generators have not been set to respond to the LFC (Load-Frequency Control) signal from the NLDC system.
- They consider that the burden of FGMO should be shared among as many generators as possible, in order to reduce the power fluctuation of each generator.
- They have a willingness to cooperate on frequency control if a system is developed that can provide compensation for the opportunity loss of power selling.
- They have a strong desire to obtain detailed information about the situation of a power system among the stakeholders, because this operation should be performed under fair and transparent terms.

(2) Necessity of improving power frequency quality

To adjust the frequency, it is necessary to supply part of the generator output as adjustment power, and the power generation operator that supplies the adjustment power needs to shoulder a specific loss in the opportunity to generate power and a fall in power generation efficiency. The resource to make up for the loss comes from electricity charges or tax, which means that citizens eventually have to bear the burden. The economic effect brought by the technological power and improvement of frequency quality in a given era and the burden of the people are in a trade-off relationship.
Quantitative evaluation is extremely difficult in reality, and the target frequency deviation values of Japan, the U.S., and European countries vary as shown in the table below.

Table 16-1 Target Frequency Deviation Values of Japan, North America, and Europe

Region	Target frequency deviation value	Criteria
Bangladesh	50±1.0 Hz max.	Instantaneous
Hokkaido	50±0.3 Hz max.	Instantaneous
Eastern region (Tohoku & Tokyo Electric Power Co.)	50±0.2 Hz max.	Instantaneous
Mid-western region (Chubu Electric Power Co. & westward)	60±0.2 Hz max.	Instantaneous
North America (NERC)	East: 0.018 Hz max. West: 0.0228 Hz max. Texas (ERCOT): 0.020 Hz max. Quebec: 0.0212 Hz max.	Annual standard deviation (average in 1 minute)
Europe (UCTE)	50±0.04 Hz max., 90% min. 50±0.06 Hz max., 99% min.	Hour stay rate

Source: JICA Survey Team

Consumers, and especially general households, use electric appliances and IT products that have an inverter circuit and distributed power source systems such as for solar and wind power generation are connected to an inverter in many cases. For this reason, the influence of frequency fluctuation on electric equipment is smaller than before. It is therefore becoming more difficult to dig out the need for suppressing frequency from general consumers than before.

On the other hand, however, industries are said to suffer from the adverse influences stemming from frequency fluctuation as shown in the table below, and the potential need for frequency fluctuation suppression is considered to remain high.
From the viewpoint of suppressing frequency fluctuation, it will be very effective to coordinate synchronization with other countries (coordination through AC transmission lines). In this case, however, there is a risk that a decrease in power quality or a power outage in one country spreads to the other countries. Realizing such coordination is therefore considered very difficult. However, the potential need for suppressing frequency fluctuation to the equivalent of that of developed nations is considered high in the future.

Table 16-2 Examples of Adverse Influence of Power Frequency Fluctuation on Industries

Industry	Influences of frequency fluctuation
Chemical fiber	Yarn may break or the thickness may become uneven because the speed of winding varies.
Paper manufacturing	Paper may break or the thickness may become uneven because the speed of winding varies.
Oil	Controlling pressure for decomposition and desulfurization may be affected and impurities cannot be removed.
Steel & aluminum	Rolling process may be affected, making the thickness of the product uneven.
Automobile	Welding strength and quality of appearance may be affected because the energization time of the body panel varies.

Source: JICA Survey Team

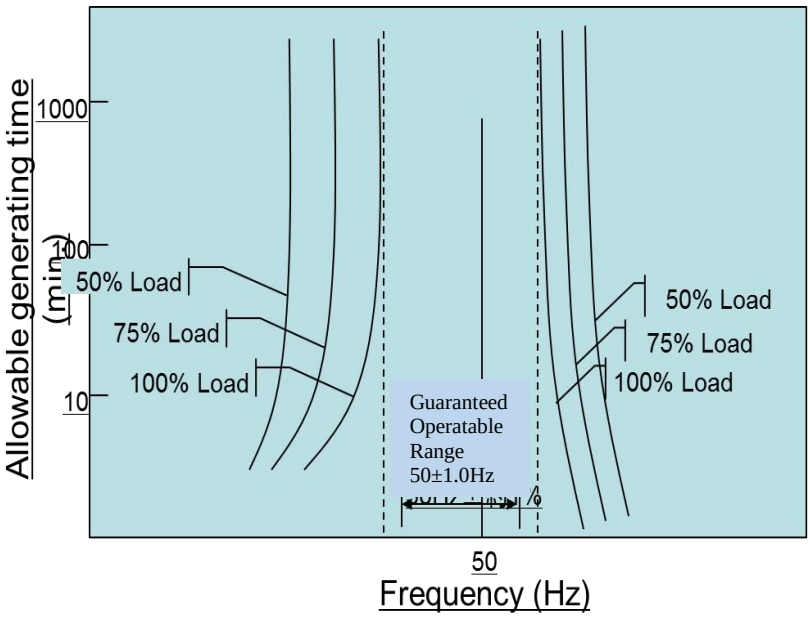
Thermal power generators and synchronous power generators have the following restrictions. These generators are designed not to operate continuously, from the viewpoints of generation of repetitive stress and member fatigue due especially to resonation of the turbine moving blade and shaft vibration, unless the frequency fluctuation is kept to within a specific value (within ±1% in Japan). Therefore, the need for suppressing frequency fluctuation is potentially high from the viewpoint of protecting machines and equipment. The effect of reducing failures of generators by suppressing frequency fluctuation can also be expected.

Table 16-3 Example of Operational Restrictions of Synchronous Generators

Turbine	Resonation of moving blade, shaft vibration
Generator	Over excitation, overload
Boiler, auxiliary device	Drop in capability of feed water pump, etc.

Source: JICA Survey Team

Figure 16-7 illustrates a conceptual diagram of a characteristic curve that indicates how long a generator is allowed to operate by the restrictions concerning resonation and shaft vibration of the turbine moving blade at a frequency (which is proportional to the number of revolutions of the turbine).
This generator can continuously run in the vicinity of the reference frequency (50 Hz) but the duration it can operate is rapidly shortened in the region outside the allowable limit. In addition, the lighter the load of the generator, the wider, though slightly, the frequency region where the generator can operate.
In general, the allowable range in the higher frequency region is narrower than in the lower frequency range because the problem of centrifugal force is added to the problem of resonation of the turbine moving blade.



Source: Created based on documents made public

Figure 16-7 Conceptual Diagram of Frequency vs Continuous Operable Time Characteristics of Synchronous Generator

Based on the information described above, it can be said that the existing status of the frequency quality is inadequate from the viewpoint of protection management of generators.
Particularly, in order to maintain stable operation of a nuclear power generator planned to be connected to a power system in around 2024, it will be eagerly desired to enhance the quality level of frequency fluctuation to the global standard as shown in Table 16-1.

According to "Electric Grid Reliability and Interface with Nuclear Power Plants", issued by the IAEA, the following frequency quality shall be required in the case of connecting nuclear power plants:

- A generating unit is able to operate continuously at full output for the normal range of variation of grid frequency -- +/-1.0% (49.5Hz～50.5Hz).
- A generating unit is able to operate for a limited time, on a few occasions per year, perhaps at reduced output, for a range of frequency outside the normal range -- +4%, -5% (48.0Hz～52.0Hz).

In order to fulfill these requirements, frequency fluctuation must be improved to half or less within the coming decades, so it is an urgent problem for Bangladesh.

16.3 Scope of This Investigation

The scope of this project is as follows:

(1) Proposal for preparation of a legal framework, revision of rules and work procedures

- JICA survey team will propose and provide support for preparation or amendment of various rules with reference to the rules in Japan (or Europe/America, if necessary) and TEPCO.
- JICA survey team will check process of supply-demand balance planning and frequency control, and propose several improvement points.

(2) Draft of plan for frequency quality improvement

- Estimation of frequency sensitivity in response to sudden change of power supply or demand, and evaluation of frequency quality improvement by introducing generators equipped with frequency control function.
- Development of future plan for securement of spinning reserve, such as FGMO and LFC, considering generation development plan and roadmap for frequency quality improvement.

(3) Improvement plan for EMS/SCADA system in NLDC

- Confirming needs for introducing new functions or adding data to the EMS/SCADA system, in order to realize online output instruction orders to power stations.

16.4 Investigation of the Regulatory Framework for Electricity Business

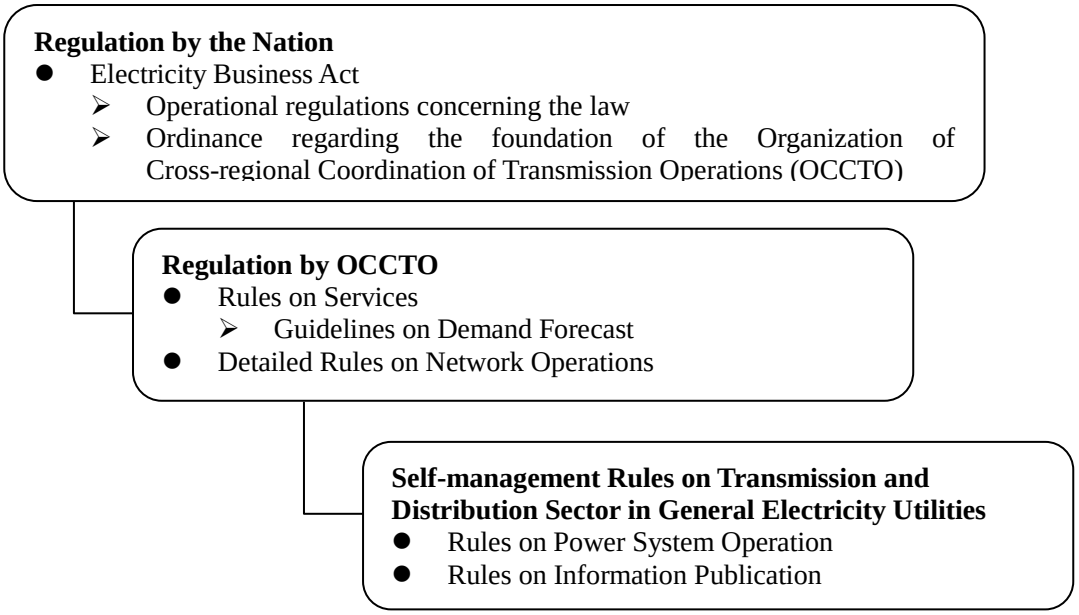
16.4.1 Regulatory framework for power system planning/operation

(1) The case in Japan

The majority of the electric power companies are profit-making corporations with a joint-stock (limited liability) company system. Therefore, their business managements are subject to/under the protection of the provisions of general laws, such as civil laws, commercial laws or criminal laws.

In addition, they are regulated by a special law - the Electricity Business Act - in order to promote their sound development, to protect consumers' interests, to secure public safety and to preserve the environment.

As shown in Figure 16-8, the legal and regulatory structure in relation to the power system operation, and in particular the demand/supply operation or frequency control, consists of 3 stages.



Source: JICA Survey Team

Figure 16-8 Regulatory Framework for Electricity Supply Industry in Japan

The Organization of Cross-regional Coordination of Transmission Operations

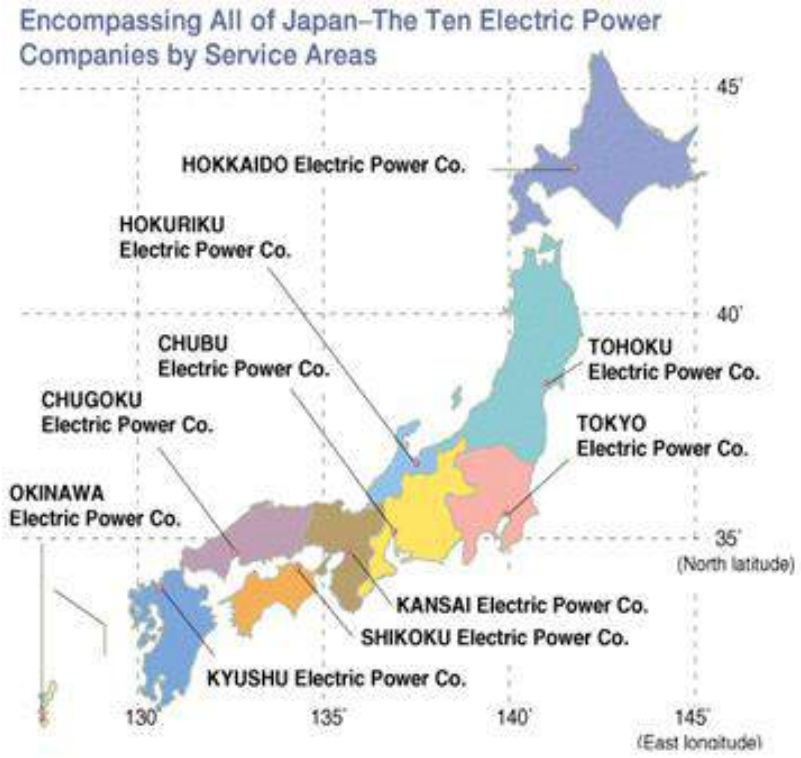
The Organization of Cross-regional Coordination of Transmission Operations (hereinafter shortened to OCCTO) was founded in April 2015, in order to manage the development work for nation-wide bulk power networks and to enhance the function of nation-wide power exchange under normal and emergency conditions. All electricity supply companies become a member of OCCTO, and are regulated neutrally and fairly under the rules, mentioned in Figure 16-8 (hereinafter "OCCTO Grid Code".)

The following are the main tasks:

- To enhance the nation-wide transmission facilities such as interconnection lines, including frequency converting stations, and the nation-wide power exchange though these inter-ties, by coordinating the demand/supply balancing plans and the network development plans.
- To perform nation-wide backups for regional operation of demand/supply balancing and frequency control under normal conditions, conducted by each operator of general electricity utilities.
- To take the initiative in coordinating the nation-wide power supply under emergency conditions such as disasters.
- To conduct the reception work for generators' access to the network in a neutral and transparent manner by publicizing power system information.

General Electricity Utility

A General Electricity Utility means a major electric power company supplying electric power to meet the needs of the general electricity demand in Japan. As shown in Figure 16-9, there are 10 regional service areas and, in each area, there is one company. (In total, there are 10 companies in Japan.)



Source: JICA Survey Team

Figure 16-9 Ten General Electricity Utilities and their Service Areas

Since the foundation of the companies in 1952, based on the current Electricity Business Act, they had been vertically integrated monopolies in each area. Then, partial liberalization of the electricity retail market started in 2000. After that, as described in Figure 16-10, full liberalization of the electricity retail market started in April 2016, and general electricity utilities will be unbundled into 3 sectors – power generation sector, transmission and distribution sector and retailing sector - by 2020.

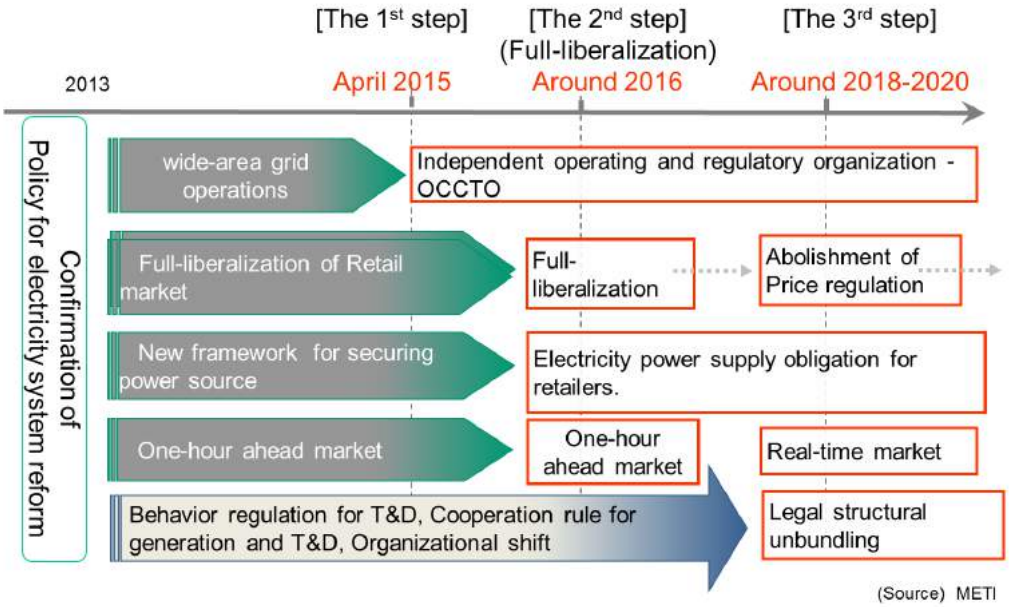
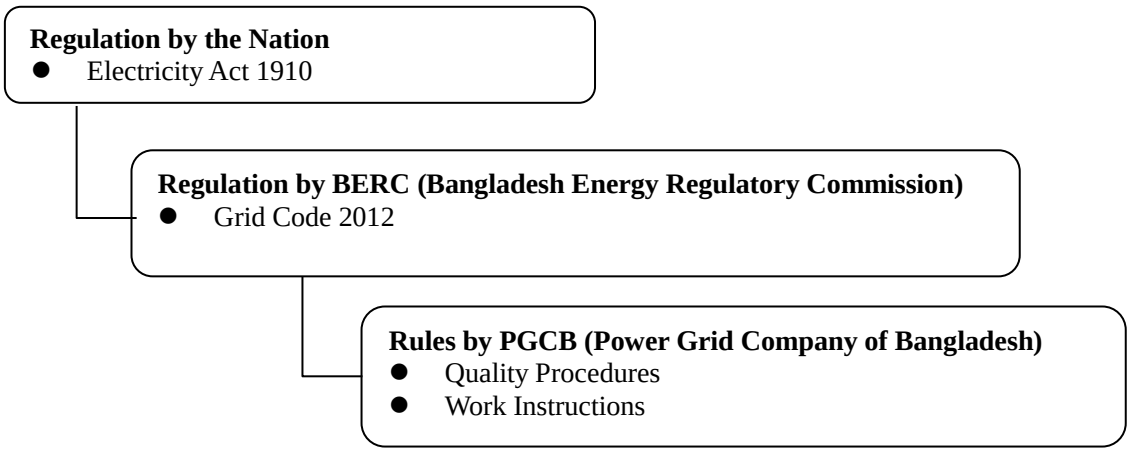


Figure 16-10 Schedule of Deregulation and Unbundling in Japanese Electricity Industry

The network operation sector will still monopolize and own the network facilities, and, like TSOs in Europe, will continue to implement the construction and O&M work.
For these reasons, the network operation sector in each area is regulated by the OCTTO Grid Code, and detailed local rules, bearing each area's circumstances fully in mind, are drawn up and disclosed to the public as "self-management rules".

(2) The case in Bangladesh

As shown in Figure 16-11, the legal framework in relation to supply/demand balancing and frequency control for the electricity industry in Bangladesh consists of 3 stages, like in Japan.



Source: JICA Survey Team

Figure 16-11 Regulatory Framework for Electricity Supply Industry in Bangladesh

16.4.2 Regulation by the Electricity Acts

The following are those things required in legal restraints, in general:

- ✧ To secure continuous power supply for all consumers with adequate quality
- ✧ To give authority to some entities to impose penal provisions on offenders

The Electricity Business Act in Japan has various regulatory terms on electricity supply companies (in particular, the public utilities) with the aim of sound expansion of the industry and protection of consumers.

Above all, the following are the important items in relation to stable demand/supply operation and frequency control:

- ✧ Obligation to supply
- ✧ Obligation of preparing and obtaining official approval for general supply provisions and their amendments
- ✧ Obligation to endeavor to maintain voltage/frequency value
- ✧ Obligation of preparing and notifying of a supply plan and its amendments
- ✧ Restriction on use of electricity
- ✧ Penal provisions

Table 16-4 describes the results of a rough comparative study between the provisions of Japan and Bangladesh.

A detailed comparative investigation and some proposals are drafted in Table 16-5.

Table 16-4 Rough Comparison of the Electricity Act between Japan and Bangladesh

Provisions	General Remarks	Electricity Business Act (Japan)			Electricity Act 1910 (Bangladesh)		
		Article	Obliges	Penalty	Article	Obliges	Penalty
Obligation to supply	Key rules in order to force the utilities to maintain and guarantee the following power quality: ✧ No interruptions. ✧ Proper voltage/frequency value.	18	Electricity Utilities	Imprisonment , fine, or both	None	-	-
Obligation to prepare "General Supply Provisions"		19, 19-2 20, 21	Electricity Utilities	Imprisonment , fine, or both	22	Licensee	None
Obligation to endeavor to maintain voltage/ frequency value		26	Electricity Utilities	Fine	None (Only in the Grid Code)	-	-
Obligation to prepare a "Supply Plan"	Key rules in order to force the utilities to promote development of power plants and to procure adequate power sources	29	Electricity Utilities	Fine	None	-	-
Restrictions on Use of Electricity	Key rules in order to prevent wide area interruption as a last resort	27	Consumers	Fine	None (Only in the Grid Code)	-	–
Other related penal provisions		115 Obstructions to Business	Offenders	Imprisonment , fine	29 [30 [39 Dishonest abstraction, etc. of energy	Offenders	Imprisonment , fine
		116 Unlicensed Business	Offenders	Imprisonment , fine, or both	39A Installation of artificial means, etc.	Offenders	Imprisonment , fine
					32 [40 Maliciously wasting energy or injuring works	Offenders	Imprisonment , fine
					36 [41 Unauthorized supply of energy by non-licensees	Offenders	Imprisonment , fine
					38 [43 Illegal transmission or use of energy	Offenders	Imprisonment , fine

Source: JICA Survey Team

Table 16-5 Comparison between the Terms of Electricity Business Act in Japan and Electricity Act 1910 in Bangladesh

Provisions	General Remarks	Electricity Business Act (Japan)	Electricity Act 1910 (Bangladesh)	Considerations/Proposals
Obligation to supply **Obligation of preparing and obtaining official approval for general supply provisions and their amendments**	In order to maintain adequate power quality, it can be simply said that: ✧ There are no interruptions. ✧ Voltage/frequency value is stably constant. Purpose of these three provisions are to guarantee the above mentioned power quality.	● An Electricity Utility shall not refuse to supply electricity without justifiable grounds. ● A General Electricity Utility shall formulate general supply provisions to set rates and other supply conditions, obtain official approval for them and publicize them. ● These articles carry penalties (imprisonment, fine, or both)	Following are the main points of provisions of "**Obligation on licensee to supply energy"** (Article 22)[81] ● Where energy is supplied by a licensee, every person within the area of supply shall, in principle, be entitled to a supply on the same terms as those on which any other person in the same area is entitled in similar circumstances to a corresponding supply. ● Provided that no person shall be entitled to continue to receive from a licensee a supply of energy unless he has agreed with the licensee to pay to him such minimum annual sum as will; ➢ give him a reasonable return on the capital expenditure ➢ cover other standing charges incurred by him ● There seem to be no penal provisions	Provisions of "obligation of supply" and "obligation to endeavor to maintain the voltage/frequency value" are among the most fundamental terms to force an Electricity Utility to promote development of power plants or voltage control equipment and to secure adequate active/reactive power sources and reserves from a long/medium-term viewpoint. This provision in Bangladesh corresponds to "general supply provision" in Japan. Moreover, it carries no penal provisions, so this provision seems to be a kind of exemption clause for utilities. Therefore, the provisions of "Obligation of supply", carrying a penalty, should be added to the Act in order to protect consumers' interests via administrative control.
Obligation to endeavor to maintain voltage/frequency value		● An Electricity Utility shall endeavor to maintain the voltage value or frequency value of electricity at the levels as below. ✧ Voltage: Nominal Voltage / Acceptable Range 100V / 101V±6V 200V / 202V±20V ✧ Frequency: specified value (50Hz, 60Hz) ● Official order for improvements of values, with penalty (fine) ● Obligation to measure/record/preserve[82] values, with penalty (fine)	● Provisions in relation to voltage/frequency quality are stipulated not in Electricity Act 1910, but in Grid Code and relevant rules. (refer to Table 16-13) ● There seem to be no penal provisions.	
Obligation of preparing and notifying of a supply plan or its amendments	Provision of "Supply Plan", together with the "obligation of supply", is another of the most important terms to force an Electricity Utility to promote development of power plants and to secure adequate power sources and reserves from a long/medium-term viewpoint.	● An Electricity Utility shall prepare a plan on the supply of electricity[83] and the installation and operation of Electric Facilities[84] (hereinafter referred to as a "Supply Plan") and notify the competent minister of the plan or its amendments (via OCCTO), with a penalty (fine). ● Official recommendation or order for improvements to plan, with penalty (fine).	There seem to be no provisions concerning securing the long-term adequacy of power sources in Electricity Act 1910, nor in Grid Code. There seem to be no penal provisions.	In Bangladesh, There may be no need to regulate the electricity utilities for the purpose of long/medium-term adequacy of power sources, because it may be secured by policy makers and national-level initiatives. The important thing is that an appropriate decision-making process is eagerly required and legislated, in which all relevant entities can participate, such as national government, regulatory authorities, electricity utilities, power system operators, etc., in order to realize a stable power supply by legally binding regulatory control.
Restrictions on Use of Electricity	There is a risk of affecting the supply-demand balance and wide area interruption caused by the excessive consumption of electricity by certain users.	● The competent minister may restrict the use of electricity, by limiting the power usage or peak load or specifying the purpose of use or the date and time when power usage should be stopped, if no adjustment is made to the supply and demand of electricity and a shortage of electricity supply will adversely affect the national economy and	Provisions in relation to load shedding are stipulated not in Electricity Act 1910, but in Grid Code and relevant rules.	This provision is applied only to the emergency condition that all countermeasures to secure the power source to meet the demand by power system operators have been exhausted. Under the condition of chronically significant deficiency of power sources in Bangladesh, this provision may be a severe term for

[81] **Obligation on licensee to supply energy**
22. Where energy is supplied by a licensee, every person within the area of supply shall, except in so far as is otherwise provided by the terms and conditions of the license, be entitled, on application, to a supply on the same terms as those on which any other person in the same area is entitled in similar circumstances to a corresponding supply:
Provided that no person shall be entitled to demand, or to continue to receive, from a licensee a supply of energy for any premises having a separate supply unless he has agreed with the licensee to pay to him such minimum annual sum as will give him a reasonable return on the capital expenditure, and will cover other standing charges incurred by him in order to meet the possible maximum demand for those premises, the sum payable to be determined in case of difference or dispute by arbitration.

[82] Following items in relation to frequency shall be recorded and preserved for 3 years.
- Specified value
- Daily maximum and minimum values, Monthly accumulated deviation
- Type and number of the meter
- Name of the person who is in charge of metering

[83] Major notification items in relation to "supply of electricity":
- Yearly maximum power and energy (from 1 to 10 years ahead)
- Monthly maximum power and energy (1 year ahead)

[84] Major notification items in relation to the "installation and operation of the Electric Facilities"
- New construction or enhancement plans for generating stations, generation costs (which will commence to operate or be constructed within 10 years, and have rated capacity of 350MW or more)
- New construction or enhancement plans for substations or transmission facilities (which will commence to operate within 10 years)
- Generating plan (1 year ahead)
- Fuel operation plan for the thermal power plants (1 year ahead)
- Electricity marketing plans (from 1 to 10 years ahead), Documents for marketing plans (1 year ahead)
- Power system maps and power flow diagrams (1, 5 and 10 years ahead)
- others

Provisions	General Remarks	Electricity Business Act (Japan)	Electricity Act 1910 (Bangladesh)	Considerations/Proposals
	Therefore, in an unavoidable case, restrictions of usage even to sound consumers are strongly required by the administrative control.	standard of living or public interest. ● This article carries a penalty (fine).		system operators because they have no choice except to conduct load shedding even under normal conditions, according to the Grid Code or rules for work process. However, in order to prevent unforeseeable outages, fair and transparent processes and rules for load shedding or rolling outages under administrative control may be eagerly required.
Penal provisions		In addition to the penal provisions carried by provisions of obligation and administrative orders, there are other specific penal provisions in the Electricity Business Act. The following are examples of penalties in relation to demand/supply operation or frequency control: ● **Obstructions to Business** ✓ Obstructions to the generation, transformation, transmission or distribution of electricity; ➢ by damaging the Electric Facilities or causing interference with the functioning of Electric Facilities. ➢ by operating the Electric Facilities without due cause. ✓ These articles carry a penalty (imprisonment, fine) ● **Unlicensed Business** ✓ Electricity supply under unlicensed conditions. ✓ This article carries a penalty (imprisonment, fine, or both)	The following are examples of penalties in relation to demand/supply operation or frequency control: ● Penalty for dishonest abstraction, etc. of energy[85] ● Penalty for installation of artificial means, etc.[86] ● Penalty for maliciously wasting energy or injuring works[87] ● Penalty for unauthorized supply of energy by non-licensees[88] ● Penalty for illegal transmission or use of energy[89]	

Source: JICA Survey Team

[85] **29[30[39.** (1) Whoever dishonestly abstracts, consumes or uses energy shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to three years and shall also be liable to a fine of ten thousand taka.

[86] **39A.** Whoever installs or uses any device, contrivance or artificial means for dishonest abstraction, consumption or use of energy of a licensee, whether he derives any benefit therefrom or not, 31[shall be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a fine which may extend to twenty thousand taka] and if it is proved that any device, contrivance or artificial means for such abstraction, consumption or use exists or has existed on a premises, it shall be presumed, unless the contrary is proved, that such person has committed an offence under this section.

[87] **32[40. (1)** Whoever maliciously causes energy to be wasted or diverted, or, with intent to cut off the supply of energy, cuts or injures, or attempts to cut or injure, any electric supply-line or works shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to five years and shall also be liable to a fine of ten thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such second or subsequent conviction be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a fine which may extend to twenty thousand taka.]

[88] **36[41. (1)** Whoever, in contravention of the provisions of section 28, engages in the business of supplying energy shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to five years and shall also be liable to a fine which may extend to fifteen thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such-second or subsequent conviction, be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a daily fine of one thousand taka.]

[89] **38[43. (1)** Whoever, in contravention of the provisions of section 30, transmits or uses energy without giving the notice required thereby, shall be punishable with imprisonment of either description for a term which shall not be less than one year but which may extend to three years and shall also be liable to a fine of ten thousand taka.
(2) A person who after being convicted under sub-section (1), is convicted for the second or subsequent times, he shall, for every such second or subsequent conviction, be punishable with imprisonment of either description for a term which shall not be less than three years but which may extend to five years and shall also be liable to a daily fine of one thousand taka.]

16.4.3 Regulation by independent regulatory organization

This section provides a comparative study between the two Grid Codes established by the regulatory commission of both countries, BERC and OCCTO.

As shown in Figure 16-8 and Figure 16-11, there are detailed rules or work process manuals based on the Grid Code in both countries. However, these rules will be referred to only when necessary, because the major scope of this section is to provide an overview of the general framework of both Grid Codes.

In this section, the JICA survey team performed a comparative study of the following provisions in relation to the supply-demand operation and frequency control:

- Long-term supply-demand operation plan
  - A) Supply plan
- Short-term supply-demand operation plan
  - A) Demand forecasting
  - B) Planned Outage Coordination of Generator/Network
  - C) Plans for Demand-supply Balance and Generation Schedule
  - D) Real-time System Operation and Frequency Quality Control
  - E) Information Publication for Power System

Table 16-6 describes an outline of the items in both Grid Codes.

Table 16-6 Outline of Grid Codes in Both Countries concerning Supply-demand Operation and Frequency Control

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)
Supply Plans (Power Plants and Network Development Plan)		● Responsibility of OCCTO to collect, coordinate and study the Supply Plans from the nation-wide viewpoint.	None
Demand Forecasting	**Variety of Forecasting**	● Type, contents and deadline for submission	● Type, contents and deadline for submission
	Responsibility of Forecasting	● General Electricity Utilities: Area-wide forecast ● OCCTO: Nation-wide forecast	● The Distribution Utilities: each demand and load shedding estimation. ● The Licensee: Integrated demand estimation.
	Post Facto Inspection	● Responsibility of OCCTO to perform post facto inspection of demand estimation by General Electricity Utilities.	None
Planned outage coordination of generator /Network	**Integration for the Draft Plans**	● Responsibility of OCCTO to integrate "original plans" submitted by utilities into yearly and monthly "draft plan" of Generator/Transmission Outage.	● Responsibility of the Licensee to integrate into a draft Outage program based on a transmission outage planned by itself and the plans of generator/distribution utility.
	Coordination between Users and Finalization of the Plans	● Responsibility of OCCTO to re-coordinate the "draft plan" in response to the requirement from members and formulate and share the "final plan".	● Responsibility of the Licensee to interact with all Users as necessary to review and optimize the draft plan.
	Particular Points to note	● Preparation of a list of operation steps prior to actual operation. ● Operation shall be implemented based on the instructions by dispatching office. ● Work process in case of suspension, reconsidering or extension of outage.	● Restriction of removal from service without specific release from the NLDC. ● Responsibility of NLDC and Users concerned to inform the other party of suspension of works together with revised estimation of restoration time.
Plans for Demand - supply Balance and Generation Schedule	**Preparation of the plan and Monitoring the balance**	● Responsibility of each Electricity Utility, Supplier and OCCTO to submit, coordinate, prepare and monitor the supply-demand plans and generation plans.	● Responsibility of the NLDC, Licensee, and generators to submit, coordinate, and prepare the load/generation balance schedules and generation schedules.
	Operating Reserves	● Responsibility of General Electricity Utilities to strive to secure reserves which can promptly raise their output against a deficiency in power sources.	None
	Spinning Reserves	● There is no description in OCTTO Grid Code.	None

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)
		Instead, the self-management rule in TEPCO has provision for CLDO's responsibility to strive to secure adequate spinning reserves.	
	Margin for lowering	● Responsibility of CLDO to secure margin for lowering the power source when frequency rises during lower demand season.	None
	Measures when supply demand balance worsens	● Instruction by OCCTO when supply-demand balance grows worse gradually ● Instruction by OCCTO when supply-demand balance reaches emergency condition ● Sanctions on members who refuse to obey the instructions	● The processes of normal load control and emergency load control are stipulated in the "Load Control (Load Shedding) (WI-PSO-02)"
Real-time System Operation and Frequency Quality Control	**Frequency Control**	● There is no description of frequency target value in OCTTO Grid Code. Instead, Self-management rules of General Electricity Utilities have the values as 50Hz +/- 0.2-0.3Hz or 60Hz +/- 0.2-0.3Hz. ● Detailed operation processes under normal conditions and abnormal conditions are stipulated in self-management rules in General Electricity Utilities.	● Normal state : 49.0Hz-51.0Hz ● Emergency state: Generating unit is capable of operating at full rated power output within the range of frequency: 47.5Hz-52.0Hz, voltage: +/-10% rated value and power factor: 0.8 lagging to 0.95 leading. ● Detailed operation processes for frequency control are stipulated in the "Frequency & Voltage Control (WI-PSO-01)" and "Load Control (Load Shedding) (WI-PSO-02)"
	Power Quality Analysis	● Responsibility of OCCTO and work processes to put together a report on the results of analysis for power quality in relation to frequency, voltage and interruptions based on the data provided from General Electricity Utilities.	None
Information Publication		● There are provisions to publicize several items of network information on the websites of OCCTO and each General Electricity Utility.	None

Source: JICA Survey Team

In the following several sections, the JICA survey team conducts a detailed comparative study between the Grid Codes of both countries, and proposals for necessary improvements are drafted from Table 16-7 to Table 16-13.

(1) Long-term supply-demand operation plan

(a) Supply plan (power plants and network development plan)

In order to maintain the supply-demand balance for an extended period, demand should be estimated properly, and steady development of power plants and enhancement of the network based on the estimation is crucial.
Development or enhancement of electric facilities needs an appropriate duration of more than several years or several tens of years, for planning, engineering, procuring and construction.

Bangladesh has very high potential in economic progress and rapid growth in power demand. Therefore, it is essential to secure power sources in a long-term, sustained way.

In Japan, Electricity Utilities are obliged to prepare a "Supply Plan", as described in previous sections, and OCCTO collects and analyzes the plans to monitor the long-term circumstances of the nation-wide balance. As a result of their study, OCCTO can require the utilities to revise the plans.

(2) Short-term supply-demand operation plan

(a) Demand forecasting

Demand Forecasting is an important process for preparing the supply-demand operation plan from the long-term viewpoint of steady development of power sources, and from the short-term viewpoint of

stable operation with adequate power sources and reserves.

In Japan, the official demand forecast is implemented by the following 3 entities:

- OCCTO Nation-wide forecast
- TDS of the General Electricity Utilities Area-wide forecast
- Electricity retailing companies Each company's own forecast

The area-wide forecast is the most important value because the TDS in General Electricity Utilities is legally responsible for maintaining the supply-demand balance in their own service area. For this reason, the OCCTO Grid Code has several provisions regarding a common method of area-wide demand estimation. The OCCTO Grid Code also has terms of study, revision and post facto evaluation process for these estimations in comparison with the nation-wide demand estimated by itself.

In the case of the Bangladeshi Grid Code, there are some simple provisions for a Licensee's obligations. According to the Grid Code, demand forecasting from 2-year ahead to day ahead estimation shall be implemented by the Licensee. Unfortunately, participation of NLDC in the process of estimation seems not to be clear.

(b) Planned outage coordination for generator/network

As preparation for the supply-demand operation plan, it is essential to implement fair and transparent coordination between generation outage plans or network outage plans which affect the generating operation (their necessity, season, duration, and so on) from the following points of view:

- Interests of network owners or operators: To maintain the healthiness of network facilities by certain implementation of periodic maintenance, on the premise of securing adequate power sources (including reserves).
- Interests of generators: In addition to obtaining approval for the necessary maintenance outage plans, to coordinate on network outages and adjust the outage time and duration in order not to affect the generation plans.

(c) Plans for demand-supply balance and generation schedule

Short term demand-supply balance plans and generation plans shall be reviewed at every occasion of preparing yearly, monthly, weekly, day-ahead, and day plans incorporating revised demand forecast, generation plans and outage plans.
In the Grid Code, it is important to stipulate the provisions for monitoring and regulating from the viewpoint of adequacy of power sources, including reserves to meet the forecasted demand.

The OCCTO Grid Code has not only the above-mentioned provisions, but also terms giving OCCTO the authority to instruct electricity utilities to exchange power to solve partial power shortages.

In Bangladesh, the provisions for the preparation process are appropriately stipulated in the Grid Code and Quality Procedures/Work Instructions (PGCB). However, there seem to be no provisions for securing reserves (operating reserves, spinning reserves and so on).

(d) Real-time system operation and frequency quality control

In Japan, the OCCTO Grid Code stipulates several provisions for the fundamental framework, and self-management rules of each TDS in General Electricity Utilities stipulate rules for specific values and detailed processes because there are some special necessities in each service area.

In Bangladesh, the Grid Code has almost the same framework as Japan, and it sufficiently stipulates the necessary items, these processes and responsible entities.
Unfortunately, there are some provisions that seem to be not as efficacious as they are expected to be, based on the results of investigations at sites.

(e) Information Publication for Power System

Publication of power system information has a risk of threatening the system security. However, under the liberalized and unbundled structure, it is necessary to disclose information to users of the network.
In Japan, as shown in Table 16-13, a wide-range of power system information is publicized for fair and transparent business processes. In Bangladesh, there seem to be no rules in the BERC Grid Code.

When visiting the power stations in Bangladesh, there were some comments such as:
"At present, there are only one-sided instructions from NLDC regarding increase/decrease of output."
"We would like to know information on the overall supply-demand balance to cooperate with NLDC"

The content of system information in Japan is still said to be insufficient, but information publication is important for users and, in particular, generators to make estimations of profitability, and for fair and transparent transactions of energy, reserves and ancillary services at the electricity market.

16.4.4 Summary

In general, amendment of the relevant Acts is urgently required regarding several kinds of obligation rules, their penal provisions, etc., in order to maintain and improve the power quality by administrative control.

Grid Code and work process rules in Bangladesh, on the other hand, seem to be still rougher than those in Japan, but have most of the necessary and minimum provisions which clearly mention the must-have terms and their responsibilities.

However, unfortunately, these provisions seem to be not as efficacious as they were expected to be because they do not correspond to the actual conditions found in some field surveys. For these reasons, it is essential to tighten the regulations by means of social sanctions such as post facto investigations or deprivation of licenses for offenders. It is also eagerly desirable to implement the necessary legal steps to accuse offenders of civil or criminal responsibility.

The Grid Code should be amended so that the NLDC has fitting authority and independence for their important responsibility of maintaining and improving the power quality. PGCB, BPDB and BERC should devote themselves to providing backup support.

Interviews with staff in NLDC reveal the following issues, which can be fully appreciated:

- BPDB deals with all processes from generation planning through implementing plans to O&M; NLDC cannot take part in these processes.
- There is no obligation/responsibility or penal rule for the generators to provide reserves for FGMO/LFC.
- Grid Code 2012 has already come into operation, but still has no effectiveness.
- Establishment of ancillary services in relation to frequency control is eagerly desirable in Code 2012.

Table 16-7 Grid Code concerning the Demand Forecast/Demand Estimation

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
Supply Plans (Power Plants and Network Development Plan)		● OCCTO shall request from all members their 10 year-ahead plans for power plants and network development in order to integrate, coordinate and study them from the nation-wide viewpoint, and then, submit them to the competent minister and publicize them. ● OCCTO shall investigate whether the plans are adaptable to the "Detailed Rules of Network Operations (OCCTO)"and "Guidelines on Demand Forecast (OCCTO)". If necessary, according to the results of this study, OCCTO coordinates them or requests that members make a revision of them. For the coordination, the following points are taken into consideration: ✧ Trends of actual demand ✧ Past records of demand estimation in the plans ✧ Guidelines and description requirements set separately by the nation ✧ The level of reserves ✧ Any factor that significantly affects the supply-demand balance ✧ Others ● OCCTO shall investigate the following points, based on the "Detailed Rules of Network Operations" or business experiences: ✧ Appropriateness of the plans ✧ Adequacy of power source to meet the estimated demand.	There seems to be no provisions concerning this category.	In Bangladesh, where is expected to be under the high potential of economic growth and remarkable demand rise, development of large-scale power plants and enhancement of the network need to be forwarded in cooperation with national policy, including the issue Whether the NLDC or PGCB should shoulder the consistent responsibility throughout the plans to actual operation. Therefore, it is not the matter of being stipulated in Grid Code, but being clarified within the policy-making process in relation to overall electricity industry.
Demand Forecasting	**Variety of Forecasting**	● For long term: From 3 to 10 year-ahead Max. kW and kWh each year ● For short term: Refer to Table 16-9.	● The year ahead: Monthly peak/off peak period demand ● The month ahead: Daily peak/off peak period demand ● The day ahead: Hourly demand	
	Entity and Process of Forecasting	**Area-wide demand estimation** ● General Electricity Utilities shall forecast the electricity demand based on the "Guidelines on Demand Forecast"[90], economy forecast, the latest trend of demand, past records of actual demand, specific matters, and so on. **Nation-wide demand estimation** ● OCCTO shall prepare a "Reasonable Level of Nation-wide Electricity Demand" in order to perform an appropriate estimation. In the preparation, the results of studies, regression analysis among the population, economic indicators and actual demand will be taken into account. ● OCCTO shall study the appropriateness of area-wide demand forecast compared with the "Level", adaptivity to the "Detailed Rules of Network Operation" and "Guideline on Demand Forecast", and then, if necessary, require revision of the estimation from General Electricity Utilities. ● OCCTO shall publicize the demand forecast for nation-wide and area-wide by the end of January, each year.	● The **Licensee**[91] shall make a demand estimation for every division described above, based on the demand estimation[92] and load-shedding estimation by **Distribution Utilities**. According to the "Procedure for Power System Operation & Control (QP-PSO-1)" ● DMLDC makes daily demand planning on the basis of the following: ➢ Season & weather condition ➢ Previous day's/year's demand conditions ➢ Working days or holidays ➢ Existence of any emergency/priority situation, etc.	According to the Grid Code 2012 in Bangladesh, Licensee and NLDC shall separately estimate the demand from 2-year ahead to the day ahead, and the day respectively. For seamless planning, it is important to make enormous efforts to cooperate with each other, though both entities are members of the Operating Committee. The JICA Survey Team heard in the field survey that there is a reorganization plan for NLDC to become an Independent System Operator (ISO). Bangladesh should take the opportunity to centralize responsibility and authority in the new organization.
	Post Facto Inspection	● General Electricity Utilities shall submit the following information to OCTTO. ✧ Actual demand for 10 years (Max. kW and kWh) ✧ Influence of temperature on the actual demand. ✧ The results of self-comparative study between estimated and actual demand[93] ● OCCTO shall study the following points based on its business experiences: ✧ Difference between estimated and actual area-wide demand, causes and trends. ✧ Appropriateness of concept and process for self-studies performed by General Electricity Utilities.		In general, it is difficult to accurately estimate electricity demand because it is influenced by various factors such as temperature, humidity, social activities, or other factors. So, establishment of a continuous improvement cycle, a so-called PDCA cycle, is an effective measure. In this cycle, participation of a disinterested party such as BERC may be an essential requirement.
Planned outage	**Integration for the Draft**	OCCTO shall prepare the "draft plan" of Generator/Transmission Outage by integrating the "original plans" submitted by TDS in General Electricity Utilities.	All **Generators** and all **Distribution Utilities** shall provide their proposed Outage programs according to the following manner:	

[90] OCCTO prepares "Guideline on Demand Forecast" so that the estimation works well and smoothly. This guideline includes the following contents:
- Fundamentals for demand forecasting (Duration, Responsible entities, etc.)
- Correcting method based on the temperature, an intercalary year, and so on.
- Estimation method for area-wide demand (short term, long term)
- Estimation method for each electricity supplier. (short term, long term)

[91] In Grid Code 2012, "Licensee" is defined as "The holder of the Transmission License for the bulk transmission of electricity between Generators and Distributors"

[92] **Distribution Utilities** shall provide to the **Licensee** their estimation of each inter-connection point on a 2 year ahead, year ahead, month ahead, week ahead and day ahead basis.

[93] In comparative studying, factors which can influence the electricity demand, such as temperature, population, economic trends and so on, should be taken into account.

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
coordination of generator /network	**Plans**	**Varieties of the plan** (For preparation schedule, refer to Table 16-8) ✧ Yearly plan (1 & 2 years ahead) ✧ Monthly plan (1 & 2 months ahead) **Plans to be coordinated** ● Outage plans for following network facilities and Generators connected to them. ✧ Inter-area lines ✧ Transmission lines, Bus-bars operated at the highest and the second highest voltage in each area, and transformers connected to them. ✧ Network facilities whose outages can affect the ATC of the inter-area lines. ● Outage plans for remaining facilities are prepared and coordinated within the general electricity utilities and members who have interests. **Items to be considered when coordinating scheduled outages** ✧ Public and personnel safety ✧ Electric facilities' preservation ✧ Power system security, reliability ✧ Adequacy of reserves ✧ Degree of influence on major electricity consumers' operation plans ✧ Avoidance of unplanned restraint of generating operation ✧ Rationality of outage schedule ✧ Others	● 2 year ahead, and year ahead (July to June) ● Generators' program: to Licensee and NLDC by 31st March each year ● Distribution Utilities' program: to Licensee by 31st March each year The **Licensee** shall prepare a draft Outage program based on a yearly transmission Outage program produced by itself and the information received from **Generators** and **Distribution Utilities**, taking into account the demand estimation. The Licensee, the NLDC and the Generators shall establish Operating Committees, and establish procedures relating to the operational interfaces between parties. They shall include Outage coordination, generation scheduling, and so on.	
	Coordination between Users and Finalization of the Plans	● Any member who comes under the following can ask for re-coordination of the draft plans: ✧ Members whose utilization plan for inter-area lines may be affected. ✧ Members whose generating plan may be affected. ➢ OCCTO shall re-coordinate the "draft plan" and formulate and share the "final plan".	The Licensee shall interact with all Users as necessary to review and optimize the draft plan, and then release the finally agreed transmission outage plan to all Users by 31st May each year. The Licensee shall review the plan monthly, and Users' requests for additional outages will be considered and accommodated to the extent possible.	
	Process of Outages	● TDS in General Electricity Utilities and on-site engineers shall cooperate with each other to prepare a list of operation steps prior to actual operation in order to prevent an unexpected accident and interruption. ● An actual operation shall be implemented based on the instruction from shift engineers of load dispatching office. ● Both parties shall confirm the starting and finishing time of outages. ● In the case of suspension, reconsidering or extension of outage, both parties shall confirm all the facts and reasons for these changes.	Notwithstanding provision in any approved Outage plan, no cross boundary circuits or Generating Unit of a Generator shall be removed from service without specific release from the NLDC. Once an Outage has commenced, if any delay in restoration is apprehended, the NLDC or Users concerned shall inform the other party promptly together with a revised estimation of restoration time.	This provision seems not to be as efficacious as it is expected to be because it does not correspond to the actual conditions – the JICA survey team heard that many generators are not operated conforming to the instructions issued by NLDC. For these reasons, it is vital to tighten the regulation by NLDC.
Plans for Demand - supply Balance and Generation Schedule	**Preparation of the plan and Monitoring the balance**	● Each Electricity Utility and Supplier shall submit the supply-demand plan (Table 16-9), generation plan (Table 16-10) or its amendment to TDS in General Electricity Utility. ● Each General Electricity Utility shall integrate the supply-demand plan in its service area, and submit it to OCCTO. ● OCCTO shall supervise the following items: ✧ Supply (including reserves) and demand balance of each Utility ✧ Supply (including reserves) and demand balance of each area ✧ Supply (including reserves) and demand balance of the whole of Japan	**Load/generation Balance Schedule** ● The NLDC and the Licensee shall coordinate and prepare load/generation balance schedules and generation schedules, and shall provide them to the Licensee and Generators according to the schedules shown in Table 16-12. **Generation Schedules** ➢ All Generators shall provide the MW/MVAR declared availability capacity (0:00-24:00 hours) of all Generating Units, to the NLDC during each hour of the day commencing 36 hours ahead and provisionally, for the day immediately after (plant availability notification) by 12:00 hours. ➢ Hydro Power Stations shall take into account their respective reservoir levels and any other restrictions and shall report the same to the NLDC. ✧ The NLDC shall produce a day ahead hourly generation schedule after consolidation of the data provided by Generators. It shall consist of Availability, Scheduled generation, Allocated spinning reserve and Generating Unit Standby requirements	This provision also seems not to be as efficacious as it is expected to be. For these reasons, it is necessary to give authority to NLDC (PGCB) and BERC to take the initiative in the procurement of reserves.
	Operating Reserves	● TDS in General Electricity Utilities shall strive to secure reserves which can promptly raise their output against the deficiency of power sources caused by trouble at electric facilities, estimation errors of demand or total generation output. ● Reasonable level of operating reserves is under consideration. ● According to the self-management rules of TDS in TEPCO: ➢ CLDO shall strive to secure operating reserves of more than 5% of maximum demand forecast for the day taking following items into account: ✧ Error in maximum demand forecast caused by error in temperature ✧ Trouble at generator ✧ Congestion of generation caused by trouble in network ➢ Operating reserves shall be secured by the following measures: ✧ Hydro and thermal power in partial load		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
		✧ Hydro power in stand-by mode ✧ Emergency Gas Turbine Generators		
	Spinning Reserves	● According to the self-management rules of TDS in TEPCO: ➢ CLDO shall strive to secure spinning reserves of more than 3% of maximum demand forecast for the day against sudden change of load or shut-off of generators ➢ Spinning reserves shall be secured by the following measures: ✧ FGMO of generators ✧ Emergency power injection from HVDC or FC ✧ Switching off the pump up operation of pump-storage hydro power		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.
	Margin for lowering	● CLDO shall secure margin for lowering the power source when frequency rises during the lower demand season. ● Reasonable level for the margin is under consideration.		Establishment of these provisions in Grid Code 2012 is strongly recommended for future improvement of power quality.
	Measures when supply demand balance worsens	**Instruction by OCCTO when supply-demand balance grows worse gradually** ● OCCTO can instruct members to exchange surplus power or lease network facilities. **Instruction by OCCTO when supply-demand balance reaches emergency condition** ● Heavy load case: suspension of planned outage, start of stand-by generators, output increase of in-service generators, restriction of electricity use based on the contracts ● Light load case: export to the area which has adequate lowering margin **Sanctions on members who refuse to obey the instructions** ➢ Notification to the competent minister	**According to the "Load Control (Load Shedding) (WI-PSO-02)"** ● The whole country is divided into 9 distribution zones -- DESA, Chittagong, Comilla, Sylhet, Mymensing, Khulna, Barisal, Rajhsahi, and Rangpur ● Load control will be imposed in proportion to the demand of the respective zones as per the load control chart. **Normal Load Control** ➢ Load dispatching control room will send the message for load allocation (together with amount, duration and cause) to the respective zone over carrier telephone. ➢ The despatcher closely monitors whether the load control is implemented properly or not with the help of telemetering/SCADA system. ➢ If any zone does not carry out the given load control plan properly, the despatcher will implement forced load control by switching off 33kV feeders, after giving an alert to the zone. **Emergency Load Control** ➢ The direct actions of switching off 33kV feeders by the despatcher will be prioritized. Refer to "**Operation in a frequency drop"**, described below.	In Bangladesh, load shedding is performed not only in emergency operation, but in normal operation, frequently. In Japan, OCCTO Grid Code and Self-management rules of TDS stipulate that load shedding is performed only when the power source deficiency condition has gone beyond the operator's control. The principle that the load shedding scheme is the last resort should be specified in the Grid Code, so that electricity utilities are urged to make efforts to procure sufficient reserves.
Real-time System Operation and Frequency Quality Control	**Frequency Control**	● There is no description of the frequency target value in OCTTO Grid Code. Instead, Self-management rules of General Electricity Utilities have the values as 50Hz +/- 0.2-0.3Hz or 60Hz +/- 0.2-0.3Hz. ● Reasonable level of LFC or FGMO capacity is under consideration. ● In the case of significant frequency deviation due to sudden trip of electric facilities or change in demand, the following measures shall be taken, in addition to LFC and FGMO: ✧ Emergency trip or rapid output control of generation/pump up ✧ Emergency power exchange through the inter-area lines ✧ Load control or shedding as a last resort ✧ Disconnection of inter-area lines to prevent nation-wide blackout.	**Responsibility** ● NLDC shall monitor actual load and generation balance and regulate generation and demand to maintain frequency. ● Generators shall follow the dispatch instructions issued by NLDC. ● All Generating Units shall have the governor available and in service and must be capable of automatic increase or decrease in output within the normal declared frequency and within their respective capability limit. **Acceptable frequency range** ● Normal state : 49.0Hz-51.0Hz ● Emergency state: Generating unit is capable of operating at full rated power output within the range of Frequency: 47.5Hz-52.0Hz, Voltage: +/-10% rated value, Power factor: 0.8 lagging to 0.95 leading	Effectiveness of this provision in Grid Code 2012 is crucial for future improvement of power quality.
	Frequency Control (Detailed)	**According to the self-management rules in TEPCO** **Control under normal conditions** ● CLDO shall adjust the supply-demand balance in each service area by means of output control instruction to the generators in response to the change in demand. ● CLDO shall secure the reserves for LFC amounting to 1-2% of total demand. ● Acceptable range: 50.0±0.2Hz Acceptable time-lag：±15 sec. ● All generators shall obey the instructions issued from CLDO, and inform of any change of circumstances if they cannot obey the instructions without delay. ● All generating units which can serve the output control or LFC operation shall be operated under FGMO, in general. **Control under abnormal conditions** In the case of significant frequency deviation due to sudden trip of electric facilities or change in demand, the following measures shall be taken: ● CLDO shall issue an instruction of manual trip or output change to the most	**Generation Dispatch** ● All Generators shall comply with a dispatch instruction issued by NLDC. ● In absence of any dispatch instructions by the NLDC, Generators shall generate according to the day ahead generation schedule. ● Dispatch instruction feedback from Generators shall be issued by telephone or computer to computer communication. ● The generator shall promptly inform the NLDC in the event of any unforeseen difficulties in carrying out an instruction. ● Generators shall inform the NLDC of any change of AVR and/or governor control mode of service with reasons. ● Generators shall not de-synchronize Generating Units without instruction from the NLDC except on the grounds of safety to plant or personnel. ● Generators shall report any abnormal voltage and frequency-related operation of Generating Units promptly to the NLDC. **According to the results of site investigation work, "Frequency & Voltage Control (WI-PSO-01)" and "Load Control (Load Shedding) (WI-PSO-02)"**	It is vital to tighten the regulations by means of social sanctions such as post facto investigations or deprivation of licenses for offenders or uncooperative entities. It is also eagerly desirable to implement the necessary legal steps to accuse offenders of civil or criminal responsibility. In Bangladesh, load Shedding is performed not only in

Provisions	Details	OCCTO Grid Code (Japan)	Grid Code 2012 (Bangladesh)	Considerations/Proposals
		effective generating unit to restore the frequency quality, such as a unit which is rapidly adjustable or has wide margins. ● CLDO can issue the load control/shedding instructions only when control by the generating units cannot meet the required amount for restoration from under-frequency condition. ● CLDO shall disconnect the inter-area lines to prevent the cascading blackout. **Abnormal under-frequency conditions** ➢ CLDO shall endeavor to rapidly restore the frequency to 48.5Hz or above, by generation or load control. **Abnormal over-frequency conditions** ➢ CLDO shall endeavor to rapidly restore the frequency to 50.5Hz or below, by generation or load control.	**Operation in a frequency drop (Supply < Demand)** ● In the situation of load shedding, each generator output is operated at available capacity and not in FGMO (in load-limit mode instead). ● Demand-supply balancing control is performed by load shedding. To be concrete, NLDC allocates a cap of available power to each of the 9 ALDC (Area Load Dispatching Center). And then the ALDC shuts off the 33kV distribution lines so that the power demand in the ALDC = allocated available power. ● In the case of a sudden decrease in frequency due to the unplanned outage of a generator, inadequate load shedding, and so on, automatic switching control by SCADA system is performed. (Controllable capacity is 547 ccts of distribution lines; maximum demand of 6,837MW in whole power system) ● In the case of further frequency decrease despite the SCADA control, load shedding by UFR (Under Frequency Relay) is performed in the range of 48.90Hz to 49.50Hz. UFR can shed a maximum of 2,000MW loads. **Operation in a frequency rise (Supply > Demand)** ● Operated in following manner and order: ① Re-charging of shed distribution lines ② Instruction for power output decrease	emergency operation, but in normal operation, frequently. In Japan, OCCTO Grid Code and Self-management rules of TDS stipulate that load shedding is performed only when the power source deficiency condition has gone beyond the operator's control. The principle that the load shedding scheme is the last resort should be specified in the Grid Code, so that electricity utilities are urged to make efforts to procure sufficient reserves.
	Power Quality Analysis	● OCCTO shall put together a report on the results of analysis for power quality in relation to frequency, voltage and interruptions based on the data provided from General Electricity Utilities. ● All General Electricity Utilities shall submit, every year, the actual data for a duration time ratio per year that the frequency deviation was controlled within 0.1Hz, 0.2Hz, 0.3Hz and more than 0.3Hz, to OCCTO.		Framework of continuous monitoring, analysis and evaluation of frequency quality should be stipulated in Grid Code 2012.

Source: JICA Survey Team

Table 16-8 Submission of Outage Plans to General Utilities (Japan)

	Annual plan (1 & 2 years ahead)	Monthly plan (1 & 2 months ahead)	Revision Unplanned Outage
Original	The end of October, each year	1st, each month	Any time (without delay)
Draft	The end of December, each year	10th, each month	
Final	Mid-February, each year	The middle of each month	

Source: JICA Survey Team

Table 16-9 Submission of Supply-demand Plans by Each Utility (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	The end of October every year	The 1st day of every month	Every Tuesday	Every noon	Any time
Forecasted demand	Max./Min. power (kW) by weekday/holiday of each month	Max./Min. power (kW) by weekday/holiday of each week	Max./Min. power (kW) and time every day	Energy (kWh) every 30 min.	Energy (kWh) every 30 min.
Supply for demand	Total planned value of supply power (procured/unprocured)				

Source: JICA Survey Team

Table 16-10 Submission of Generation Schedule by Each Supplier (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	The end of October every year	The 1st day of every month	Every Tuesday	Every noon	Any time
Schedule by power stations	Max./Min. power (kW) by weekday/holiday of each month	Max./Min. power (kW) by weekday/holiday of each week	Max./Min. power (kW) and time every day	Energy (kWh) every 30 min.	Energy (kWh) every 30 min.

Source: JICA Survey Team

Table 16-11 Integration of Supply-demand Plans (Japan)

	Annual schedule (1 & 2 years ahead)	Monthly schedule (1 & 2 months ahead)	Weekly schedule (1 & 2 weeks ahead)	Day ahead schedule	The day schedule
Deadline	25th March every year	25th every month	Every Thursday	17:30 every day	Any time
Demand of service area	Maximum demand of each month	Maximum demand of each week	Maximum demand every day	Max./Min. power (kW) and time of the next day	Max./Min. power (kW) and time of the day
Supply for demand	Total value of supply power				

Source: JICA Survey Team

Table 16-12 Generation Scheduling by Licensee (Bangladesh)

	Annual plan (year ahead)	Quarterly plan (quarter ahead, remaining quarter of current year)	Monthly plan (following 2 months)	Weekly plan (week ahead)	Day ahead schedule
Deadline	Not less than 90 days before the beginning of each calendar year	Not less than 60 days before the beginning of each quarter	Not less than 14 days before the beginning of each month	Not less than 48 hours before the beginning of each week	Not less than 7 hours before the beginning of each day
Items	Monthly basis	Weekly basis	Daily basis	Hourly basis	Hourly basis

Source: JICA Survey Team

Table 16-13 Details of Information Publication Rules in OCCTO Grid Code

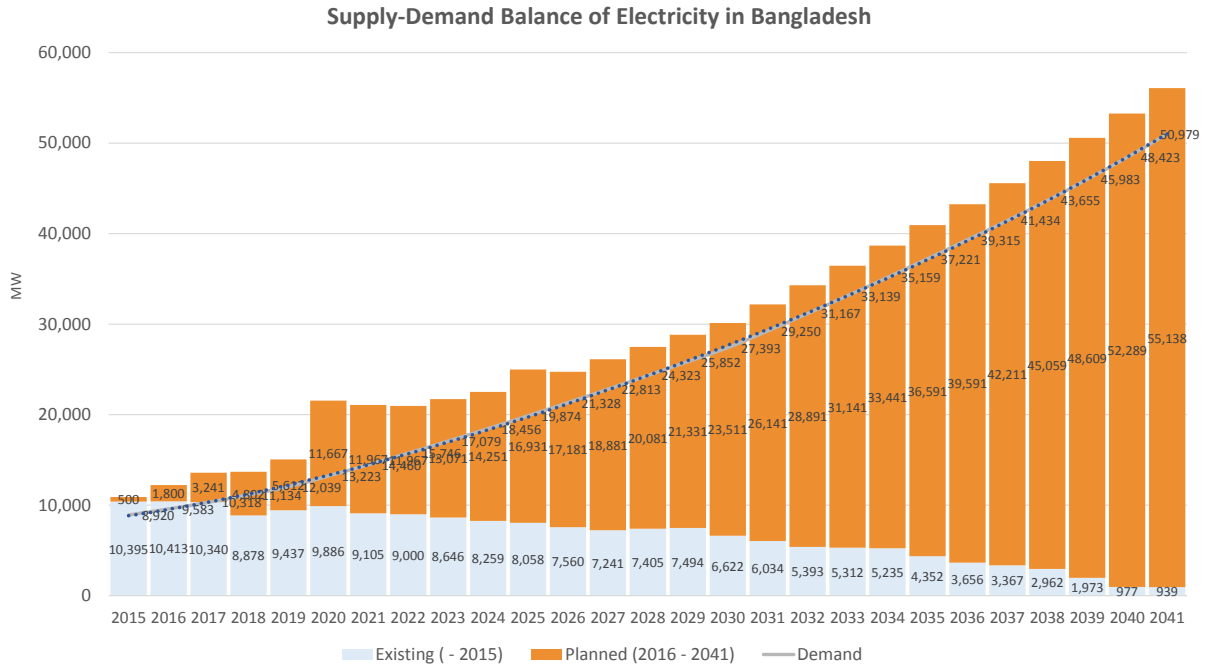
On the Website of OCCTO	On the Website of General Electricity Utility
(a) Information for system interconnection ・ Simplified diagram of transmission system drawn on a map showing restriction in system interconnection of generation facilities (154kV or over) ・ Plans for the construction of network system	(a) Information for system interconnection ・ Simplified diagram of transmission system drawn on a map showing restriction in system interconnection of generation facilities (154kV or over) ・ Plans for the construction of network system
(b) Nationwide demand forecasting ・Nationwide demand power Maximum demand power in each month for 1 and 2 years ahead Maximum demand power in the following month Maximum/minimum demand power and forecasted time on the following day ・Nationwide supply power Maximum supply power in each month for 1 and 2 years ahead Maximum supply power in the following month Maximum supply power on the following day	(b) Area-wide demand forecasting ・Area-wide demand power Maximum demand power and forecasting time in the following month Maximum demand power and forecasted time on the following day ・Area-wide power supply Maximum supply power on the following day Maximum supply power on the day
(c) Actual demand power ・Total amount for nationwide; present demand power actual demand curve of the day and previous day ・Total amount for nationwide and area-wide; actual maximum demand power of the day generation time of the day	(c) Actual demand power ・Total amount for area-wide; present demand power actual demand curve of the day and previous day actual maximum demand power of the day generation time of the day
(d) Output limitation of RES ・Area where output limitation occurred ・Date and time when output limitation occurred ・Total amount of output limitation ・Causes	(d) Output limitation of RES ・Date and time when output limitation occurred ・Total amount of output limitation ・Causes
(e) OCCTO Grid Code ・Rules for Services ・Detailed Rules for Network Operations ・Guidelines on Demand Forecast	(e) Rules for TDS ・Rules for information publication ・Rules for system development ・Rules for interconnection ・Rules for power system operation

Source: JICA Survey Team

16.5 Proposal for Frequency Quality Improvement Roadmap

16.5.1 Future electricity demand and power sources in Bangladesh

The relationship between future electricity demand and power sources in Bangladesh is shown in Figure 16-12.



Source: JICA Survey Team

Figure 16-12 Prospect of Demand and Supply Balance to 2041 (PSMP2016)

Future demand is assumed to increase at a rate of about 5 to 10% per year. Supply for the increase in demand is planned to be secured by the increase in imports due to the new construction and expansion of coal-fired and gas-fired power plants, nuclear power, and an international tie-line of high-voltage direct current (HVDC).

In the range of this Master Plan existing generators (pale blue colored) are expected to continue as part of supply. However, these cannot be expected as a stable supply and primary reserve because machine trouble or output reduction due to aging and lack of maintenance has frequently occurred.

Fortunately, these existing units are gradually being dismantled or replaced by new units. Moreover, along with the strong economic development, generators which are planned to be newly constructed and expanded after 2015 (orange colored) are expected to occupy an overwhelming share. Therefore, the following matters should be taken into account:

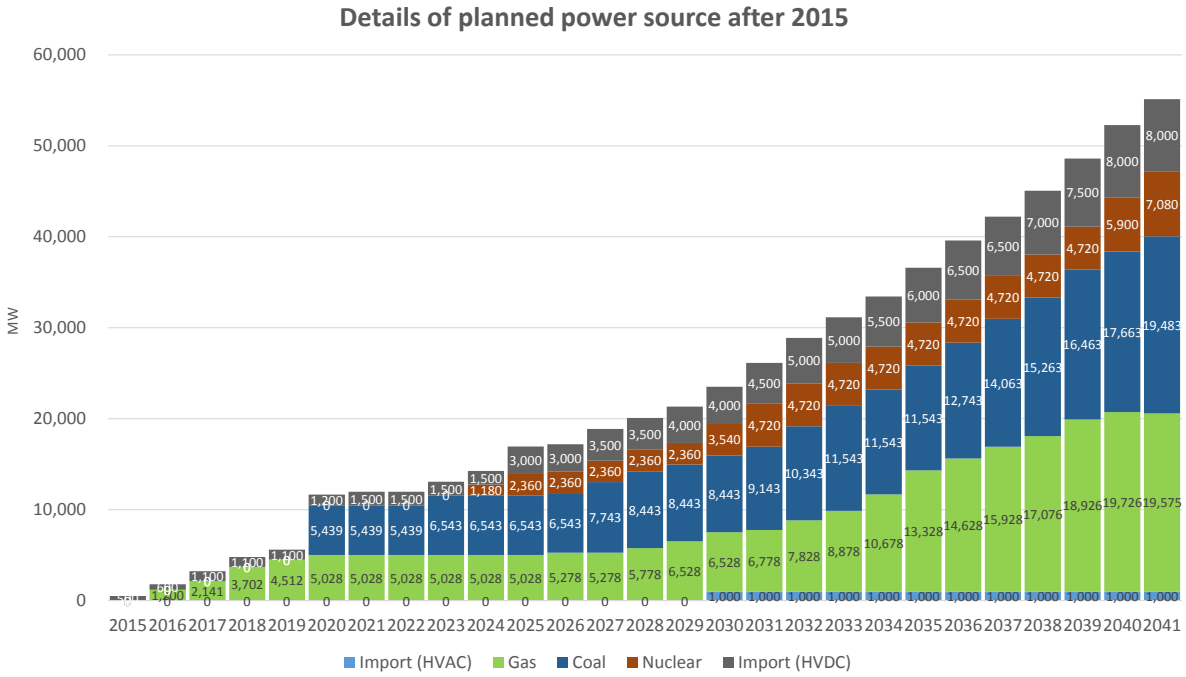
- To establish a system of periodic maintenance, so that these generators can stably output up to the rated capacity throughout their life.
- To consider the free-governor mode operation (FGMO) and load frequency control (LFC) at the design stage, so that the frequency control function is appropriately provided from the commencement of operation.

16.5.2 Reserves for power frequency control

(1) Trial calculation of availability for reserves

(a) Availability from newly constructed generation units (commissioned after 2015)

Figure 16-13 shows details of planned power sources after 2014, which are classified by types, fuels and power producers in the case of gas-fired type. Power sources in the future highly depend on the coal-fired and gas-fired plants (producers have not been decided yet). Power imports from neighboring countries and nuclear power, planned for 2024 and 2025, also account for more than a few power sources.
In addition, there is a development plan for hydroelectric power in Meghalaya, India after 2030 (pumped-storage hydro power is highly recommended), which is, as one of the ideas, directly interconnected to the power system in Bangladesh through an AC transmission line. Although its proportion is small, the flexibility of demand-supply control is expected to be increased.



Source: JICA Survey Team

Figure 16-13 Details of Planned Power Sources after 2015

All of the newly constructed power sources should ideally provide reserves. In fact, there are the following problems and risks:

HVDC international tie-line — From a technical point of view, it is possible to equip the LFC function in normal and emergency conditions, such as the Hokkaido-Honshu HVDC Link in Japan. Actually, international agreements and the establishment of fair and transparent rules are strictly required because this function affects the power frequency quality of another country.

Nuclear power generation — From a technical point of view, while FGMO and LFC (AGC: Automatic Generation Control) can be applied to nuclear power plants, a political decision-making process may be required to be undertaken. In Japan, in order to give priority to the stable operation of the plant, power system operators are restricted in issuing FGMO and LFC instructions, to say nothing

of output change.

Coal-fired generation － In Japan, the generation cost for coal-fired is low because of the low fuel cost (variable cost). Therefore, from the point of view of the most economical dispatch and the merit order, it is expected, together with nuclear power, to provide base load capacity (24 hour full operation). In order to recover the equipment cost of the regulation function (fixed cost) and ancillary service cost (variable cost), such as FGMO and LFC, the development of a framework for cost recovery (including the market mechanism) is necessary.

According to the interviews with PGCB, BPDB and NLDC, they plan to impose an obligation to provide reserves on 50% of coal-fired generators, while HVDC tie-lines and nuclear power plants are not expected to provide reserves. Besides, all providable generators are required to provide 10% - 15% of rated capacity as reserves, each. Therefore, the JICA survey team performed the trial calculation on the condition that each of the available newly constructed hydro, oil-fired and gas-fired generators, and half of the coal-fired generators, should provide 10% - 15% of rated capacity power as reserves (in units of 1%). [94]

(b) Efforts of existing generation units (commissioned before 2014)

In November 2015, the first discussion meeting between power producers and BPDB was held in the Ministry of Power, Energy and Mineral Resources (MOPEMR), concerning the expansion of contribution for frequency control of existing generators. In order to rapidly improve the power quality, the following content was discussed and agreed:

- In order to secure at least 300MW of primary reserve, there is an urgent need to carry out the FGMO, at least by 8-10 power plants, and to secure 300MW of primary reserves.
- Thus, the generation units listed in Table 16-14 agreed to carry out FGMO around January 2016.

As described in section 16.5.1 , although the JICA survey team has some concerns about the existing generating units as qualified providers of primary reserves, above all, the power plants in Table 16-14 can be expected to provide the primary reserve.
However, it is difficult to expect a long-term primary reserve, because the existing generating units are being gradually dismantled or replaced by new units. Therefore, they are not incorporated into the primary reserve.

Table 16-14 The List of Existing Units Which are Expected to Perform FGMO from January 2016

SL. No	Name & Capacity	Owner
1	Sikalbaha 1x150 MW	BPDB
2	Sylhet 1x150 MW	BPDB
3	Baghabari 100 MW	BPDB
4	Baghabari 71 MW	BPDB
5	Kaptai 4&5	BPDB
6	Shahajibazar 8&9 (2x35 MW)	BPDB
7	Siddhirganj 2x120 MW	EGCB
8	RPCL (Steam 75 MW)	RPCL
9	Sirajganj 225 MW (150+75 MW)	NWPGCL
10	Khulna 1x150 MW	NWPGCL

[94] The upper and lower limits of LFC control are generally set as follows in TEPCO. Therefore, to determine whether it is possible to require the supplying of 10% to 15% of rated output, it is necessary to undergo a careful process.

- Thermal power generator : The upper/lower limits are ±5% of output instruction (base output)
- Hydro power generator : The difference between current output and the upper/lower limits of machine output
- Nuclear power generator: No settings.

11	Summit Bibiyana-2 (1x222 MW)	Summit Power
12	Summit Meghnaghat (2x110 GT+1x110 ST MW)	Summit Power

Source: JICA Survey Team

Incidentally, the JICA survey team was separately provided with the list of existing units which currently obey the output adjustment instructions from NLDC by phone, as shown in Table 16-15.
Although they mostly overlap with the lineup of Table 16-14, the yellow-colored units are out of FGMO test operation. They urgently require maintenance to be able to contribute to the reserve expansion.

Table 16-15 The List of Existing Units Which Obey Instructions of Output Adjustment from NLDC

SL. No	Name & Capacity	Owner
1	Sikalbaha 1x150 MW	BPDB
2	Sylhet 1x150 MW	BPDB
3	Baghabari 100 MW	BPDB
4	Baghabari 71 MW	BPDB
5	Kaptai 4&5	BPDB
6	Shahajibazar 8&9 (2x35 MW)	BPDB
7	Siddhirganj 2x120 MW	EGCB
8	Haripur Power Ltd. (1x235+125)	HPL
9	Sirajganj 225 MW (150+75 MW)	NWPGCL
10	Khulna 1x150 MW	NWPGCL
11	Summit Bibiyana-2 (1x222 MW)	Summit Power
12	Meghnaghat Power Ltd (2x150+150 MW)	MPL

Source: JICA Survey Team

(c) Estimation of the planned outages (maintenance outages) and unplanned outages

The ratio of planned outages (maintenance outages) and unplanned outages of generators is one of the most uncertain but important elements in conducting a trial calculation.
Unfortunately, information on this point could not obtained in the investigation in Bangladesh, so the JICA survey team assumed the outage rates as 0% to 20% (in 5% increments).

(d) Risk of delay in developing the LFC by SCADA/EMS in NLDC

Moreover, as per the details described in section 16.6 , a risk of delay in developing the LFC by SCADA/EMS in NLDC should be taken into consideration. Thus, preparation of the available primary reserve list provided by only FGMO is required.
Fortunately, there seems to be no risk in realizing FGMO with the newly constructed generators commissioned after 2015, for the following reasons:

- All generators are generally equipped with governors for the purpose of maintaining constant rotor speed.
- FGMO can be easily realized by setting up the permanent speed variation and limiter of the governor.

From TEPCO's experiences, the primary reserves (FGMO + LFC) have been secured from 3% to 5% of the maximum demand. Spinning reserves (FGMO) have been secured at around 2% of the maximum demand. Thus, the ratio of FGMO among the primary reserves amounts to one-third to two-thirds.
In the case of Bangladesh, the primary reserve is planned to secure at least 10% of the maximum demand, so the contribution of FGMO can be estimated at about 3% to 7% of the maximum demand.

(e) The results of calculations

Table 16-16 shows the available primary reserves, when both FGMO and LFC are carried out.
Table 16-17 shows the available primary reserves, when only FGMO are carried out.

Hereinafter, the study will be performed based on Table 16-17, for a more severe estimation.

Table 16-16 Available Primary Reserve List

Rate of operation	Rate of reserve	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
100%	10%	0	120	214	370	451	775	775	775	830	830	830	855	915	1000	1075	1175	1235	1400	1565	1745	2010	2200	2396	2571	2816	2956	3032
	11%	0	132	235	407	496	852	852	852	913	913	913	940	1006	1100	1182	1292	1358	1540	1721	1919	2211	2420	2636	2828	3097	3251	3335
	12%	0	144	257	444	541	930	930	930	996	996	996	1026	1098	1200	1290	1410	1482	1680	1878	2094	2412	2640	2875	3085	3379	3547	3638
	13%	0	156	278	481	587	1007	1007	1007	1079	1079	1079	1111	1189	1300	1397	1527	1605	1820	2034	2268	2613	2860	3115	3342	3660	3842	3941
	14%	0	168	300	518	632	1085	1085	1085	1162	1162	1162	1197	1281	1400	1505	1645	1729	1960	2191	2443	2814	3080	3354	3599	3942	4138	4244
	15%	0	180	321	555	677	1162	1162	1162	1245	1245	1245	1282	1372	1500	1612	1762	1852	2100	2347	2617	3015	3300	3594	3856	4224	4434	4548
95%	10%	0	114	203	352	429	736	736	736	788	788	788	812	869	950	1021	1116	1173	1330	1487	1658	1909	2090	2276	2442	2675	2808	2880
	11%	0	125	224	387	471	810	810	810	867	867	867	893	956	1045	1123	1228	1290	1463	1635	1823	2100	2299	2504	2686	2942	3089	3168
	12%	0	137	244	422	514	883	883	883	946	946	946	975	1043	1140	1225	1339	1408	1596	1784	1989	2291	2508	2731	2931	3210	3370	3456
	13%	0	148	264	457	557	957	957	957	1025	1025	1025	1056	1130	1235	1328	1451	1525	1729	1933	2155	2482	2717	2959	3175	3477	3650	3744
	14%	0	160	285	492	600	1030	1030	1030	1104	1104	1104	1137	1217	1330	1430	1563	1642	1862	2081	2321	2673	2926	3187	3419	3745	3931	4032
	15%	0	171	305	527	643	1104	1104	1104	1183	1183	1183	1218	1304	1425	1532	1674	1760	1995	2230	2487	2864	3135	3414	3663	4012	4212	4320
90%	10%	0	108	193	333	406	697	697	697	747	747	747	769	823	900	967	1057	1111	1260	1408	1570	1809	1980	2156	2314	2534	2660	2729
	11%	0	119	212	366	447	767	767	767	822	822	822	846	906	990	1064	1163	1223	1386	1549	1727	1990	2178	2372	2545	2788	2926	3001
	12%	0	130	231	400	487	837	837	837	896	896	896	923	988	1080	1161	1269	1334	1512	1690	1885	2171	2376	2588	2776	3041	3192	3274
	13%	0	140	250	433	528	906	906	906	971	971	971	1000	1070	1170	1258	1375	1445	1638	1831	2042	2352	2574	2803	3008	3294	3458	3547
	14%	0	151	270	466	568	976	976	976	1046	1046	1046	1077	1153	1260	1354	1480	1556	1764	1972	2199	2532	2772	3019	3239	3548	3724	3820
	15%	0	162	289	500	609	1046	1046	1046	1120	1120	1120	1154	1235	1350	1451	1586	1667	1890	2113	2356	2713	2970	3234	3470	3801	3990	4093
85%	10%	0	102	182	315	383	659	659	659	705	705	705	727	778	850	914	999	1050	1190	1330	1483	1708	1870	2037	2185	2393	2512	2577
	11%	0	112	200	346	422	724	724	724	776	776	776	799	855	935	1005	1099	1155	1309	1463	1631	1879	2057	2240	2404	2633	2764	2835
	12%	0	122	218	378	460	790	790	790	847	847	847	872	933	1020	1096	1198	1260	1428	1596	1780	2050	2244	2444	2622	2872	3015	3092
	13%	0	133	237	409	499	856	856	856	917	917	917	945	1011	1105	1188	1298	1365	1547	1729	1928	2221	2431	2647	2841	3111	3266	3350
	14%	0	143	255	440	537	922	922	922	988	988	988	1017	1089	1190	1279	1398	1470	1666	1862	2076	2392	2618	2851	3059	3351	3517	3608
	15%	0	153	273	472	575	988	988	988	1058	1058	1058	1090	1167	1275	1371	1498	1575	1785	1995	2225	2563	2805	3055	3278	3590	3769	3865
80%	10%	0	96	171	296	361	620	620	620	664	664	664	684	732	800	860	940	988	1120	1252	1396	1608	1760	1917	2057	2253	2365	2425
	11%	0	106	188	326	397	682	682	682	730	730	730	752	805	880	946	1034	1087	1232	1377	1536	1769	1936	2108	2262	2478	2601	2668
	12%	0	115	205	355	433	744	744	744	797	797	797	821	878	960	1032	1128	1186	1344	1502	1675	1930	2112	2300	2468	2703	2837	2910
	13%	0	125	223	385	469	806	806	806	863	863	863	889	952	1040	1118	1222	1284	1456	1628	1815	2090	2288	2492	2674	2928	3074	3153
	14%	0	134	240	415	505	868	868	868	930	930	930	958	1025	1120	1204	1316	1383	1568	1753	1954	2251	2464	2683	2879	3154	3310	3395
	15%	0	144	257	444	541	930	930	930	996	996	996	1026	1098	1200	1290	1410	1482	1680	1878	2094	2412	2640	2875	3085	3379	3547	3638

Source: JICA Survey Team

Table 16-17 List of Primary Reserve by FGMO Only

Rate of operation	Rate of reserve	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
100%	3%	0	36	64	111	135	232	232	232	249	249	249	256	274	300	322	352	370	420	469	523	603	660	719	771	845	887	910
	4%	0	48	86	148	180	310	310	310	332	332	332	342	366	400	430	470	494	560	626	698	804	880	958	1028	1126	1182	1213
	5%	0	60	107	185	226	387	387	387	415	415	415	427	457	500	537	587	617	700	782	872	1005	1100	1198	1285	1408	1478	1516
	6%	0	72	128	222	271	465	465	465	498	498	498	513	549	600	645	705	741	840	939	1047	1206	1320	1438	1542	1689	1773	1819
	7%	0	84	150	259	316	542	542	542	581	581	581	598	640	700	752	822	864	980	1095	1221	1407	1540	1677	1799	1971	2069	2122
95%	3%	0	34	61	105	129	221	221	221	237	237	237	244	261	285	306	335	352	399	446	497	573	627	683	733	802	842	864
	4%	0	46	81	141	171	294	294	294	315	315	315	325	348	380	408	446	469	532	595	663	764	836	910	977	1070	1123	1152
	5%	0	57	102	176	214	368	368	368	394	394	394	406	435	475	511	558	587	665	743	829	955	1045	1138	1221	1337	1404	1440
	6%	0	68	122	211	257	442	442	442	473	473	473	487	522	570	613	670	704	798	892	995	1146	1254	1366	1465	1605	1685	1728
	7%	0	80	142	246	300	515	515	515	552	552	552	569	608	665	715	781	821	931	1041	1160	1337	1463	1593	1710	1872	1966	2016
90%	3%	0	32	58	100	122	209	209	209	224	224	224	231	247	270	290	317	333	378	423	471	543	594	647	694	760	798	819
	4%	0	43	77	133	162	279	279	279	299	299	299	308	329	360	387	423	445	504	563	628	724	792	863	925	1014	1064	1091
	5%	0	54	96	167	203	349	349	349	373	373	373	385	412	450	484	529	556	630	704	785	904	990	1078	1157	1267	1330	1364
	6%	0	65	116	200	244	418	418	418	448	448	448	462	494	540	580	634	667	756	845	942	1085	1188	1294	1388	1520	1596	1637
	7%	0	76	135	233	284	488	488	488	523	523	523	539	576	630	677	740	778	882	986	1099	1266	1386	1509	1620	1774	1862	1910
85%	3%	0	31	55	94	115	198	198	198	212	212	212	218	233	255	274	300	315	357	399	445	513	561	611	656	718	754	773
	4%	0	41	73	126	153	263	263	263	282	282	282	291	311	340	365	399	420	476	532	593	683	748	815	874	957	1005	1031
	5%	0	51	91	157	192	329	329	329	353	353	353	363	389	425	457	499	525	595	665	742	854	935	1018	1093	1197	1256	1288
	6%	0	61	109	189	230	395	395	395	423	423	423	436	467	510	548	599	630	714	798	890	1025	1122	1222	1311	1436	1507	1546
	7%	0	71	127	220	268	461	461	461	494	494	494	509	544	595	640	699	735	833	931	1038	1196	1309	1426	1530	1675	1759	1804
80%	3%	0	29	51	89	108	186	186	186	199	199	199	205	220	240	258	282	296	336	376	419	482	528	575	617	676	709	728
	4%	0	38	68	118	144	248	248	248	266	266	266	274	293	320	344	376	395	448	501	558	643	704	767	823	901	946	970
	5%	0	48	86	148	180	310	310	310	332	332	332	342	366	400	430	470	494	560	626	698	804	880	958	1028	1126	1182	1213
	6%	0	58	103	178	217	372	372	372	398	398	398	410	439	480	516	564	593	672	751	838	965	1056	1150	1234	1352	1419	1455
	7%	0	67	120	207	253	434	434	434	465	465	465	479	512	560	602	658	692	784	876	977	1126	1232	1342	1440	1577	1655	1698

Source: JICA Survey Team

(2) Trial calculation of the required amount of reserves

Fundamental concept of assumption of possible faults

In order to make a trial calculation, the assumption of possible faults is an important factor in calculating the required amount of reserves, i.e.:

N-0 → Frequency control under no contingency situation
N-1 → The largest loss of power supply due to single apparatus contingency, such as sudden trip of one maximum capacity generating unit or sudden trip of one transmission line which results in loss of multiple generating units.
N-2 → The largest loss of power supply due to double simultaneous apparatus contingency.

The probability of simultaneous multi-apparatus faults is smaller than that of a single fault, while the impact on the frequency fluctuation is larger. In case studies for demand-supply operation planning, N-1 tends to be applied as the severest contingency from the viewpoint of global trends, including TEPCO. Therefore, the JICA survey team also considered the N-0 and N-1 contingency in this study.

(a) N-0 Case (Normal Conditions)

In this section, the JICA survey team will perform a trial calculation for the necessary primary reserves.
Unfortunately, there is no globally standardized method to calculate the necessary reserve in frequency control. Therefore, it should be noted that the following description is a very challenging study, and no more than a rough estimation.

The goal of this section is to provide a roadmap for frequency quality improvement. Therefore, it is useful to find a relationship between power demand and the necessary reserves for frequency control.

In this study, for simplicity, the necessary amount of reserves is considered to be equal to the amount of load fluctuation.[95] Therefore, the mission for this section can also be set as finding the relationship between power demand and load fluctuation.

Estimation of the load fluctuation requires statistical analysis of a great amount of past data. The JICA survey team, however, doesn't have enough time to collect and analyze the data in Bangladesh, and it is also very difficult to find good correlation factors among the data because many factors may influence the load fluctuation such as total demand, weekdays/holidays, time zone, power system condition, and so on.

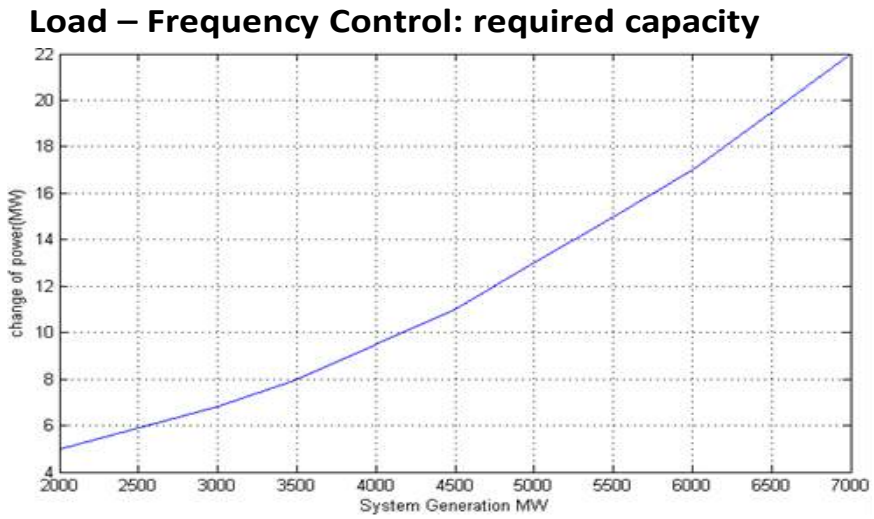
Therefore, the JICA survey team will try to apply the proportional expression between the load fluctuation and power demand obtained via analyses of load fluctuation in Japan, and to obtain a proportionality constant by using the data from 3 cases of frequency control practice and the frequency fluctuation chart at the time of generator or load tripping fault provided by NLDC.

[95] The frequency fluctuation can be theoretically canceled out by regulating the reserves in a simultaneous and commensurate manner in response to the load fluctuation. In fact, it is impossible to make the output from reserves follow the load fluctuation with pinpoint accuracy. Therefore, some frequency deviation is practically allowed (50+/-0.2Hz in TEPCO) due to the control delay. Thanks to this allowable frequency deviation, the necessary amount of reserves is less than the amount of load fluctuation. In this study, however, the JICA survey team set the calculation conditions to be more severe.

The data concerning the frequency control provided by NLDC

Case 1: Load-frequency chart in NLDC

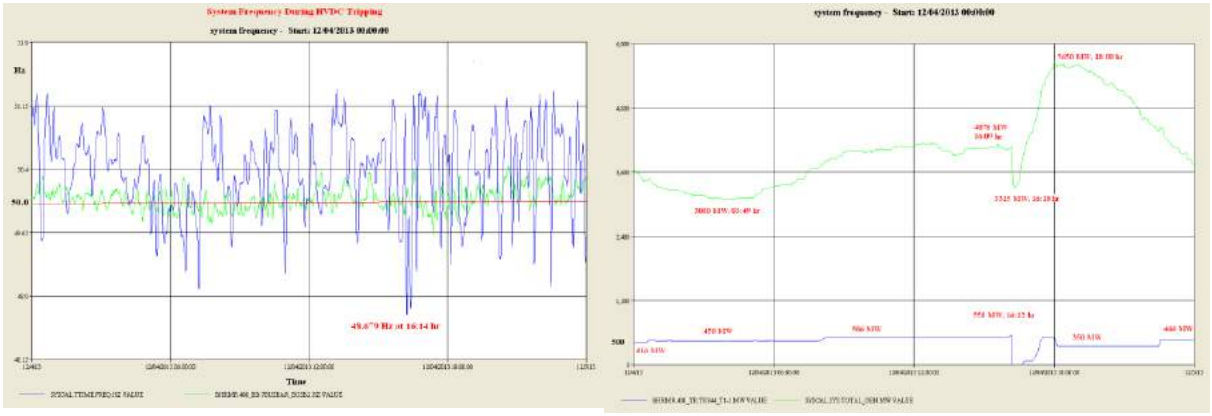
NLDC prepares a chart as shown in Figure 16-14, which indicates the necessary amount of reserves to improve frequency fluctuation by 0.1Hz at a given power demand. For example, the necessary reserves to improve frequency fluctuation by 0.1Hz are 22MW when the power demand is 7,000MW.



Source: NLDC

Figure 16-14 The Necessary Reserve to Improve 0.1[Hz] of Frequency Fluctuation

Case 2: HVDC international tie-line tripping fault (occurred on Dec. 4th 2013)



Source: JICA Survey Team

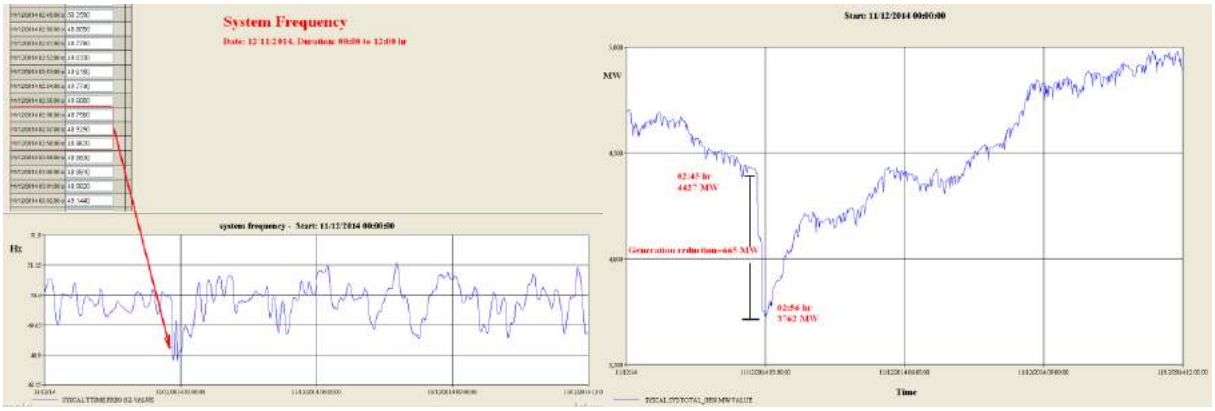
Figure 16-15 Impact of Tripping HVDC Link (System Frequency & Generation Records)

Date & Time	Frequency Hz	Load MW	Generation MW	HVDC Import MW
12/04/2013 16:10:00 s	50.934	3739.832	4060.916	549
12/04/2013 16:11:00 s	51.056	3725.427	4066.471	554
12/04/2013 16:12:00 s	51.06	3715.312	4071.837	558
12/04/2013 16:13:00 s	49.181	3512.534	3638.304	0
12/04/2013 16:14:00 s	48.679	3361.106	3527.44	0
12/04/2013 16:15:00 s	48.702	3183.347	3420.231	0

From the data above, the JICA survey team can estimate that import power of 558MW from India was suddenly interrupted due to a trip of the HVDC international tie-line. As a result, the total supply decreased sharply from 4,072MW to 3,638MW. At the same time, load shedding by Under Frequency Relay (UFR) seemed to occur and demand decreased from 3,715MW to 3,512MW.

From this consideration, it can be calculated that the frequency was lowered by 0.1Hz due to the supply shortage of about 12.3MW, under the total demand of 3,715MW.

Case 3: Tripping fault at a few units of the generator in Ashuganj area (occurred on Nov. 12th 2014)



Source: JICA Survey Team

Figure 16-16 Impact of Tripping Generators on the System Frequency

Since the data for load fluctuation has not been provided, the JICA survey team considered that only generator tripping occurred and load-shedding did not occur. In addition, in the right figure, although NLDC reported that total generation decreased from 4,427MW to 3,762MW in one event, there are obviously two generator trip events, determined by observing the chart closely. From this observation, at the first frequency drop, demand is considered to have decreased to only about 4,240MW.
In this data, there is no information on the demand, but the JICA survey team considers that total generation output was almost equal to the total demand because the frequency immediately before the fault was about 50.2 [Hz], which indicates that the demand and supply had been almost balanced.

Based on the considerations above, it can be calculated that the frequency was lowered by 0.1Hz due to the supply shortage of about 12.8MW, under the total demand of 4,427MW.

Trial calculations of necessary reserves for frequency control (load fluctuation)

From the results of the 3 cases, the JICA survey team will make a trial calculation of the relationship between demand and load fluctuation.

According to the technical report from the Committee of Experts in the Institute of Electrical Engineers of Japan (technical report No. 869, IEEJ), there is a result in statistical analysis where the standard deviation of load fluctuation (σ) is proportional to the square root of the power demand (P). Here, the JICA survey team simply assumed that the load fluctuation (ΔP), in other words, the necessary reserves (=ΔP), is also proportional to the square root of the total demand (P). i.e.:

$$\Delta P = \alpha * \sqrt{P} \quad [MW]$$

Assuming that the quantity of reserves consumed and the degree of frequency improved (for example; 0.1 [Hz]) are in proportion to each other, the equation above can be converted into the following equation relationship between demand and the amount of necessary reserve for improving 0.1[Hz]. i.e.:

$$\Delta P = \alpha * \sqrt{P} \quad [MW/0.1Hz]$$

Here, the results of Cases 1, 2, 3 – relationship between the total power demand and necessary reserves to improve frequency by 0.1Hz – are substituted into the equation. Then, the proportionality constant α can be determined as follows:

$\Delta P = 0.263*\sqrt{P}$ [MW/0.1Hz] : Case 1
$\Delta P = 0.201*\sqrt{P}$ [MW/0.1Hz] : Case 2
$\Delta P = 0.193*\sqrt{P}$ [MW/0.1Hz] : Case 3

Though the calculation results of constant α vary widely from 0.193 to 0.263, hereinafter, the study team uses the equation of case 1 because, in that, the amount of load fluctuation (necessary reserve) becomes the largest.[96]

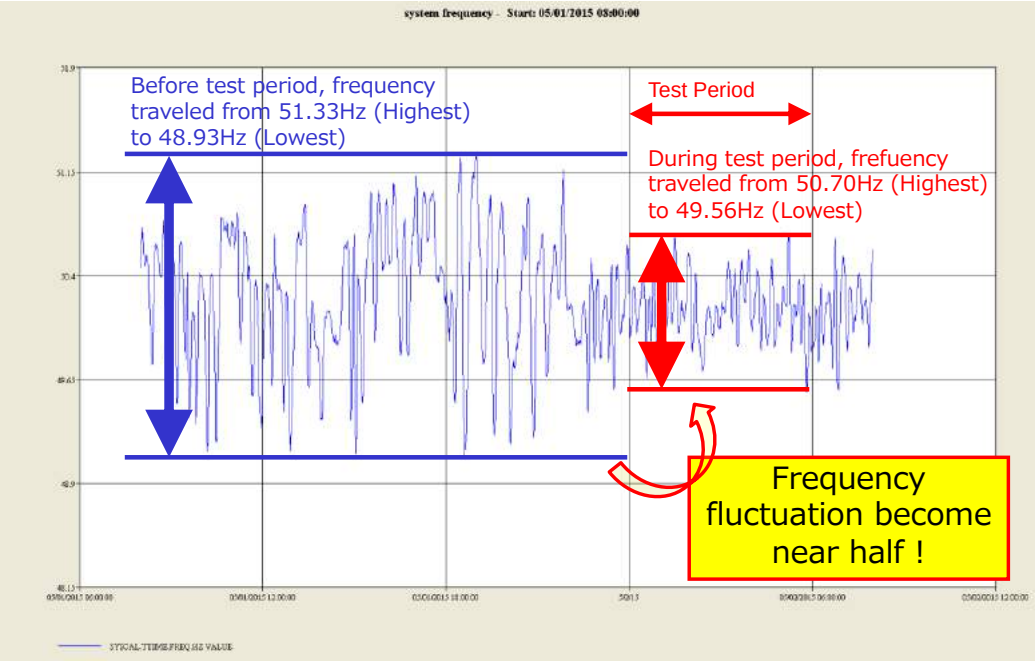
In terms of solitary information that can verify the derived equation, there are useful results from the frequency control test that was carried out in the Khulna power station in May 2015. An outline of this test is shown in Table 16-18.
According to the explanation from NLDC, in this test, they examined the effects of frequency improvements by realizing the action of FGMO by repeating the telephone instructions to the power station during the test time. Assuming that the power demand during the test time was around 5,000MW on average, the necessary reserve to improve frequency quality by 0.1Hz can be calculated at about 18.6MW from the equation. On the other hand, the frequency fluctuation decreased from about ±1.2 [Hz] to ±0.55 [Hz] due to using the gas turbine machine as reserves. From these facts, about 121MW from the rated output of 158MW was used for reserves. Though there are, unfortunately, no records of generator output that can support this estimation it is not improbable.

Table 16-18 Outline of Frequency Control Test in Khulna Power Station

Date	May 2nd, 2015 (SAT.) 0:00 – 6:00 AM (for 6 hours)
Site	Khulna Power Station (Rated output: 158MW×1 unit, Gas-Turbine, fuel: HSLO: High-sulfur light oil)
Conditions	Realizing simulated FGMO by repeating the telephone instructions from NLDC shift engineers to Khulna power station.
Total demand	5,870MW (at 0:00 AM) - 4,500MW (at 6:00 AM)
Effectiveness	Before/After the test: 51.33Hz - 48.93Hz (+2.66% -- -2.14%) During the test: 50.70Hz - 49.56Hz (+1.40Hz -- -0.88%)

Source: JICA Survey Team

[96] This equation is not consistent with the characteristics of the graph as shown in Figure 16-14. This figure shows the lower convex curve where the rate of increase in the amount of necessary reserve rises as demand increases, but the above relational equations are clearly the upper convex curve to demand. However, qualitatively, it is considered that a load that fluctuates randomly is connected more to the power system as demand increases. If there are many random elements, since the whole variation is suppressed and smoothed, the upper convex curve is believed to be close to actual conditions.

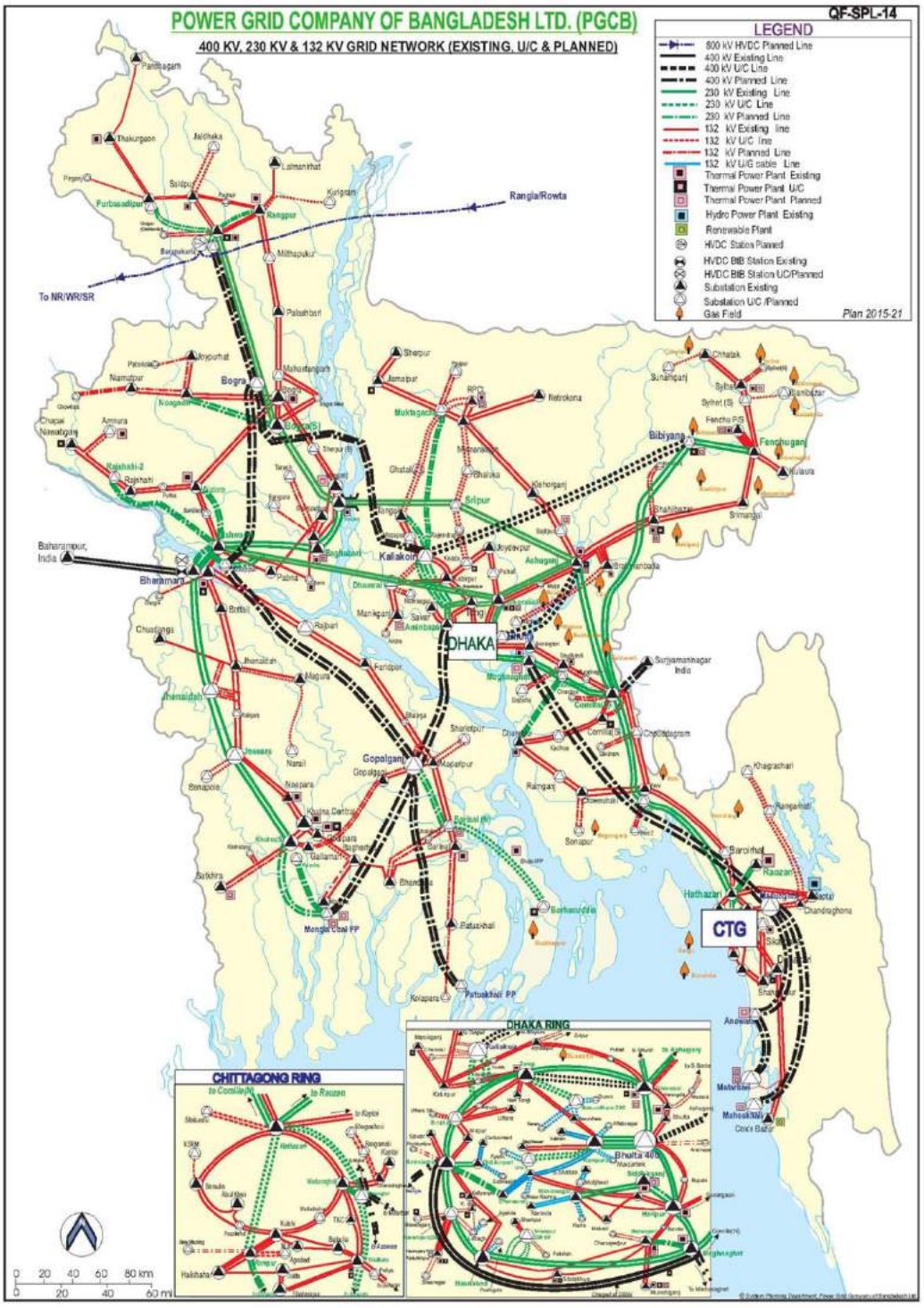


Source: JICA Survey Team

Figure 16-17 Frequency Fluctuation Record during Test Operation in Khulna Power Station

(b) N-1 Case (Emergency Conditions)

The case which may cause great frequency fluctuations due to a single apparatus fault is generation tripping or load tripping. As per the power system diagram shown inFigure 16-18, since almost all the 400kV, 230kV and 132kV transmission facilities in Bangladesh consist of double-circuit transmission lines and are operated by a meshed configuration, it can be said that there are no cases in which frequency fluctuates greatly due to an N-1 fault in the AC system.



Source: JICA Survey Team

Figure 16-18 Power System Diagram of Bangladesh

It should be considered, but rather in the following cases:

- Single generation tripping of maximum capacity
- Import power cut-off due to single apparatus fault such as HVDC transmission line or Back to Back (BTB)

Specific amounts and factors regarding supply tripping that should be considered in future years' development of the power system are shown as follows:

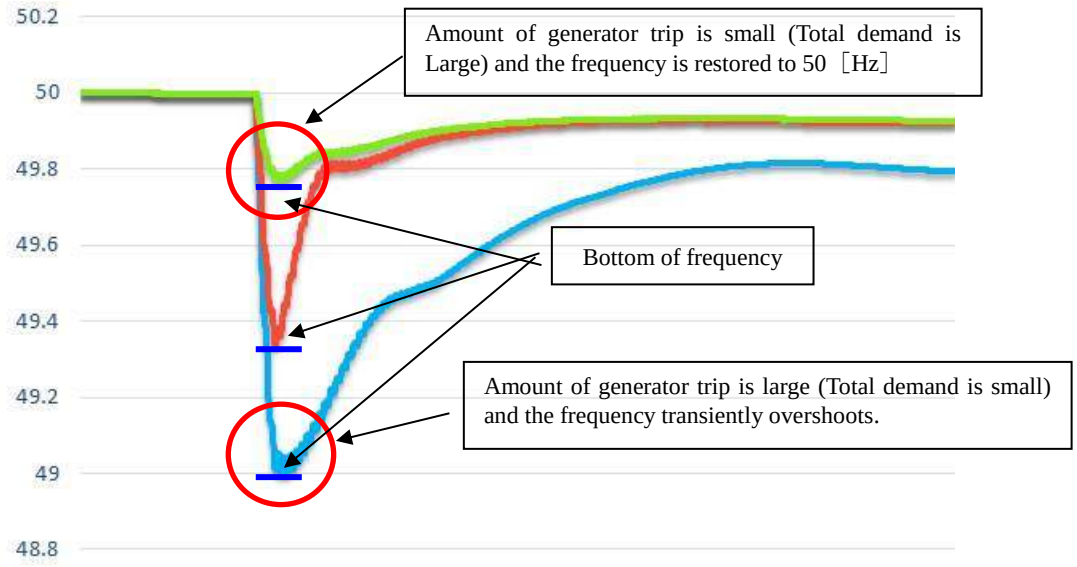
Table 16-19 Supply Tripping Amount and Factors That Should Be Considered in Each Year

Year	Supply tripping amounts	Factors
2015~2024	500MW	Single apparatus fault of HVDC 500MW
2024~2041	1180MW	Single unit tripping of Rooppur nuclear power plants

Source: JICA Survey Team

In this study, the JICA survey team will check the adequacy of reserves for each year by comparing with these supply tripping amounts.

The important thing is that it is not always perfect even if there is a sufficient amount of reserves as shown in the above table. As shown in Figure 16-19, if the reserve is secured as shown in the table, it is possible to finally recover to normal frequency. However, immediately after the generator tripping, the frequency transiently decreases rapidly, since the output of generators provided as reserves cannot keep up with the sudden loss of supply. The greater the ratio of the generator capacity among the total supply power becomes, the more severe this tendency becomes.



Source: JICA Survey Team

Figure 16-19 Time-shift Illustration of Frequency Fluctuation at the Time of Generation Tripping

Therefore, for example, if frequency overshoots below the permissible under-frequency range of the generator due to the tripping of a large capacity generator in the low demand season or time zone, other generators are simultaneously tripped (i.e. reference Figure 16-7). This leads to a further frequency decrease. Then, the power system will collapse and a so-called cascading outage occurs. In the worst case, there is a possibility that the whole power system will experience a black out.

Bangladesh has already experienced a black out due to the cut-off of about 500MW of imported power from India via the HVDC international tie-line, in November 2014.

In order to avoid cases like this, adequate capacity of automatic load shedding by UFR is provided as a back-up scheme. Besides, in the above-mentioned IAEA guideline, in order to avoid load shedding that exceeds the permissible range, one nuclear generator capacity in the low demand period is recommended to be selected to be less than 10% of the total demand.

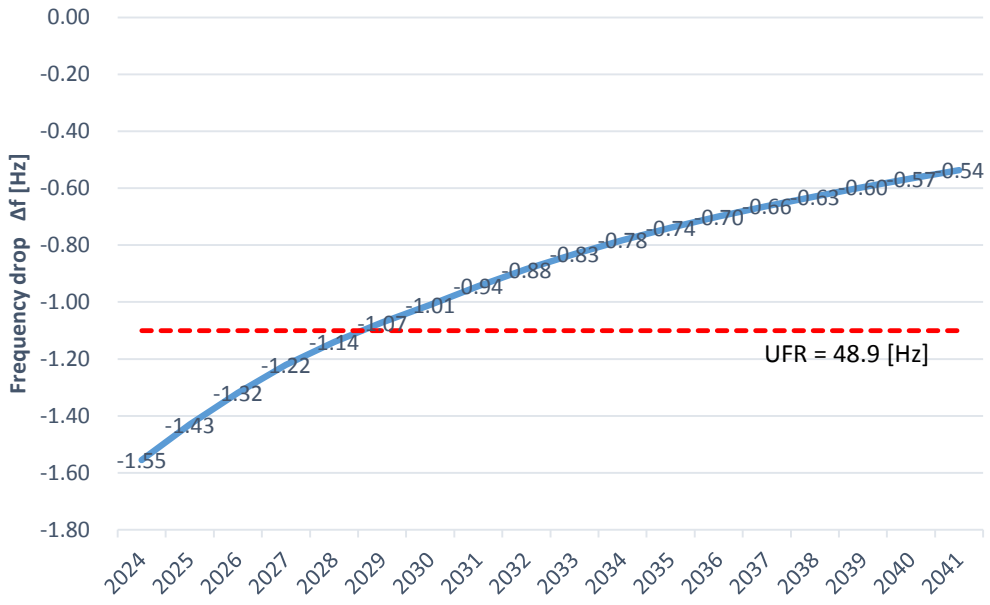
Fig. 16-20 shows the trend of frequency deviation (Δ f) when a sudden trip of Rooppur nuclear power unit (1180MW) occurs under the minimum demand conditions each year after 2024. The bottom of frequency is as shown in Fig. 16-19. The calculation formula of the frequency drop is as follows:

A mathematical relation:

$$\frac{\Delta f}{50}\ [\%/Hz] \times K\ [\%MW/\%Hz] = -\frac{1{,}180}{P}\ [\%MW]$$

where,

K : k-factor of the = 5.0 [%MW/%Hz] (a standard value in TEPCO)
P : Minimum demand each year



Source: JICA Survey Team

Figure 16-20 Trend of Bottom of Frequency Immediately after a Sudden Trip of Rooppur Unit

As shown in the graph above, frequency overshoots below the UFR settings, 48.9Hz, due to the trip of the Rooppur unit in a low demand season or time zone that leads to load shedding until 2028. However, it should be allowed in order to avoid a cascading outage and blackout.

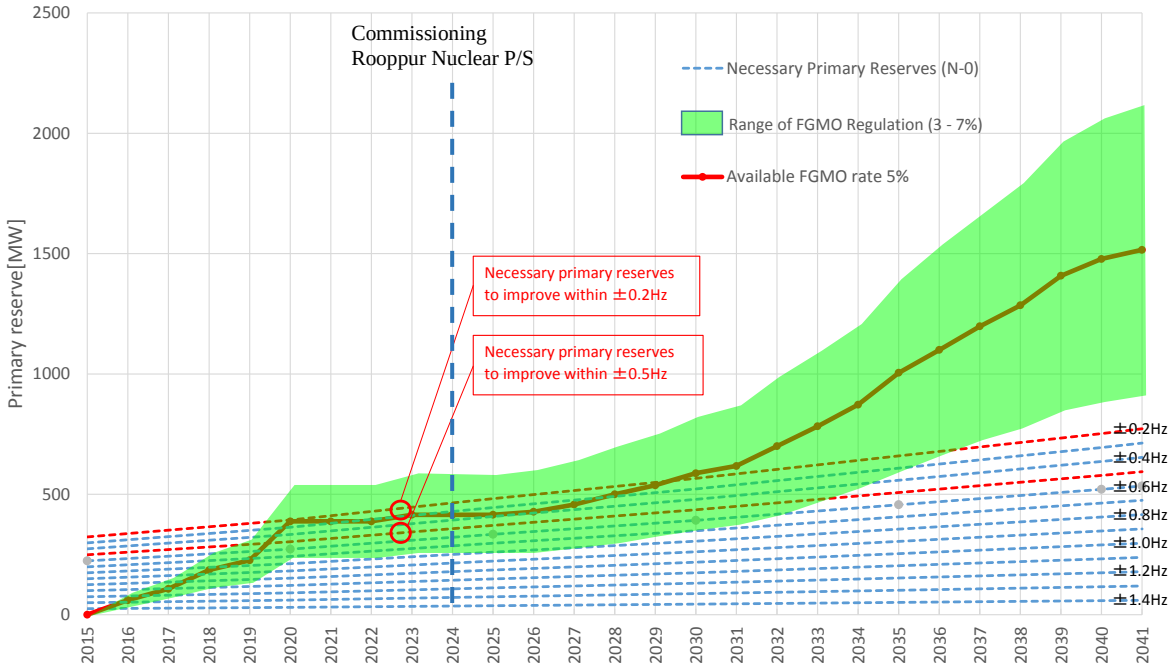
(3) Verification of Adequacy of Reserves

Figure 16-21 and Figure 16-22 show the balance of available primary reserves and necessary reserves for improving frequency fluctuation in units of 0.1Hz, from the study results of section 16.5.2 (1) and 16.5.2 (2). Here, prerequisite conditions are as follows:

- The available reserves are colored green, based on the case of 100% and 80% operation rate in

Table 16-17.

- The necessary reserves are calculated based on the equation $\Delta P = 0.263 \times \sqrt{P}$ (MW/0.1Hz), to improve frequency quality from the current situation (assuming +/-1.5Hz) to certain values in +/-0.1Hz segments. Then they are drawn in dashed lines from +/-1.4Hz-quality (+/-0.1Hz improvement) to +/-0.2Hz-quality (+/-1.3Hz improvement).
- When the green range is on dashed lines, it is the balance point between available and necessary reserve. Therefore, the range indicates the trend of frequency quality improvement.



Source: JICA Survey Team

Figure 16-21 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator: 100%)

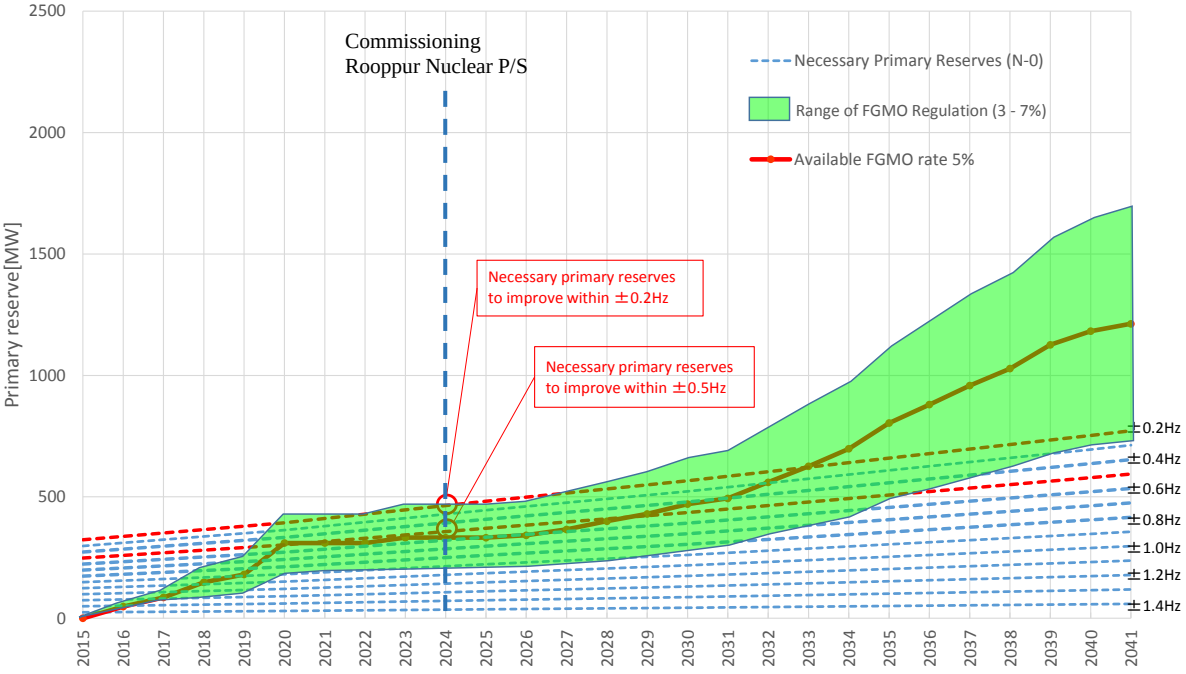


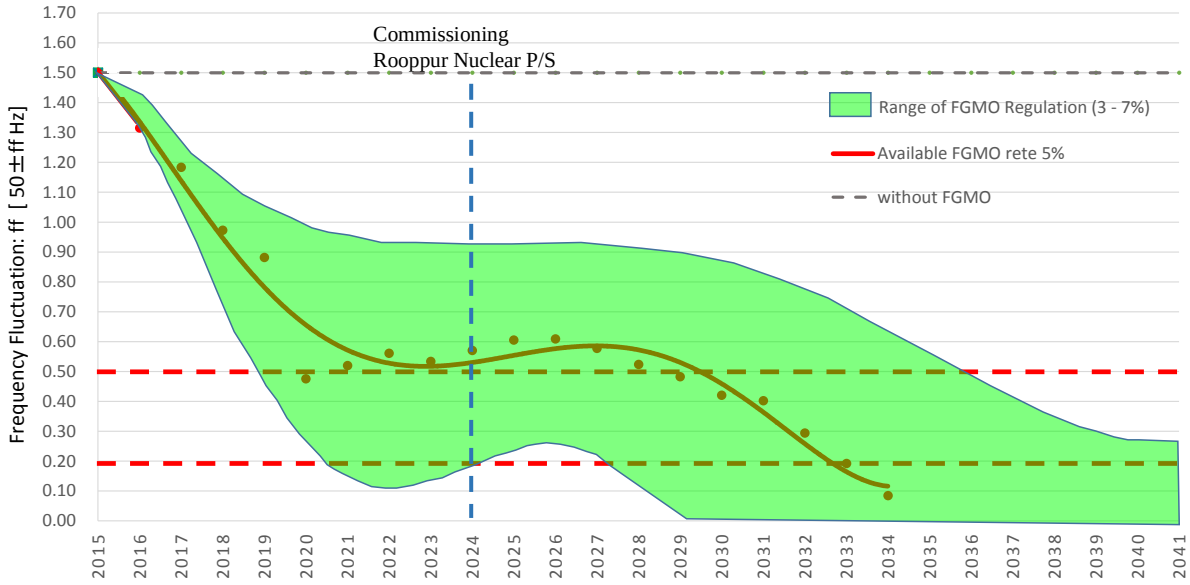
Figure 16-22 The Comparison of Securing the Amount of Necessary Reserve and Available Reserve (The rate of operational generator: 80%)

Source: JICA Survey Team

As shown in Figure 16-21, in ideal conditions, where the rate of the operational generator is 100%, it is expected to be improved to within ±0.2 [Hz], which is equivalent to the frequency quality of TEPCO in 2037 at the latest. However, in reality, maintenance outages of the generation plant are inevitable, and unplanned maintenance outages should also be taken into account as risks. Figure 16-22 shows the 80% operational-rate case (maintenance outage + unplanned maintenance outage: 20%).
If the rate of the operational generator is 80%, there is a possibility that the frequency will deviate from the target range of ± 0.2Hz even in 2041. However, as mentioned above, it can be said that there are no big challenges at 80% operational-rate, because it contains a considerable margin upon a trial calculation.

(4) Roadmap for frequency quality improvement

Figure 16-23 shows the future trend of frequency quality improvement when the current frequency fluctuation is assumed to be ± 1.5Hz, based on the study of the demand-supply balance of reserves, shown in Figure 16-22. Here, the plots shown in Figure 16-23 are calculated values for each year, and the curves are quadratic approximate curves obtained from the plots.



Source: JICA Survey Team

Figure 16-23 Future Roadmap of Improving Frequency Quality

According to Figure 16-22 and Figure 16-23, the following are points to note:

Frequency control in normal conditions

- If the effective amount of FGMO is 5% of total demand as an average value, it is possible that the frequency fluctuation can be controlled to within ±0.5Hz until the commitment of the Rooppur nuclear generation plant at 2024.
- A risk that the effective amount of FGMO is less than 5% cannot be denied. However, as mentioned above, it is considered that the risk can be ignored because it contains a considerable margin upon the accumulation of necessary primary reserve.
- It is sufficiently possible to secure the reserve in order to improve the frequency quality to within ±0.2Hz by 2041.

Frequency control in abnormal conditions

- After the first commitment of a Rooppur nuclear generation unit in 2024, the frequency drop

becomes remarkable due to the trip of that unit. As a result, a cascading trip of other generators occurs and there is a risk of blackout.
Therefore, the steady accumulation of primary reserve is essential. Also, in order to avoid a total blackout, the amount of load shedding by UFR should be secured sufficiently for the time being.

Therefore, it is a major challenge for the time being to improve the frequency quality to a level where a nuclear power plant can be in stable operation. Therefore, the important points for this are as follows:

Institution design, Apparatus design
- Framework to foster economic incentives such as purchase of reserves at a reasonable price and grants of compensation
- Incorporating FGMO and LFC functions into design specifications as an interconnection requirement for new generators and implementing the functional tests before commitment. The FGMO is implemented immediately after commitment.
- Coal-fired thermal power is planned to provide the primary reserve from 50% of them at present. If there is an intention to avoid load shedding by UFR as much as possible, so that the primary reserve is provided by all of the coal-fired thermal power plants for the time being, it is essential for all new generators to incorporate the FGMO and LFC functions into the design specification.

Operation and maintenance of conventional apparatus
- Since conventional generators are also expected to contribute as a further reserve, rehabilitation of generators except for those already incorporated into the reserve is essential, and this aims to secure several hundred MW of reserve.
- In particular, after the commissioning of nuclear power, in order to secure the reserve in the low demand season, maintenance outage planning should be taken adequately into consideration in the weekly, day before, day demand and supply planning.
- The effect of frequency drop due to the trip of a Rooppur nuclear power unit is big for the time being. Thus, in order to avoid a total blackout, it is acceptable to secure the amount of load shedding by UFR which is the rated output of a Rooppur nuclear power unit.

Also, in this study the following points should be noted.

- The trial calculation of the amount of necessary supply reserve is inferred from records of load variation in Japan.
- The trial calculation of the amount of available supply reserve is inferred from the current power development planning. Because a theoretical calculation of effective amount with FGMO is impossible, it is only an inference in the light of the Japanese experience.

Therefore, from now on, on the basis of such records for FGMO, which has been scheduled to be carried out in Bangladesh since the end of January 2016, we must verify its effect. And then it is necessary to refine the roadmap for the frequency quality improvement further.

16.6 Actual Condition of EMS/SCADA System in NLDC for Load Frequency Control (LFC)

As long as the current operation rules allow the current frequency deviation (±1.0Hz), instruction by phone is still acceptable. However, in order to improve the quality toward the level of developed countries (±0.05Hz~0.2Hz), utilization of automatic control will be essential, so the urgent enhancement of FGMO by each generation unit and LFC by SCADA/EMS in NLDC is strongly desired.

16.6.1 Installed functions in NLDC system

At present, there is a French (Areba)–built SCADA/EMS in NLDC, which has the function of LFC within it, but it has not been connected to generators owned by IPPs, nor has it had its data set to work well.

Table 16-20 Functions of SCADA/EMS and Current Status of Usage

Functions	Outline	Current Problem
SCADA Functions (Monitoring of the power system)	Monitor status change of power system by receiving supervisory and telemetry (hereinafter TM) data from RTU. When detected status changes and there is a deviation in TM values, it will inform the operator through the operation display. Following are monitored: - Frequency - Voltage - Power Flow - Post-fault Analysis	Information display failure on the system monitoring panel is recognized. Reasons as follows: - Failures existing in tele-communication between NLDC and substations. Failure occurs at substations including high voltage substations, substation apparatus such as Trd, IED, RTU, power supply equipment installed at the substations. - Intermittent tele-communication between NLDC and other companies - Online information supply excluded from contract - Substation facilities mainly owned by PGCB; however, do have substations owned by other company. - PGCB owns some power plants as well.
Load Frequency Control (LFC)	Maintain primary frequency regulation capacity. LFC function controls power output of generators based on frequency deviation, and maintains frequency within adequate range. Frequency control is accomplished through generator governor response (primary frequency regulation) and LFC.	Current problems includes the following: - Grid Code and Power Purchase Agreement (hereinafter PPA) arrangements are not suitable for LFC and Automatic Generation Control (hereinafter AGC) - No disclosure of Generation Parameters. Despite above, no complaints from customers about the frequency variation are received, since 60% of the customers are not using electronic products (even if used, only fan or lighting) Poor power quality is not a problem with motivation to solve it, and there is no penalty for PGCB for providing such electricity.
Voltage and Reactive power control (VQC)	This function sends a reactive power signal to generators to regulate voltage targeted to this function. Reactive power signal originates from operators' key input value.	Voltage condition of each region is as below: - West, and North: In poor condition due to long transmission line, and lack of generators. Deployment of line voltage regulator, static tap changer, shifting to higher voltage may be a solution. - South: Generally in good condition. Voltage is high at night, and low in daytime. - East: In good condition due to existence of large generator. High voltage is maintained. Shunt reactor deployment is recommended when in high voltage. (Unsure whether exists.)
State Estimation, Network Security Analysis, and System Optimization	Real time contingency analysis for N-1 Security Real time monitoring of P-V curve and Voltage Stability	Problems regarding the state estimation include the following; - There are places in results where the estimated value (pink) and measured value (green) are quite different. - Measured values not delivered in timely manner, and data update not completed in time. Regulation condition was poor. No regulated interface existed between EMS and SCADA system.
Economic Dispatch Control (EDC)	Economic Dispatch Control (EDC) calculates economic dispatch output schedule for each generator of different efficiency to control its power output depending on the change in power demand. EDC is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, while serving power to the public in a robust and reliable manner. Scheduling/Real-Time Dispatching.	- EDC function was unused. - Generators operate in accordance with power generation planning at the power plants, hence NLDC is not involved in power generation plan.
Demand Forecast and Generation Scheduling	The Demand Forecast Function calculates total demand from weather forecast information and the past record data, and allocates the most economical generation schedule for each generator via Generation Scheduling Function. The demand forecast function predicts the gross demand for the next day by using multiple regression analyses based on previous data, past	In Japan, dispatching systems receive weather information from the Japan Meteorological Agency. Weather forecast is important information because electricity demand differs significantly with even a 1 degree Celsius difference in maximum temperature. The Demand Forecast Function calculates total demand from weather forecast information and the past recorded data, and allocates the most economical generation schedule for each generator via Generation Scheduling Demand. Lack of long term demand forecast program is a problem, and is needed. Desk calculation would be fine, if actual data analysis is possible.

Functions	Outline	Current Problem
	weather conditions, type of day (day of the week, singular point, etc.), and weather forecast information	
Recording, Archiving	Event recording shall be displayed on monitor when an event occurs. Also, the recorded data shall be able to be referred to (displayed) on monitor. Post-Fault Diagnosis Web Server for other Customer/administrative Services	The operating staff creates the daily report by hand, and it does not utilize the record data which the system has collected Failure history is preserved NLDC system is not connected to the outside world. Only within the NLDC.
Maintenance of database	Database modification for addition/deletion of power system components.	Dedicated maintenance team is present. DB for the new substation and outgoing Matabari are also being handled by the same team.
Configuration Control	Real-time Monitoring of SCADA/EMS network status	Configuring component devices in the system configuration screen and confirmation of RTU state is possible. RTU status screen: Green is healthy, purple is disconnected (which also includes future reserve). As preparation for power failure at NLDC, backup power supply such as a diesel engine and UPS are available.

Source: JICA Survey Team

16.6.2 Logic diagram of load frequency control in CLDO system in TEPCO

In order to implement LFC via the system in NLDC, operation data setting for each generator is required as indicated in Table 16-20.
Unfortunately, the relevant documents regarding the specification and necessary items for LFC have not been provided, so it is difficult to start the practical work toward the realization of LFC.

(1) Necessary minimum data for LFC in TEPCO (for reference)

Source: JICA Survey Team

Figure 16-24 illustrates the processing flow diagram for LFC in TEPCO. As shown in this figure, the LFC process is relatively simple due to its independence from EDC (Economic Dispatching Control). According to the diagram, data settings for following items may be enough to operate frequency control and time difference correction:

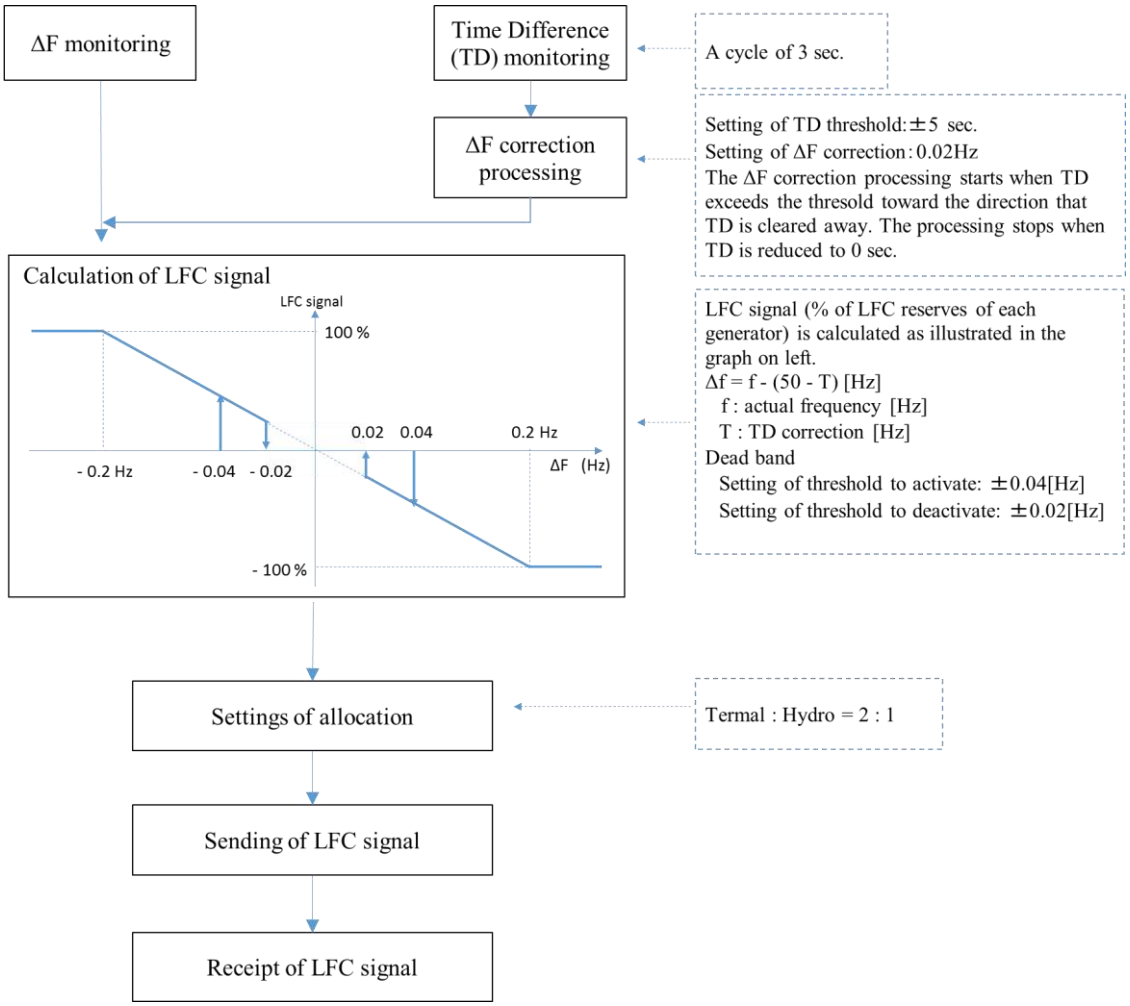
Telemetry Data

- Current frequency (deviation from 50Hz)
- Current time difference
- Current status of LFC mode (whether the generation unit can respond to the LFC signal or not)
- Current status of operation (In/Out of service), current output
- Current status of remaining margin in response to the up/down signal by LFC.

Internal Data

- Target frequency [Hz] = 50Hz
- TD Threshold (Threshold time to start time difference correction) [sec.]
- ΔF Correction (Frequency correction when starting the time difference correction) [Hz]
- Dead band of LFC [Hz]
- Allocation settings to the generators [%]
- Limiter settings of LFC signal [%]

In the case of the NLDC system in Bangladesh, there may be a possibility of realizing LFC by beginning with a simple and small scale trial, similar to TEPCO's system.



Source: JICA Survey Team

Figure 16-24 Flow Diagram for LFC in TEPCO

16.6.3 Early Applicableness of Load Frequency Control by NLDC System

The JICA survey team conducted a survey by questionnaire with the existing generating stations. Thanks to enormous efforts and cooperation by BPDB, the following 7 power stations kindly gave us their responses. According to the results of survey, there are no useful data or documents, including LFC flow diagrams, except for one station:

- Barapukuria Coal Power Plant
- Bheramara Power Plant
- Haripur 100MW Power Station
- Sylhet 150MW Combined Cycle Power Plant
- Rangpur 20MW Gas Turbine Power Station
- Saidpur 20MW Gas Turbine Power Station
- Dohazari-Kailiaish 100MW Peaking Power Station

Therefore, there is no choice except to target the newly installed generating units for LFC. It is essential to take the function into consideration when preparing the specifications or designing, and to agree to cooperate among NLDC, Generators and manufacturers to provide and perform data O&M.
It will take several years to set the project on its way, and it is still uncertain whether it will catch up

with the development and commencement of nuclear power generation in 2024.

16.6.4 Solution - Early Applicableness of FGMO

On the other hand, FGMO has high potential for prompt and wide expansion because:

- Obligation for equipment and operation of Free-Governor Mode has already been stipulated in Grid Code.
- FGMO by some gas-turbine generators has already been agreed and started execution. (Refer to 16.5.2 (3))
- FGMO can be realized for each generating unit alone. It does not need to be controlled by a central system such as SCADA/EMS in NLDC and to have communication channels developed or improved on a large scale.

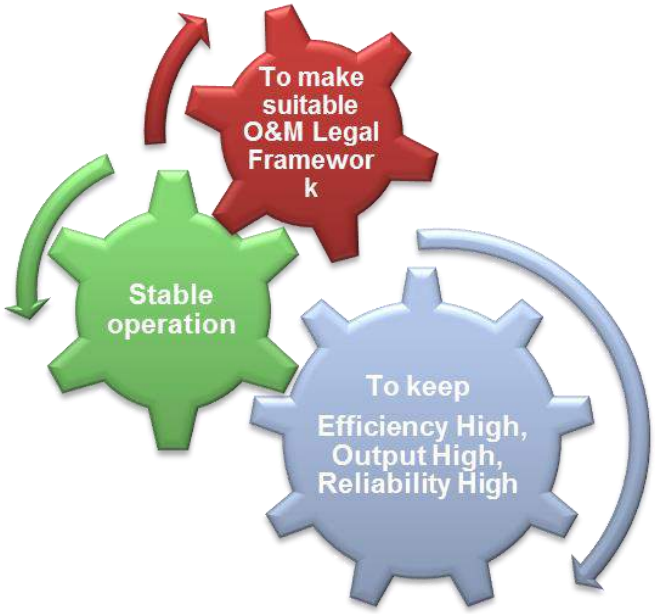
The remaining challenge is to enforce obedience to the rules and to monitor and regulate generators in order to perform FGMO from the commencement of operation.

Chapter 17 O&M Legal Framework

17.1 Introduction

17.1.1 Purpose of this study

The purpose of this study is to suggest the establishment of the suitable legal framework for Bangladesh.

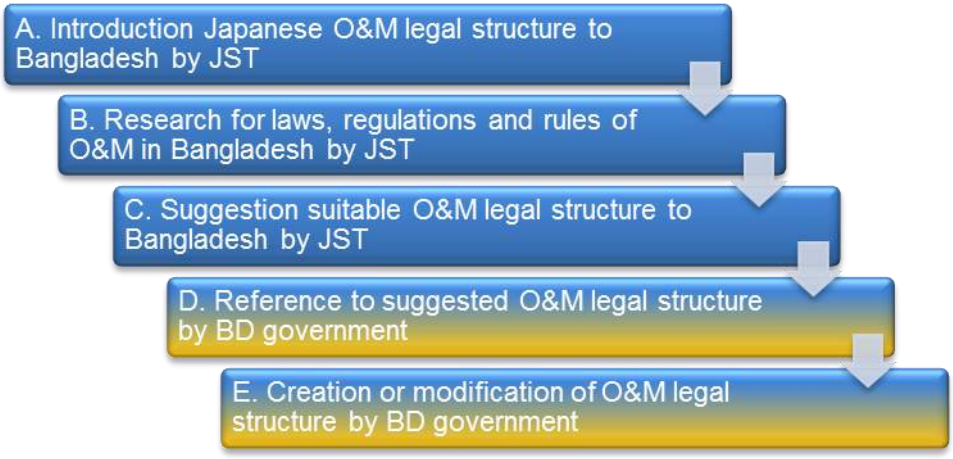


Source: JICA Survey Team

Figure 17-1 Purpose of O&M Legal Framework

17.1.2 Solutions procedure

This solutions procedure is as follows. A, B and C are done by WG, and D and E are done by the Bangladesh government. JST means JICA Survey Team.

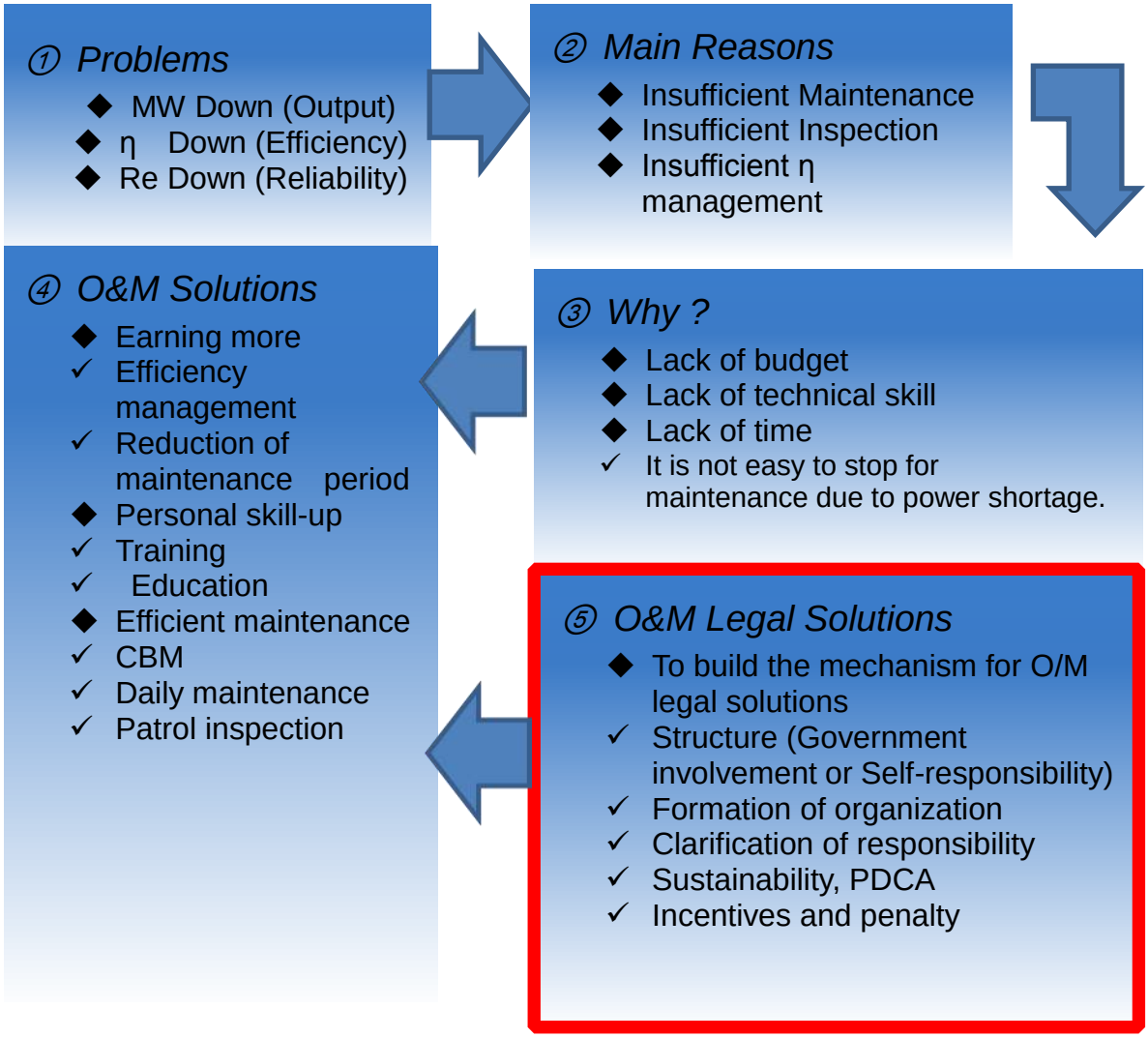


Source: JICA Survey Team

Figure 17-2 O&M Legal Solutions Procedure

17.1.3 Cause and effect diagram

Cause and effect diagram for Bangladesh is as below. The red square is this study's solutions for suitable O&M in Bangladesh.



Source: JICA Survey Team

Figure 17-3 Problems and O&M Legal Solutions

17.1.4 Scheme of O&M legal framework

The O&M Legal Framework contains 2 kinds of schemes. One is concrete measures and the other is philosophical approaches.
There are a lot of measures for stable operation, as per the below figure, and many approaches should be considered by the legal framework.



Source: JICA Survey Team

Figure 17-4 Concrete Measures



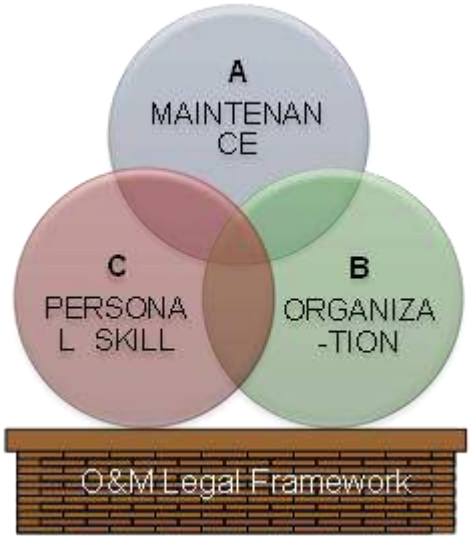
Source: JICA Survey Team

Figure 17-5 Philosophical Approach

17.1.5 Key factors for stable operation

The O&M Legal Framework should support key factors for stable operation.
The key factors for O&M are these three measures:

- MAINTENANCE
- ORGANIZATION
- PERSONAL SKILL



Source: JICA Survey Team

Figure 17-6 Key Factors for O&M



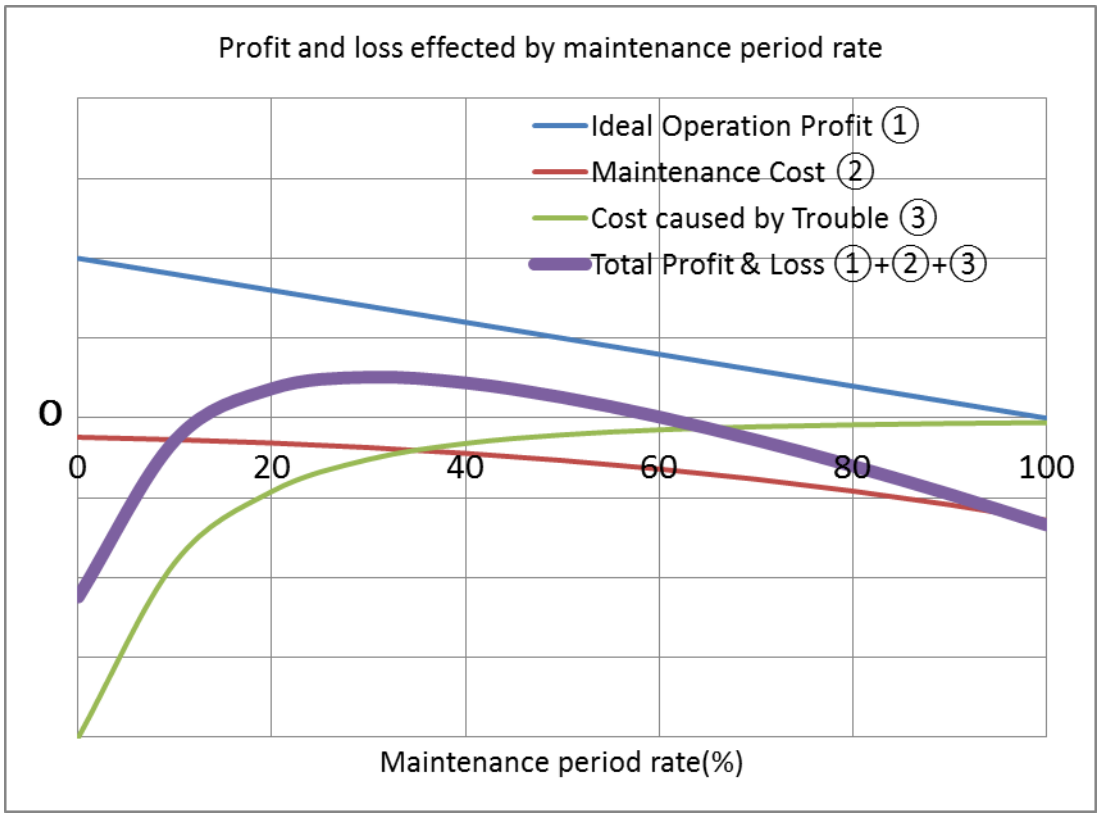
Source: JICA Survey Team

Figure 17-7 Details of Key Factors for O&M

17.1.6 General economic concept of O&M

(1) Maintenance period rate

Suitable maintenance will enable stable operation and stable operation will produce economic benefit. Maintenance Period Rate explains operational benefit easily.
**Maintenance Period Rate (%) = Maintenance days/All days
MPR 0% = No maintenance, Operation always if no trouble
MPR 100% = Maintenance always. NO operation
The following figure shows operational profit/loss against maintenance period rate. It is easy to understand that suitable maintenance produces economic benefit for P/P.



Source: JICA Survey Team

Figure 17-8 Profit and Loss Affected by Maintenance Period Rate

- Too low an MPR produces a big loss
  - Long unplanned stop, with no earnings
  - Huge cost for repair needed
- O&M legal solutions should be built to encourage suitable maintenance opportunities

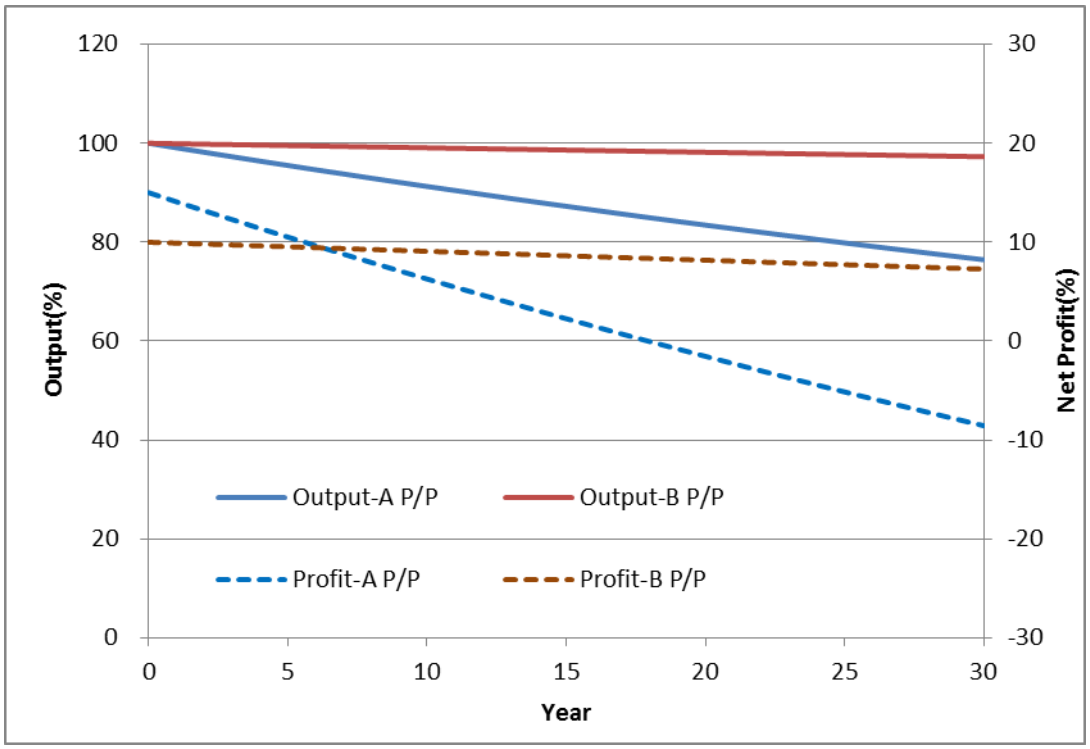
(2) Output and profit

The maintenance/inspection cost is much cheaper than operational gross profit but insufficient maintenance causes output-decrease and efficiency-decrease. The output-decrease and efficiency-decrease influence gross profit directly and cause a huge negative impact.
Two P/P, A and B, are assumed as insufficient maintenance and sufficient maintenance with some conditions. The following figure shows operational profit/loss against operation years. It is easy to understand that suitable maintenance produces economic benefit for P/P.

Table 17-1 Conditions

	A P/P	B P/P
Output(MW)	100% at COD to 77% at 30y	100% at COD to 97% at 30y
Gross Profit①	100% at COD to 77% at 30y	100% at COD to 97% at 30y
Fuel Cost②	70% at COD to 70% at 30y	70% at COD to 70% at 30y
Fixed cost③	10% at COD to 10% at 30y	10% at COD to 10% at 30y
Maintenance Cost④	5% at COD to 5% at 30y	10% at COD to 10% at 30y
Net Profit①-②-③-④	Calculated	Calculated

Source: JICA Survey Team



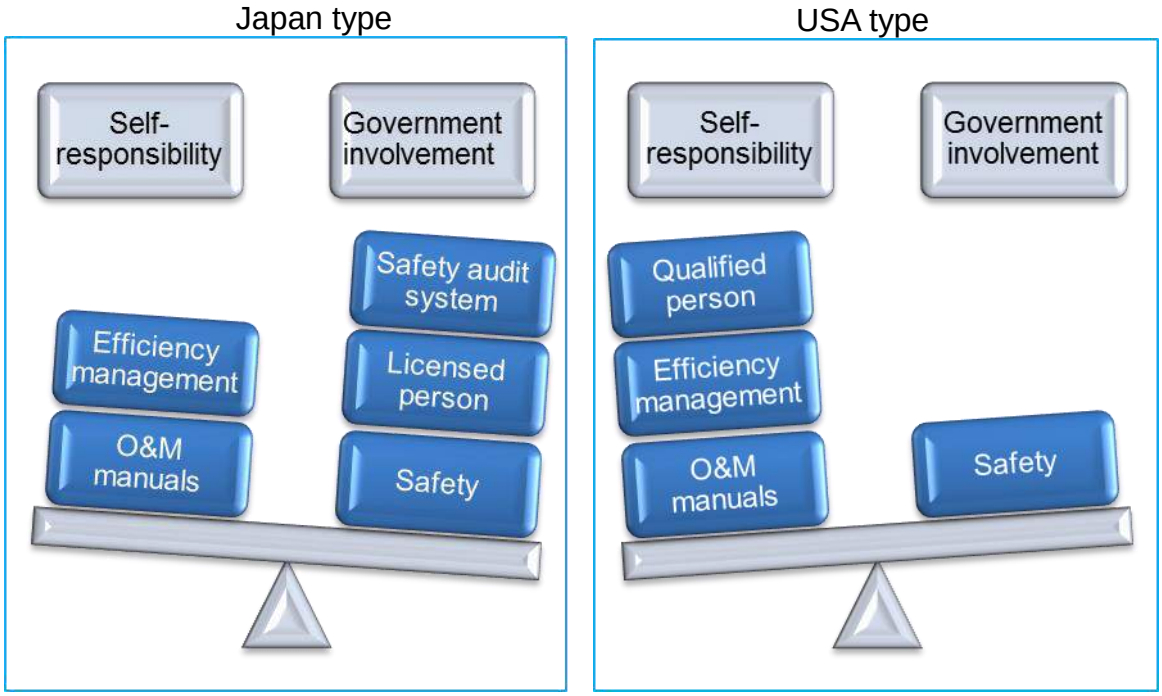
Source: JICA Survey Team

Figure 17-9 Output and Profit

17.2 Japanese O&M Legal Framework

17.2.1 General concept for regulations of O&M

The government should take into consideration how much government involvement is suitable to regulate the power sector. Too much regulation will make private sector vitality decrease and too little regulation will make the private sector uncontrollable. Japan is famous for strict government involvement in the private sector and the trend of current regulation is deregulation, but government involvement still remains.



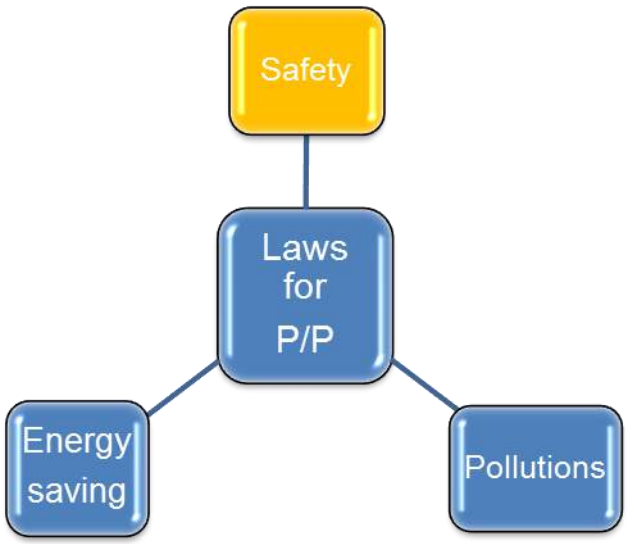
Source: JICA Survey Team

Figure 17-10 Government Involvement or Self-responsibility

17.2.2 Japanese government's main requirements for P/P

The main concepts of the Japanese O&M legal framework are as follows:

- Self-responsibility controlled by government
  - Minimum government involvement
- To meet with government requirements
  - Government regulates
    - Safety (technical standards, etc.)
    - Energy saving
    - Pollutions
  - Government doesn't regulate
    - Output (MW)
    - Efficiency (%)
- To meet with manuals decided by P/P
  - P/P makes manuals and follows the manuals
    - Maintenance manual
    - Patrol inspection manual



Source: JICA Survey Team

Figure 17-11 Legal Framework in Japan

17.2.3 Main regulations for P/P

The regulations for Japanese P/P can be divided three categories such as safety, Energy saving and Pollution. The details of regulations are as follows.

- Safety
  - Electricity Business Act Act No. 170 of July 11, 1964
    The purpose of this Act is to protect the interests of electricity users and achieve the sound development of Electricity Businesses by realizing appropriate and reasonable management of Electricity Businesses, and to assure public safety and promote environmental preservation by regulating the construction, maintenance and operation of Electric Facilities.

  - Electricians Act Act No. 139 of 1960

  - High Pressure Gas Safety Act Act No. 204 of June 7, 1951
    The purpose of this Act is to regulate the production, storage, sale, transportation and other matters related to the handling of high pressure gases, their consumption as well as the manufacture and handling of their containers and to encourage voluntary activities by private businesses and the High Pressure Gas Safety Institute of Japan for the safety of high pressure gases with the aim of securing public safety by preventing accidents and disasters caused by high pressure gases.

  - Electrical Appliances and Materials Safety Act (Tentative translation) Act No. 234 of November 16, 1961
    The purpose of this Act is to regulate the manufacture, sale, etc. of Electrical Appliances and Materials and to foster voluntary activities by private businesses to ensure the safety of Electrical Appliances and Materials, so as to prevent hazards and damages resulting therefrom.

  - Industrial Safety and Health Act Act No. 57 of June 8, 1972
    The purpose of this Act is to secure, in conjunction with the Labor Standards Act (Act No. 49 of 1947), the safety and health of workers in workplaces, as well as to facilitate the establishment of a comfortable working environment, by promoting comprehensive and systematic countermeasures concerning the prevention of industrial accidents, such as taking measures for the establishment of standards for hazard prevention, clarifying the safety and health management responsibility and the promotion of voluntary activities with a view to preventing industrial accidents

  - Act on Ensuring Fair Electric Business Practices Act No. 96 of May 23, 1970

  - Fire Service Act Act No. 186 of July 24, 1948
    The purpose of this Act is to prevent, guard against, and suppress fires in order to protect the lives, bodies and property of citizens from fires, and to reduce the damage arising from fires or disasters such as earthquakes, thereby maintaining peace and order and contributing to the promotion of social and public welfare.
    Chapter III Hazardous Materials
    Hazardous materials of the designated quantity or a larger quantity shall not be stored at facilities other than a storage facility (including a storage facility for storing or handling hazardous materials by means of a tank mounted on a vehicle (hereinafter referred to as a "mobile tank storage facility"); the same shall apply hereinafter), nor shall they be handled at facilities other than a manufacturing facility, storage facility and handling facility; provided, however, that this shall not apply where the designated quantity or a larger quantity of hazardous materials are stored or handled temporarily for not more than ten days with the

approval of the competent fire chief or fire station chief.

- Energy saving
  - Act on the Rational Use of Energy Act No. 49 of June 22, 1979
    The purpose of this Act is, with the aim to contribute to securing the effective utilization of fuel resources according to the economic and social environment concerning energy in and outside Japan, to take the measures required for the rational use of energy with regard to factories, etc., transportation, buildings, and machinery and equipment as well as other necessary measures, etc. for comprehensively promoting the rational use of energy, thereby contributing to the sound development of the national economy.

- Pollution
  - Basic Environment Law Act No. 91 of Nov. 10, 1993
    The purpose of this law is to comprehensively and systematically promote policies for environmental conservation to ensure healthy and cultured living for both the present and future generations of the nation as well as to contribute to the welfare of mankind, through articulating the basic principles, clarifying the responsibilities of the State, local governments, corporations and citizens, and prescribing the basic policy considerations for environmental conservation.

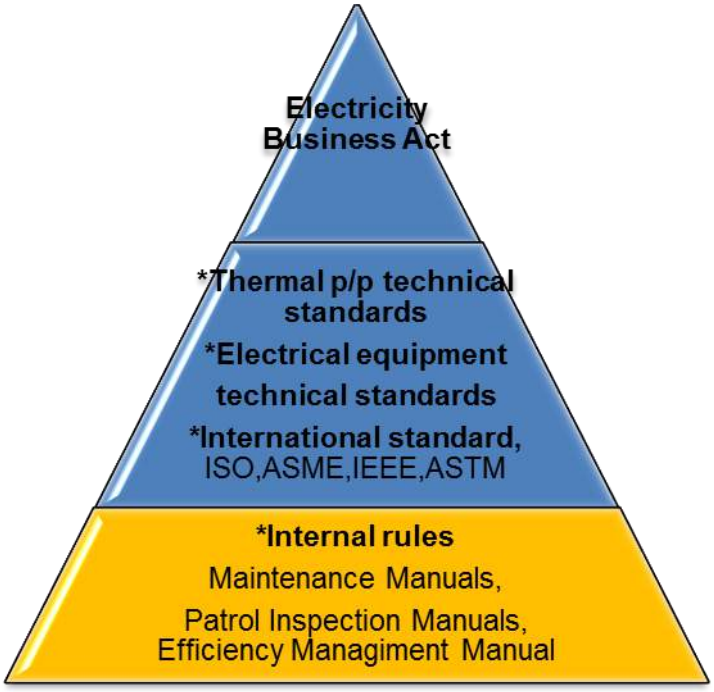
  - Air Pollution Control Act Act No. 97 of June 10, 1968
    The purposes of this Act are to protect the health of citizens and to protect the living environment from air pollution by, among other things, controlling emissions, etc. of Soot and Smoke, Volatile Organic Compounds, and Particulates associated with the business activities of factories and workplaces and with the demolition, etc. of buildings, etc., by promoting the implementation of measures against hazardous air pollutants and by setting maximum permissible limits for automobile exhaust; and to protect victims where air pollution has caused harm to human health by providing for the liability of business operators for damages.

  - Water Pollution Control Act Act No. 138 of 1970
    The purposes of this Act is to prevent the water pollution (including form of deterioration of the condition of water other than the deterioration of water quality; the same applies hereinafter) in the Public Water Areas and in the underground water by regulating effluent discharged by factories and workplaces into the Public Water Areas and infiltration of water through the underground, thereby to protect human health and to preserve the living environment and to protect sufferers by setting forth stipulations regarding the responsibilities of the business operators of factories or workplaces to compensate the damage in cases where human health is damaged by polluted water or waste liquid discharged from factories and workplaces.

  - Noise Regulation Act Act No. 98 of 1968
    The purpose of this Law is to preserve living environment and contribute to protection of the people's health by regulating noise generated by the operation of factories and other types of work sites as well as construction work affecting a considerable area, and by setting maximum permissible levels of motor vehicle noise.

17.2.4 Laws, regulations and rules concerning inspection & maintenance

The Japanese O&M legal framework is like a pyramid, as per the below figure. The blue portion is defined by the government or public organizations and the yellow portion is defined by P/P.
The Electricity Business Act contains two major parts, 1) Business and 2) Safety. The safety laws are the minimum requirement for safety but they are very strict. Therefore, P/P maintains a high quality of operation.
The Japanese government requests that P/P define the safety regulations, which consist of many manuals, by themselves and that P/P should observe the safety regulations.



Source: JICA Survey Team

Figure 17-12 O&M Legal Framework in Japan

The below table shows the individual regulations described in pyramid but the international rules are excluded.

Table 17-2 Safety Rules Related Electricity Business Act

Law	*Electricity Business Act
Cabinet order	*Electricity Business Act Enforcement Order
Ordinance	*Ministerial Ordinance for the Enforcement of the Electricity Business Act Electrical reporting rules
Ministerial ordinance	*Ministerial Ordinance for Establishing Technical Standards for Thermal Power Generation Equipment: *Ministerial Ordinance for Establishing Technical Standards for Electrical Equipment: Ordinance on the qualifications of the chief engineer based on provisions of the Electricity Business Act
Notice	*Interpretation of technical standards for Thermal Power Generation Equipment *Notice defining the details of the technical standards for Thermal Power Generation Equipment *Interpretation of technical standards for Electrical Equipment *Technical elements required to meet the technical standards ordinance based on Electricity Business Act *Q & A relates to chief engineer system *Interpretation of welding inspection in thermal power plant based on the Electricity Business Act Enforcement Regulations etc.

Source: JICA Survey Team

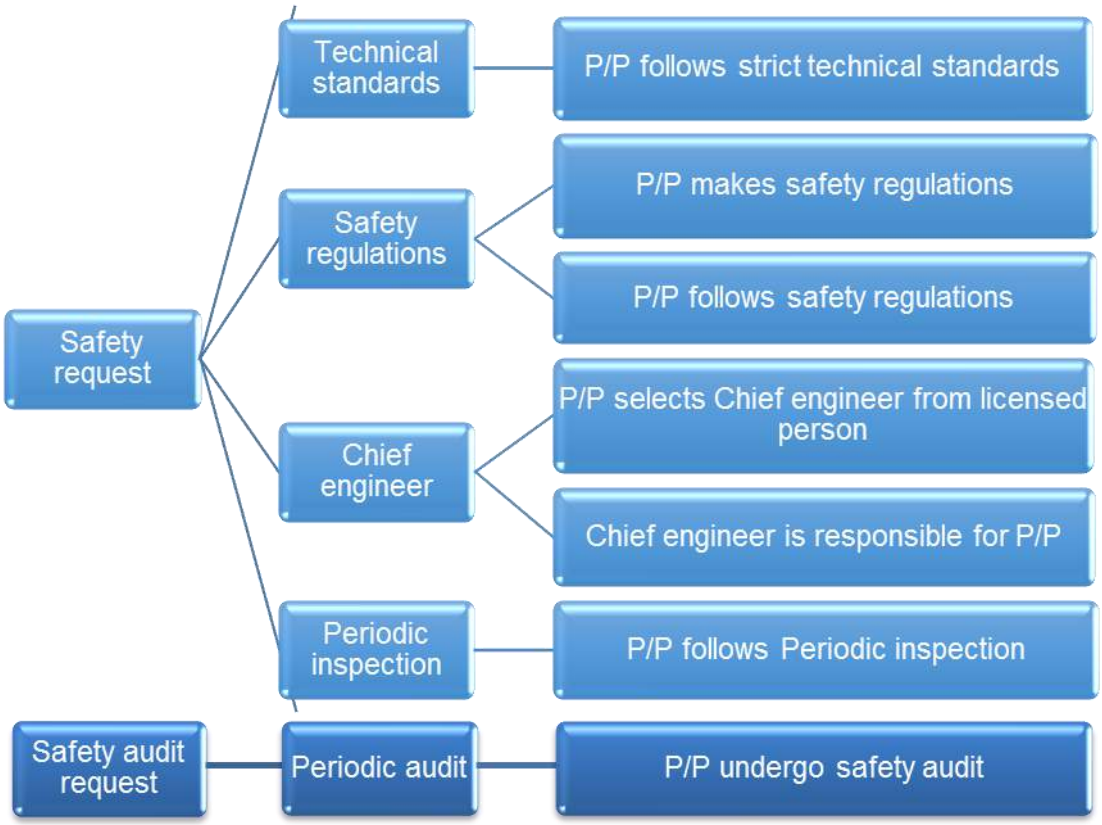
17.2.5 Safety requirements in Electricity Business Act

Safety requirements in the Electricity Business Act number five items, as per the below figures.



Source: JICA Survey Team

Figure 17-13 Government Safety Requirements for P/P (1)



Source: JICA Survey Team

Figure 17-14 Government Safety Requirements for P/P (2)

17.2.6 Details of safety requirements in Electricity Business Act

The actual text regarding safety requirements in the Electricity Business Act is as follows.

- (Technical Standards)

Article 39 (1) A person who installs Electric Facilities shall maintain the Electric Facilities to ensure that they conform to the technical standards established by an Ordinance of the Competent Ministry.

- (Safety Regulations)

Article 42 (1) A person who installs Electric Facilities shall, in order to ensure safety of the construction, maintenance and operation of the Electric Facilities, pursuant to the provision of an Ordinance of the Competent Ministry, establish safety regulations for each organization in charge of the Electric Facilities, the safety of which should be secured uniformly, and notify the Competent Minister of the regulations before the commencement of the use of the Electric Facilities by the organization (in the case of facilities requiring self-inspection set forth in Article 51, paragraph (1) or operator's inspection set forth in Article 52, paragraph (1), before the commencement of the construction of the facilities).

- (Chief Engineer)

Article 43 (1) A person who installs Electric Facilities shall, pursuant to the provision of an Ordinance of the Competent Ministry, appoint one or more chief engineers from among persons who have a chief engineer's license in order to cause him/her to supervise the safety of the construction, maintenance, and operation of the facilities.

- (Periodic Safety Management Inspection)

Article 55 (1) A person who installs Specific Electric Facilities (which means boilers, turbines and other Electric Facilities for electricity generation, which are specified by an Ordinance of the Competent Ministry and have some parts under a pressure higher than that specified under the preceding Article, as well as nuclear reactors for electricity generation and auxiliary equipment thereof, which are specified by an Ordinance of the Competent Ministry; hereinafter the same shall apply) shall, pursuant to the provision of an Ordinance of the Competent Ministry, conduct an operator's inspection of the Specific Electric Facilities at periodic intervals, record the inspection results, and preserve such records.

- (Safety Audit)

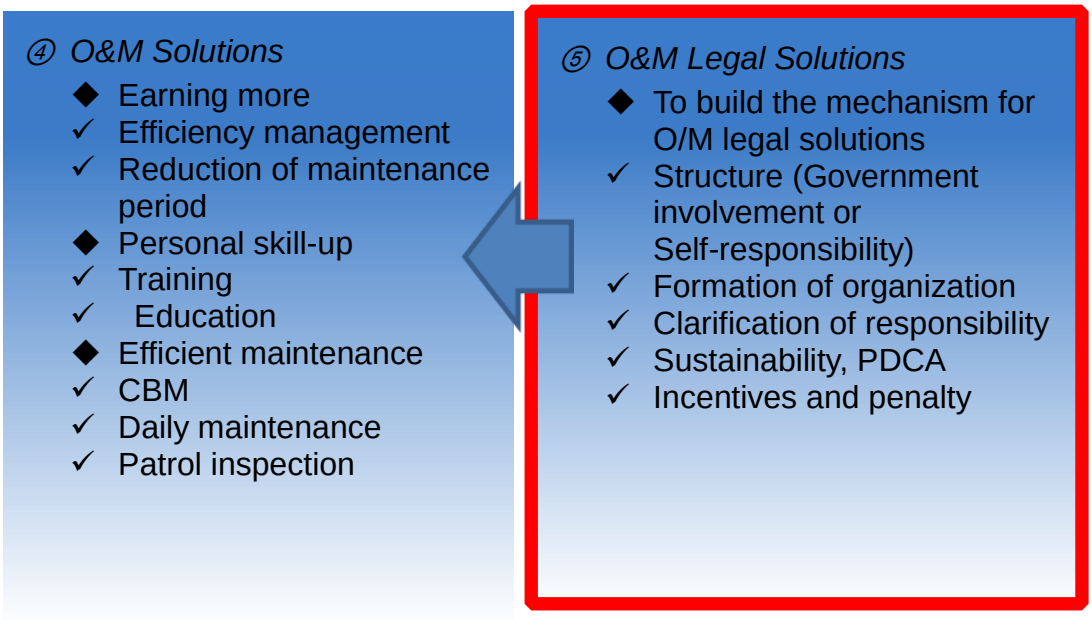
Article 55 (4) A person who installs Specific Electric Facilities subject to a Periodic Operator's Inspection shall, within the period specified by an Ordinance of the Ministry of Economy, Trade and Industry, submit the system for conducting a Periodic Operator's Inspection to undergo examination by the Minister of Economy, Trade and Industry in the case of other persons.

17.2.7 Safety regulations content defined in the Electricity Business Act

The Japanese Electricity Act imposes upon P/P the making of safety regulations, and the content defined by the government is as follows.

① Safety structure
② Duty and organization
③ Duty scope and rights of Chief Engineer
④ Safety education
⑤ Safety PDCA
⑥ Writing, modification and preserving of Documents
⑦ Documents status for safety regulations
⑧ Record
⑨ Patrol, check and inspection
⑩ Operation
⑪ Management for items and service
⑫ Safety for long no-operation
⑬ Measures for Disaster
⑭ Regular improvement for safety regulations
⑮ Important items for safety

Every P/P decides the original safety regulation, submits the safety regulation to the government, and follows the safety regulation.
The above content involves not only O&M legal solutions but also O&M solutions as described in 17.1.3 , as per the below figure; therefore, this safety regulation is a key point of the O&M legal framework in Japan.

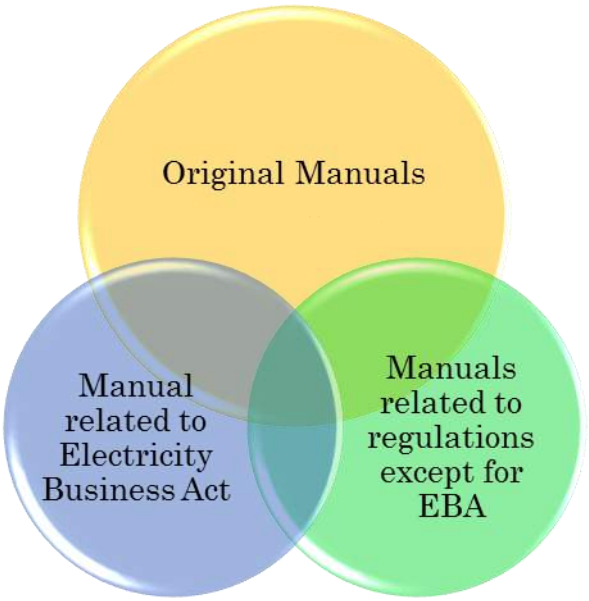


Source: JICA Survey Team

Figure 17-15 Problems and O&M Legal Solutions (excerpt)

17.2.8 Internal rules

Every P/P makes many internal manuals for O&M to achieve stable operation. The internal rules can divided three categories, such as 1) related to Electricy Business Act, 2) related to regulations which is except for Electricy Business Act, and 3) original manuals. Most of internal manuals consist of original manuals in general.



Source: JICA Survey Team

Figure 17-16 Internal Manuals in P/P

Typical original manuals in p/p are as follows.

- Inspection Manuals
  - Boiler
  - Turbine
  - Electrical
  - I&C
    - Interval (1 year, 2 years, 4 years, 8 years)
    - Inspection items

- Daily Patrol Inspection Manual
  - Patrol Route
  - Inspection items
  - Points of check (Vibration, Temperature, Pressure, Level, Noise, etc.)

- Operation Manual
  - Emergency
  - Operation against Trouble manual
    - Boiler
    - Turbine
    - Electrical
    - I&C

- Efficiency Management Manual
  - Method of Efficiency calculation

- ✧ Gas firing P/P
- ✧ Coal firing P/P
- ➢ Management against Efficiency down

- Education and Training Manual
  - ➢ Safety
  - ➢ Operation
    - ✧ Emergency
    - ✧ Continuous monitoring
  - ➢ Maintenance
    - ✧ Boiler
    - ✧ Turbine
    - ✧ Electrical
    - ✧ I&C
  - ➢ Original license system

17.2.9 Licensed and qualified persons in power plant

Japanese has a license system, defined by laws, which makes the quality of work high.

- Power plant
  - ➢ Boiler &Turbine supervisor (Boiler &Turbine chief engineer)
  - ➢ Electrical supervisor (Electrical chief engineer)
  - ➢ Energy saving supervisor (Energy Management Control Officer)
  - ➢ High pressure tank supervisor
  - ➢ Pollution prevention supervisor
  - ➢ Dangerous materials supervisor
  - ➢ etc.
- Subcontractors
  - ➢ Welder
  - ➢ Electrical technician
  - ➢ Scaffolding worker
  - ➢ Slinging worker
  - ➢ etc.

The method of license acquisition depends on each license system, as an example, the following is the Chief Engineering License.

(Chief Engineering License)
Article 44 (1) The types of chief engineering license are as follows.
(i) First-Class Chief Electricity Engineering License;
(ii) Second-Class Chief Electricity Engineering License;
(iii) Third-Class Chief Electricity Engineering License;
(vi) First-Class Chief Boiler/Turbine Engineering License;
(vii) Second-Class Chief Boiler/Turbine Engineering License.
(2) A chief engineering license is granted by the Minister of Economy, Trade and Industry to persons who fall under any of the following:
(i) a person who holds the academic record or qualification and work experience specified by Ordinance of the Ministry of Economy, Trade and Industry for each type of chief engineering license;
(ii) with respect to the types of chief engineering licenses listed in items (i) to (iii) of the preceding paragraph, a person who has passed an examination for a chief electricity engineering license.

17.2.10 Notification and reports system

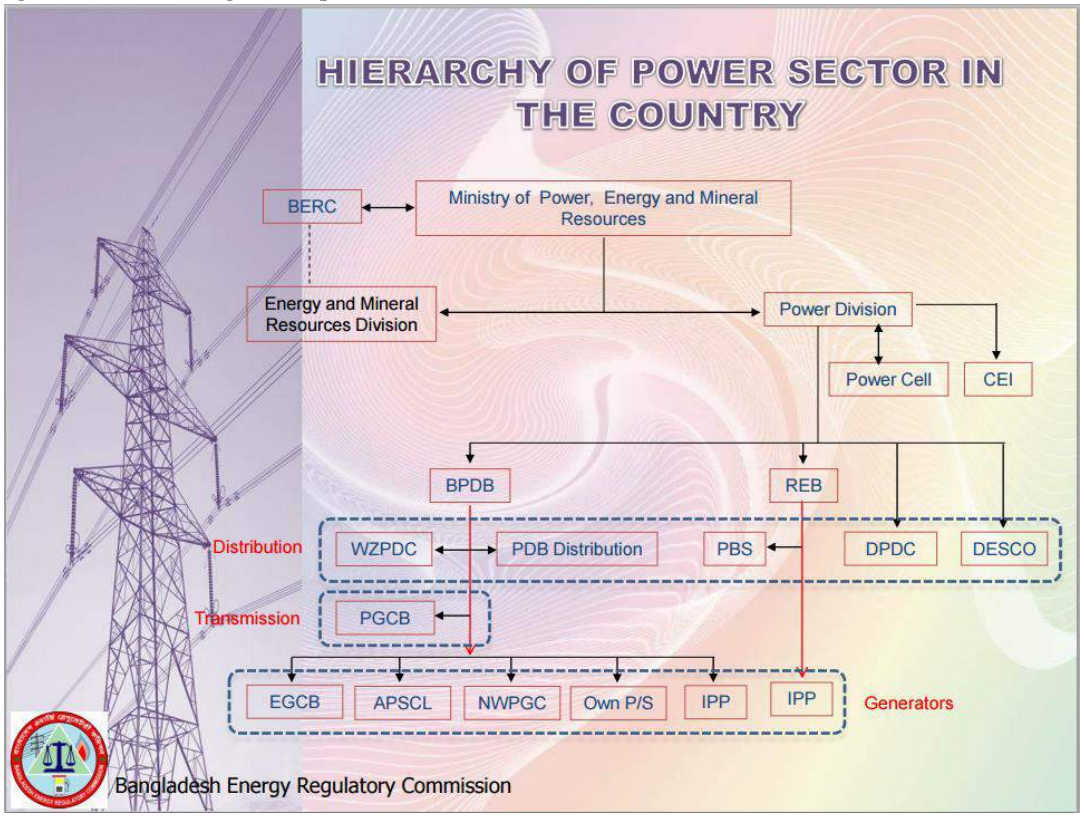
The Japanese Electricity Act has notification and reports system about O&M as below.

- Changes of Electric Facilities, etc.
- Safety Regulations
- Chief Engineer
- Plan of the construction project
- Collection of Reports
  - ➢ Periodic report
  - ➢ Report on accident
    - ✧ Fatal accident
    - ✧ Electrical fire accident
    - ✧ Accident to the public
    - ✧ Disruptive accident
    - ✧ Power supply trouble due to the accident
    - ✧ Secondary accident to the other company
  - ➢ Pollution prevention

17.3 Bangladesh O&M Legal Framework

17.3.1 Hierarchy of power sector

The organization of Bangladesh power sector is as follows.



Source:
http://www.sari-energy.org/PageFiles/What_We_Do/activities/Cross_Border_Energy_Trade_Feb_2013/Presentations/Bangladesh.pdf
Accessed: 9/6/2015

Figure 17-17 Hierarchy of Power Section in Bangladesh

17.3.2 Laws and acts in Bangladesh

There are some laws and acts regarding the power sector in Bangladesh, two of them as Electricity Act 1910 and Bangladesh Energy Regulatory Commission Act, 2003 are most important regulations about O&M in P/P.

17.3.3 Electricity Act 1910

Electricity Act 1910 has been made minor change several times and currently it is carried on making a substantial revision for the first time in 100 years. The significantly revised draft version in Bengali has been published on the internet and that web site is accepted the public opinions.
The enforcement date of the Act is undecided so far and the following is the latest version of the Act.

Table 17-3 Electricity Act 1910

PART I PRELIMINARY
1. Short title, extent and commencement
2. Definitions
PART II SUPPLY OF ENERGY
Licenses
3. Grant of Licenses
4. Revocation or amendment of licenses
5. Provisions where license of licensee, not being a local authority, is revoked
6. Provisions where license of local authority is revoked
7. Purchase of undertaking
8. Provisions where no purchase and license revoked with consent of licensee
9. Licensee not to purchase, or associate himself with other licensed undertakings or transfer his undertakings
10. General power for Government to vary terms of purchase
11. Annual accounts of licensee
Works
12. Provisions as to the opening and breaking up of streets, railways and tramways
13. Notice of new works
14. Alteration of pipes or wires
15. Laying of electric supply-lines or other works near sewers, pipes or other electric supply-lines or works
16. Streets, railways, tramways, sewers, drains or tunnels broken up to be reinstated without delay
17. Notice to telegraph authority
18. Aerial lines
19. Compensation for damage
Supply

19A. Point where supply is delivered

20. Power for licensee to enter premises and to remove fittings or other apparatus of licensee

21. Restrictions on licensee's controlling or interfering with use of energy

22. Obligation on licensee to supply energy

23. Charges for energy to be made without undue preference

24. Discontinuance of supply to consumer neglecting to pay charge

25. Exemption of electric supply-lines or other apparatus from attachment in certain cases

26. Meters

27. Supply of energy outside area of supply

PART III
SUPPLY, TRANSMISSION AND USE OF ENERGY BY NON-LICENSEES

28. Sanction required by non-licensees in certain cases

29. Power for non-licensees to break up streets

29A. Application of section 18 to aerial lines maintained by railways

30. Control of transmission and use of energy

PART IV
GENERAL

Protective Clauses

31. Protection of railways and canals, docks, wharves and piers

32. Protection of telegraphic, telephonic and electric signalling lines

33. Notice of accidents and inquiries

34. Prohibition of connection with earth, and power for Government to interfere in certain cases of default

Administration and Rules

35. Advisory Board

36. Appointment of Electric Inspectors

36A. [Omitted]

37. Power for Board to make rules

38. Further provisions respecting rules

Criminal Offences and Procedure

39. Penalty for dishonest abstraction, etc. of energy

39A. Penalty for installation of artificial means, etc.

40. Penalty for maliciously wasting energy or injuring works

40A. Penalty for the theft of line materials, tower members, equipment, etc., from any electric supply system

40B. Penalty for dishonestly receiving stolen property

41. Penalty for unauthorized supply of energy by non-licensees

42. Penalty for illegal or defective supply or for non-compliance with order

43. Penalty for illegal transmission or use of energy

44. Penalty for interference with meters or licensee's works and for improper use of energy

44A. Penalty for abettors in certain offences

45. Penalty for extinguishing public lamps

46. Penalty for negligently wasting energy or injuring works

47. Penalty for offences not otherwise provided for

48. Penalties not to affect other liabilities

49. Penalties where works belong to Government

49A. Offences by companies

50. Institution of prosecutions

50A. Power of Magistrate to pass sentence, impose fine

Supplementary

51. Exercise in certain cases of powers of telegraph-authority

52. Arbitration

52A. Bar to jurisdiction of Civil Courts

53. Service of notices, orders or documents

54. Recovery of sums recoverable under certain provisions of Act

54A. Charges for supply of energy recoverable as arrears of land revenues

54B. Requisition of police assistance

54C. Bar of Jurisdiction

55. Delegation of certain functions of Government to Electric Inspectors

56. Protection for acts done in good faith

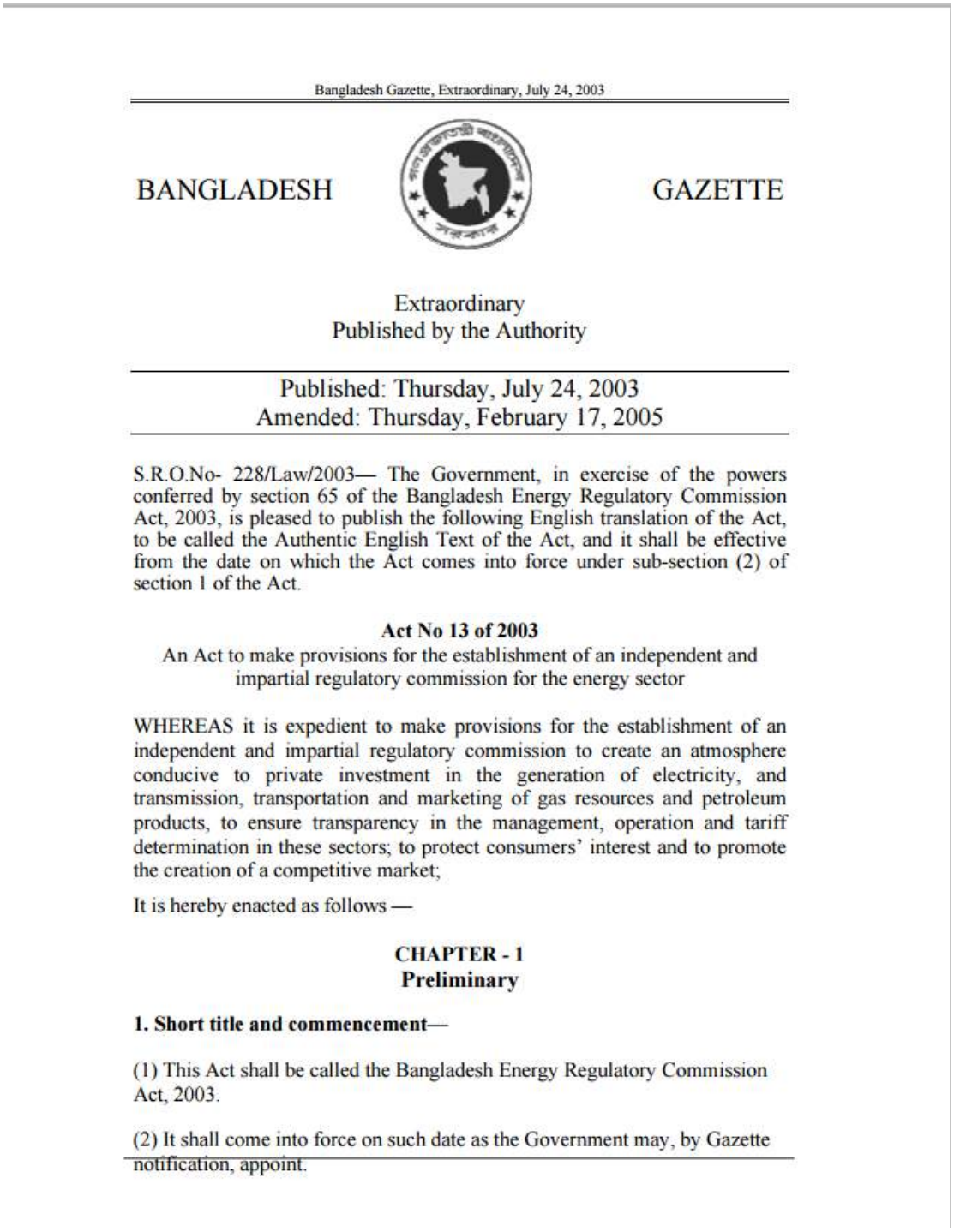
57. [Omitted]

58. [Omitted]

SCHEDULE

Source: http://bdlaws.minlaw.gov.bd/pdf_part.php?id=93
Accessed: 9/6/2015

17.3.4 Bangladesh Energy Regulatory Commission Act 2003



Bangladesh Gazette, Extraordinary, July 24, 2003

BANGLADESH GAZETTE

Extraordinary
Published by the Authority

Published: Thursday, July 24, 2003
Amended: Thursday, February 17, 2005

S.R.O.No- 228/Law/2003— The Government, in exercise of the powers conferred by section 65 of the Bangladesh Energy Regulatory Commission Act, 2003, is pleased to publish the following English translation of the Act, to be called the Authentic English Text of the Act, and it shall be effective from the date on which the Act comes into force under sub-section (2) of section 1 of the Act.

Act No 13 of 2003

An Act to make provisions for the establishment of an independent and impartial regulatory commission for the energy sector

WHEREAS it is expedient to make provisions for the establishment of an independent and impartial regulatory commission to create an atmosphere conducive to private investment in the generation of electricity, and transmission, transportation and marketing of gas resources and petroleum products, to ensure transparency in the management, operation and tariff determination in these sectors; to protect consumers' interest and to promote the creation of a competitive market;

It is hereby enacted as follows —

CHAPTER - 1
Preliminary

1. Short title and commencement—

(1) This Act shall be called the Bangladesh Energy Regulatory Commission Act, 2003.

(2) It shall come into force on such date as the Government may, by Gazette notification, appoint.

Figure 17-18 Bangladesh Energy Regulatory Commission Act 2003 (Front)

Source: http://www.berc.org.bd/images/stories/pdf/law/berc_act_2003_English.pdf
Accessed: 9/6/2015

17.3.5 Bangladesh Energy Regulatory Commission Act, 2003.(excerpt)

- *CHAPTER – 1 Preliminary*
- *CHAPTER – 2 Establishment of the Commission*
- *CHAPTER – 3 Financial matters of the Commission*
- *CHAPTER – 4 Functions, Powers and Proceedings of the Commission*
  - *22. Functions of the Commission—*
    (a) to determine efficiency and standard of the machinery and appliances of the institutions using energy and to ensure through energy audit the verification, monitoring and analysis of the energyand the economy use and enhancement of the efficiency of the use of energy;
    (b) to ensure efficient use, quality services, determine tariff and safety enhancements of electricity generation and transmission marketing, supply, storage and distribution of energy;
    (c) to issue, cancel, amend and determine conditions of licences, exemption of licences and to determine the conditions to be followed by such exempted persons;
    (d) to approve schemes on the basis of overall program of the licencee and to take decision in this regard taking into consideration the load forecast and financial status;
    (e) to collect, review, maintain and publish statistics of energy;
    (f) to frame codes and standards and make enforcement of those compulsory with a view to ensuring quality of service;
    (g) to develop uniform methods of accounting for all licencees;
    (h) to encourage the creation of a congenial atmosphere to promote competition amongst the licencees;
    (i) to extend co-operation and advice to the Government, if necessary, regarding electricity generation, transmission, marketing, supply distribution and storage of energy;
    (j) to resolve disputes between the licencees, and between licencees and consumers, and refer those to arbitration if considered necessary;
    (k) to ensure appropriate remedy for consumer disputes, dishonest business practices or monopoly;
    (l) to ensure control of environmental standards of energy under existing laws; and
    (m)to perform any incidental functions if considered appropriate by the Commission for the fulfillment of the objectives of this Act for electricity generation and energy transmission, marketing, supply, storage, efficient use, quality of services, tariff fixation and safety improvement.
  - *23. Investigation power—*
    (1) Commission shall have all those powers for the purposes of an investigation or proceedings, which are exercised by a Civil Court at the time of trial under the Code of Civil Procedure, such as: –
    (a) to summon a witness and ensure his presence and examination of the witness on oath;
    (b) to detect and present any important document which may be submitted as a document or evidence;
    (c) to collect evidence through an affidavit;
    (d) to call for public record from any court or office;
    (e) to adjourn hearing;
    (f) to ensure presence and absence of the parties; and
    (g) to review the Commission's decisions, directives or orders.
- *CHAPTER – 5 Relationship between the Government and the Commission*
- *CHAPTER – 6 License*
  - *27. Licence—*
  - *28. Issuance of licence by the Commission—*
  - *31. General duties and powers of the licencee.*
    (1) Every licencee shall make arrangement for the efficient, co-ordinated, cost-effective production, transmission and supply of energy.

(2) Every licencee shall maintain international standards and working methods at the time of discharging his duties relating to energy operation, maintenance and safety.

- *CHAPTER – 7 Tariff*
- *CHAPTER – 8 Commission's power to issue order and implement its decision*
- *CHAPTER – 9 Flow of Information*
- *CHAPTER – 10 Arbitration - Settlement and Appeal*
- *CHAPTER – 11 Offence and Penalty*
- *CHAPTER – 12 Receipt of Complaint of Consumer and disposal*
- *CHAPTER – 13 Miscellaneous*
- *CHAPTER – 14 Transitional Provision*

17.4 Comparison between Bangladesh and Japan

Next table shows that comparison between Bangladesh and Japan about main provisions of O&M regulations.

Table 17-4 Comparison between Bangladesh and Japan

	JAPAN	Bangladesh
Business Licenses	*Electricity Business Act* ***(Business Licenses)*** *Article 3 (1) A person who intends to conduct Electricity Business (excluding Specified-Scale Electricity Business; hereinafter the same applies in this Chapter (except for Article 5, item (vii) and Article 17, paragraph (1))) must obtain a license from the Minister of Economy, Trade and Industry.* *(2) The license set forth in the preceding paragraph is granted by business category, for each of General Electricity Business, Wholesale Electricity Business, or Specified Electricity Business respectively.* ***(Application for a License)*** *Article 4 (1) A person who intends to obtain a license under paragraph (1) of the preceding Article must submit a written application to the Minister of Economy, Trade and Industry, stating:* *(i) the name and address of the applicant, as well as the name of the representative if the applicant is a corporation;* *(ii) the service area, the General Electricity Utilities to which electricity is to be supplied or the service points;* *(iii) the following particulars concerning the Electric Facilities to be used for Electricity Business;* *(a) regarding Electric Facilities for the generation of electricity, the site where they are to be installed, the type of motive power, frequency, and output capacity;* *(b) regarding Electric Facilities for the transformation of electricity, the site where they are to be installed, frequency, and output capacity;* *(c) regarding Electric Facilities for the transmission of electricity, the site where they are to be installed, the electric system, installation means, number of circuits, frequency, and voltage;* *(d) regarding Electric Facilities for the distribution of electricity, the electric system,*	*Electricity Act 1910* ***Grant of Licenses*** *3. (1) The Government may, on application made in the prescribed form and on payment of the prescribed fee (if any), grant to any person a license to supply energy in any specified area, and also to lay down or place electric supply-lines for the conveyance and transmission of energy,-* *(a) where the energy to be supplied is to be generated out-side such area from a generating station situated outside such area to the boundary of such area, or* *(b) where energy is to be conveyed or transmitted from any place in such area to any other place therein, across an intervening area not included therein, across such area.* *BERC Act 2003* *CHAPTER – 6* ***Licence*** *27. Licence—* *(1) No person shall engage himself in the following business unless he is empowered by a licence or exempted from having it under this Act or any other Act, such as:-* *(a) power generation;* *(b) energy transmission;* *(c) energy distribution and marketing;* *(d) energy supply; and* *(e) energy storage.* *28. Issuance of licence by the Commission—* *Licence may be issued to any person for the following purposes in a procedure prescribed by the Commission, such as:-* *(a) for power generation;* *(b) for energy transmission;* *(c) for distribution and marketing of*

	JAPAN	Bangladesh
	frequency, and voltage. *(2) The written application set forth in the preceding paragraph must be accompanied by a business plan, estimate of business income and expenditure, and other documents specified by Ordinance of the Ministry of Economy, Trade and Industry.*	*energy;* *(d) for supply of energy; and* *(e) for storage of energy.*

	JAPAN	Bangladesh
Supervision for Safety	*Electricity Business Act* ***(Purpose)*** *Article 1 The purpose of this Act is to protect the interests of electricity users and achieve the sound development of Electricity Businesses by realizing appropriate and reasonable management of Electricity Businesses, and to assure public safety and promote environmental preservation by regulating the construction, maintenance and operation of Electric Facilities.* ***(Order for Improvement of Operational Procedure)*** *Article 30 The Minister of Economy, Trade and Industry may, when a General Electricity Utility or Specified Electricity Utility fails to make the necessary repairs or take other measures immediately to eliminate any stoppage to the electricity supply arising from an accident or he/she finds that the interest of electricity users is adversely affected because the General Electricity Utility's or Specified Electricity Utility's operational procedure for supplying electricity is inappropriate, order the General Electricity Utility or Specified Electricity Utility to improve the operational procedure.*	*Electricity Act 1910* ***Prohibition of connection with earth, and power for Government to interfere in certain cases of default*** *34. (1) No person shall, in the generation, transmission, supply or use of energy, permit any part of his electric supply-lines to be connected with earth except so far as may be prescribed in this behalf or may be specially sanctioned by the Government.* *(2) If at any time it is established to the satisfaction of the Government-* *(a) that any part of an electric supply-line is connected with earth contrary to the provisions of sub-section (1), or* *(b) that any electric supply-lines or other works for the generation, transmission, supply or use of energy are attended with danger to the public safety or to human life or injuriously affect any telegraph-line, or* *(c) that any electric supply-lines or other works are defective so as not to be in accordance with the provisions of this Act or of any rule thereunder,* *the Government may, by order in writing, specify the matter complained of and require the owner or user of such electric supply-lines or other works to remedy it in such manner as shall be specified in the order, and may also in like manner forbid the use of any electric supply-line or works until the order is complied with or for such time as is specified in the order.*

	JAPAN	Bangladesh
On-site Inspections	*Electricity Business Act* ***(On-site Inspections)*** *Article 107 (2) In addition to the on-site inspection prescribed in the preceding paragraph, the Minister of Economy, Trade and Industry may, to the extent necessary for the enforcement of this Act, have officials of the Ministry of Economy, Trade and Industry enter the business office or other office or other workplace of an Electricity Utility, and inspect the status of the services or accounting or the Electric Facilities, books, documents, and any other articles of the Electricity Utility.*	*BERC Act 2013* ***23. Investigation power—*** *(1) Commission shall have all those powers for the purposes of an investigation or proceedings, which are exercised by a Civil Court at the time of trial under the Code of Civil Procedure, such as: –* *(a) to summon a witness and ensure his presence and examination of the witness on oath;* *(b) to detect and present any important document which may be submitted as a document or evidence;* *(c) to collect evidence through an affidavit;* *(d) to call for public record from any court or office;* *(e) to adjourn hearing;* *(f) to ensure presence and absence of the parties; and* *(g) to review the Commission's decisions, directives or orders.*

	JAPAN	Bangladesh
Technical Standards	*Electricity Business Act* ***Conformity with Technical Standards*** *Article 39 (1) A person equipped with Electric Facilities for Business Use must maintain the Electric Facilities for Business Use to ensure that they conform to the technical standards established by Ordinance of the Competent Ministry.* *(2) The Ordinance of the Competent Ministry set forth in the preceding paragraph must be formulated in accordance with the following:* *(i) Electric Facilities for Business Use do not cause bodily harm nor cause damage to objects;* *(ii) Electric Facilities for Business Use do not cause electric nor magnetic interference*	***There is no technical standard established by government agencies.*** *Bangladesh Gazette, Extraordinary, July 24, 2003* ***31. General duties and powers of the licensee. –*** *(2)Every licensee shall maintain international standards and working methods at the time of discharging his duties relating to energy operation, maintenance and safety.*

	JAPAN	Bangladesh
	with the functioning of other electric equipment or objects; *(iii) damage to Electric Facilities for Business Use does not significantly hinder the supply of electricity by a General Electric Utility;* *(iv) if Electric Facilities for Business Use are used for General Electricity Business, damage to the Electric Facilities for Business Use does not significantly hinder the supply of electricity pertaining to General Electricity Business.* ***Order for Conformity with Technical Standards*** *Article 40 The competent minister may, when finding that Electric Facilities for Business Use do not conform to the technical standards established by Ordinance of the Competent Ministry under paragraph (1) of the preceding Article, order the person equipped with the Electric Facilities for Business Use to repair or alter the Electric Facilities for Business Use to ensure conformity to the technical standards, or order the person to relocate the facilities or suspend the use of them, or restrict the person from using the facilities.*	

	JAPAN	Bangladesh
Safety Regulations	*Electricity Business Act* ***Independent Safety Measures*** *(Safety Regulations)* *Article 42 (1) A person equipped with Electric Facilities for Business Use must, in order to ensure safety of the construction, maintenance and operation of the Electric Facilities for Business Use, pursuant to the provisions of Ordinance of the Competent Ministry, establish safety regulations for each organization in charge of the Electric Facilities for Business Use, the safety of*	***There is no safety regulation.***

	which should be secured uniformly, and notify the competent minister of the regulations before commencement of the use of the Electric Facilities for Business Use by the organization (in the case of facilities requiring self-inspection set forth in Article 51, paragraph (1) or operator's inspection set forth in Article 52, paragraph (1), before the commencement of the construction of the facilities). *(2) A person equipped with Electric Facilities for Business Use must, when having revised the safety regulations, notify the competent minister of the revised particulars without delay.* *(3) The competent minister may, when finding it necessary in order to ensure safety of the construction, maintenance, and operation of Electric Facilities for Business Use, order the person equipped with the Electric Facilities for Business Use to revise the safety regulations.* *(4) A person equipped with Electric Facilities for Business Use and employees thereof must observe the safety regulations.*	

	JAPAN	Bangladesh
Chief Engineer	*Electricity Business Act* ***Independent Safety Measures*** ***(Chief Engineer)*** *Article 43 (1) A person equipped with Electric Facilities for Business Use must, pursuant to the provisions of Ordinance of the Competent Ministry, appoint one or more chief engineers from among persons who have a chief engineering license in order to have said chief engineer supervise the safety of the construction, maintenance, and operation of the*	***There is no obligation to appoint chief engineers.***

	JAPAN	Bangladesh
	facilities. *(2) Notwithstanding the provisions of the preceding paragraph, a person equipped with Electric Facilities for Private Use may, when permitted by the competent minister, appoint a person who does not have a chief engineering license as a chief engineer.* *(3) A person equipped with Electric Facilities for Business Use must, when having appointed a chief engineer (excluding, however, cases of an appointment permitted under the preceding paragraph), notify the competent minister to that effect without delay. The same applies when such person has dismissed the chief engineer.* *(4) The chief engineer must perform the duty of supervising the safety of the construction, maintenance, and operation of Electric Facilities for Business Use in good faith.* *(5) People who are engaged in the construction, maintenance or operation of Electric Facilities for Business Use must follow the instructions given by the chief engineer to ensure the safety thereof.*	

	JAPAN	Bangladesh
Chief Engineering License	*Electricity Business Act* ***Independent Safety Measures*** ***(Chief Engineering License)*** *Article 44 (1) The types of chief engineering license are as follows.* *(i) First-Class Chief Electricity Engineering License;* *(ii) Second-Class Chief Electricity*	***There is no chief engineering license system.***

	JAPAN	Bangladesh
	Engineering License; *(iii) Third-Class Chief Electricity Engineering License;* *(iv) First-Class Chief Dam/Waterway Engineering License;* *(v) Second-Class Chief Dam/Waterway Engineering License;* *(vi) First-Class Chief Boiler/Turbine Engineering License;* *(vii) Second-Class Chief Boiler/Turbine Engineering License.* *(2) A chief engineering license is granted by the Minister of Economy, Trade and Industry to persons who fall under any of the following:* *(i) a person who holds the academic record or qualification and work experience specified by Ordinance of the Ministry of Economy, Trade and Industry for each type of chief engineering license;* *(ii) with respect to the types of chief engineering licenses listed in items (i) to (iii) of the preceding paragraph, a person who has passed an examination for a chief electricity engineering license.* *(3) The Minister of Economy, Trade and Industry may choose not to grant a chief engineering license to persons who fall under any of the following:* *(i) a person who was ordered to return their chief engineering license pursuant to the following paragraph, before the elapsing of a period of one year since the person was thus ordered;* *(ii) a person who was sentenced to a fine or more severe punishment for violation of this Act or any order issued under this Act, before the elapsing of a period of two years since the person served out the sentence or ceased to be subject to the sentence.* *(4) If a person who has a chief engineering license has violated this Act or any order issued under this Act, the Minister of Economy, Trade and Industry may order that person to return their chief*	

	JAPAN	Bangladesh
	engineering license. *(5) The scope of the construction, maintenance and operation of the Electric Facilities for Business Use for which a person who has a chief engineering license is in charge of safety supervision as well as the procedural particulars concerning the grant of a chief engineering license are specified by Ordinance of the Ministry of Economy, Trade and Industry.*	

	JAPAN	Bangladesh
Periodic inspection	*Electricity Business Act* ***(Periodic Safety Management Inspections)*** *Article 55 (1) A person equipped with Specific Electric Facilities (which means boilers, turbines and other Electric Facilities for electricity generation, which are specified by Ordinance of the Competent Ministry and have some parts exposed to pressures higher than those specified under the preceding Article, as well as nuclear reactors for electricity generation and auxiliary equipment thereof, which are specified by Ordinance of the Competent Ministry; hereinafter the same applies) must, pursuant to the provisions of Ordinance of the Competent Ministry, conduct an operator's inspection of the Specific Electric Facilities at periodic intervals, record the inspection results, and keep such records on file.* *(2) In the inspection set forth in the preceding paragraph (hereinafter referred to as a "Periodic Operator's Inspection"), it is necessary to confirm that the Specific Electric Facilities conform to the technical standards established by Ordinance of the Competent Ministry under Article 39, paragraph (1).*	***There is no obligation of Periodic Inspection***.

	JAPAN	Bangladesh
Safety audit	*Electricity Business Act* *Article 55 (4) A person equipped with*	***There is no safety audit system***

	Specific Electric Facilities subject to a Periodic Operator's Inspection must, within the period specified by Ordinance of the Competent Ministry (if notification has been given under Article 51, paragraph (7) as applied mutatis mutandis pursuant to paragraph (6), the period specified by Ordinance of the Competent Ministry depending on the past evaluation of the Periodic Operator's Inspection to which the notification pertained), submit the system for conducting a Periodic Operator's Inspection to undergo examination by a person registered by the Minister of Economy, Trade and Industry if that person installs Specific Electric Facilities other than Specific Electric Facilities for electricity generation by means of nuclear power, which are specified by Ordinance of the Ministry of Economy, Trade and Industry, or examination by the Minister of Economy, Trade and Industry in the case of other persons. *(5) The examination set forth in the preceding paragraph is conducted, in accordance with the principle of ensuring safety management for Specific Electric Facilities, with respect to the organization in charge of a Periodic Operator's Inspection, inspection means, process control, and other particulars specified by Ordinance of the Competent Ministry.*	

Source: JICA Survey Team

17.5 Suggestions

The JICA Survey Team suggests that the Bangladesh government take into consideration the following items in their regulations.

17.5.1 Review of research

This chapter consists from physical matters to philosophical matters, it is not easy to understand the flow of research method. Therefore the research items are reviewed again as follows.

- Introduction
  - Purpose of this study
  - Solutions procedure
  - Cause and effect diagram
  - Scheme of O&M legal framework
  - Key factors for stable operation

- General economic concept of O&M

- Japanese O&M Legal Framework
  - General concept for regulations of O&M
  - Japanese government's main requirements for P/P
  - Main regulations for P/P
  - Laws, regulations and rules concerning inspection & maintenance
  - Safety requirements in Electricity Business Act
  - Details of safety requirements in Electricity Business Act
  - Safety regulations content defined in the Electricity Business Act
  - Internal rules
  - Licensed and qualified persons in power plant
  - Notification and reports system

- Bangladesh O&M Legal Framework
  - Hierarchy of power sector
  - Laws and Acts in Bangladesh
  - Electricity Act 1910
  - Bangladesh Energy Regulatory Commission Act 2003

- Comparison between Bangladesh and Japan

17.5.2 Suggested O&M legal items

Based on the survey results of O&M Legal Framework, we found five important provisions in the Electricity Business Act of Japan were not institutionalized in Bangladesh, and we believe that these five provisions will contribute to the stable operation of the power plant in Bangladesh.

- Periodic inspection
  - Purpose
    - To avoid postponement of the inspection due to budget shortage or tight electricity demand, etc. by securing periodic inspection.
    - To prevent serious accidents by conducting the periodic inspection.
  - Action
    - Authorities decide the intervals and inspection items of periodic inspection.
    - Generators have to conduct the periodic inspection.

- Safety audit
  - Purpose
    - To audit whether periodic inspections are implemented properly or not.
    - If there is a defect in the periodic inspection, auditors instruct to correct it.
  - Action
    - Authorities decide items of safety audit
    - Generators receive priodically safety audit by authority periodically

- Chief engineer
  - Purpose
    - To clarify the responsibility of the technical matters
    - To carry out the technical management under chief engineer
  - Action
    - Authorities order generators to stipulate the responsibility of chief engineer
    - Generators select chief engineer among licensed person

- Safety regulations
  - Purpose
    - ✧ To establish self-management system by making safety regulations
    - ✧ To establish PDCA cycle of operation independently
  - Action
    - ✧ Authorities order generators to set up safety regulations
    - ✧ Generators follow their safety regulations

- Technical standards
  - Purpose
    - ✧ To prevent from accidents and disasters caused by technical issues
    - ✧ To reduce the forced maintenance works
  - Action
    - ✧ Authorities make national technical standards
    - ✧ Generators follows the national technical standards

17.5.3 Recommended schedule of regulations

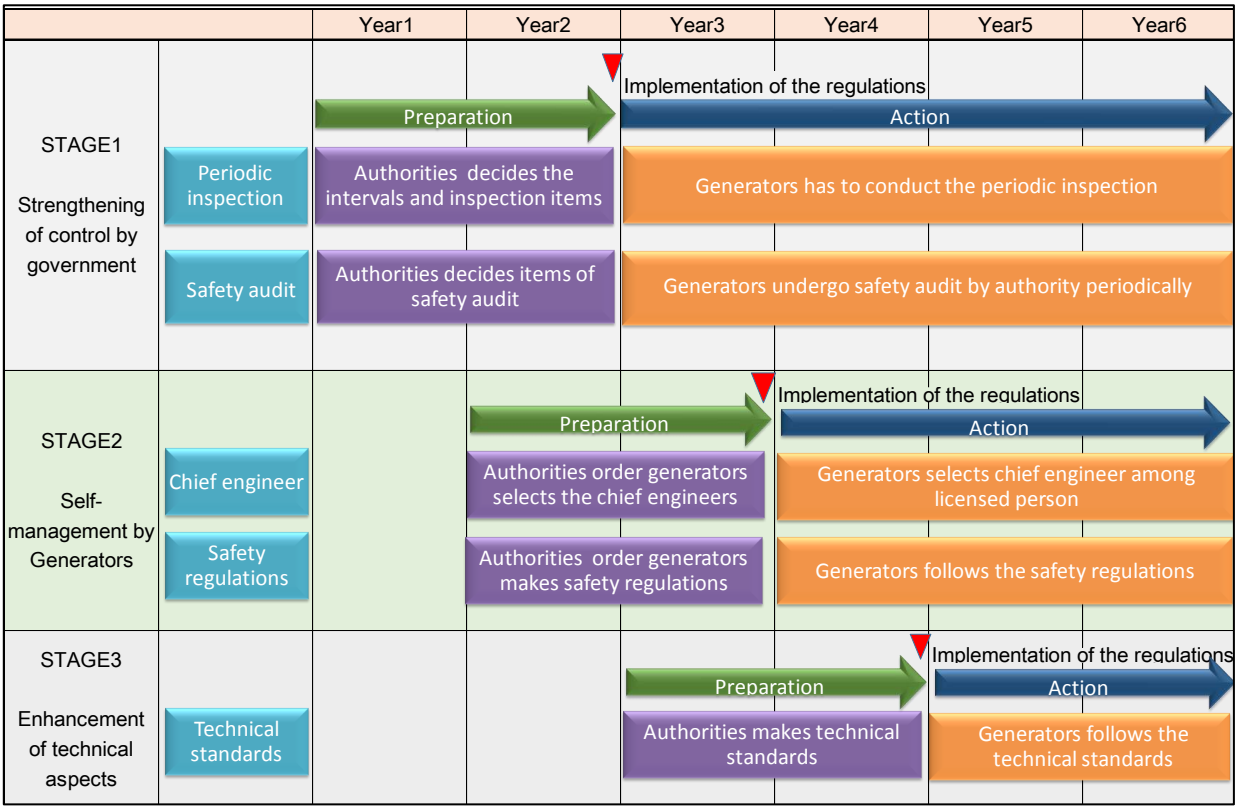
Suggested O&M legal items mentioned above can be divided into three classes as mentioned below, and these classes are recommended to achieve step by step.

1) Strengthening of control by government
   - ✓ Periodic inspection
   - ✓ Safety audit

2) Self-management by Generators
   - ✓ Chief engineer
   - ✓ Safety regulations

3) Enhancement of technical aspects
   - ✓ Technical standards

When the preparation time until implementation of regulation is set to 2 years and start time of every class has 1 year difference, the schedule becomes as follows. Because this recommended schedule is just a sample, Bangladesh government is expected to set up a reasonable schedule for the authorities and generators in consideration of power sector's situation.



Source: JICA Survey Team

Figure 17-19 Recommended Schedule

Chapter 18 Thermal Power Operations and Maintenance

18.1 Outline

The JICA team carried out a survey on the current status of Operation and Maintenance at the power facilities in Bangladesh. The findings were sorted out from the viewpoints of organizational resources such as human capital, facility, finance, and information. Our proposals include solutions for each of the organizational challenges.
Rehabilitation and conversion to combined cycle are proposed as countermeasures against facility deterioration. Implementation of information management is advised for a best practice of O&M contributing to maintenance and budget planning. In human development, new training facilities with practical training programs are suggested.

18.2 Basic Survey for Bangladesh Thermal Power

18.2.1 Equipment

The existing power stations and those planned for construction are as follows.

Data source : PGCB Daily Gen, Petro Bangla Daily, Summit power, GTCL Daily, TGTDCL, PGCL, BCMCL, BPDB AR 11-12, Project list 2014

Serial Number of PGCB	Plant name	Configuration	Original installed capacity (MW)	Derated capacity as 2015/01 (MW)	Generation Capacity 2012-2013 (MW)	Sector	Producer (Source: PGCB)	Commercial Operation Date
1a	Ghorasal Power Station ST-1	55 MW ST; Unit-1	55	85	48	Public	BPDB	1974
1a	Ghorasal Power Station ST-2	55 MW ST; Unit-2	55		39	Public	BPDB	1976
1b	Ghorasal Power Station ST-3	210 MW ST; Unit-3	210	170	180	Public	BPDB	1986/9/14
contracted	ST-3 repowering plan	add 206MW GT				Public	BPDB	2017/Feb
1c	Ghorasal Power Station ST-4	210 MW ST; Unit-4	210	180	180	Public	BPDB	1989/3/18
1d	Ghorasal Power Station ST-5	210 MW ST Unit-5	210	190	190	Public	BPDB	1994/9/15
1e	Ghorasal Power Station ST-6	210 MW ST ; Unit-6	210	190	190	Public	BPDB	1999/1/31
under evaluation	ST-6 repowering plan	add 304MW GT						2017/May
2	Ghorashal 100 MW QRPP (Aggreko)	12x0.85MW	100	100	100	Private	QRPP 3yrs, Aggreko	2010/8/23
3	Ghorashal 45 MW QRPP (Aggreko)	50x0.85	45	45	45	Private	QRPP 3yrs, Aggreko	2010/8/19
4	Ghorashal MAX Power 78MW	4x15.0MW	78	78	78	Private	RPP, Max power	2011/5/27
5	Ghorasal(Regent) 108MW	108MW (34*3.35MW)	108	108				
6	Haripur GT-1	BPDB 33MW / PGCB 32 MW	32	60	20	Public	SBU, BPDB	1987
6	Haripur GT-2	BPDB 33MW / PGCB 32 MW	32		20	Public	SBU, BPDB	1987
6	Haripur GT-3	BPDB 33MW / PGCB 32 MW	32		20	Public	SBU, BPDB	1987
7	Haripur 412MW CCPP	412MW (3on1)	412	412		Private	IPP	2014/March7
8	Haripur NEPC (HFO) 110MW	110MW (8x15MW)	110	110	85	Private	IPP	1999
9	Haripur Power CCPP 360MW , AES	360MW (GT+255MW+ST+125MW)	360	360	360	Private	IPP	2001/5/23
10	Meghnaghat CCPP , AES	450MW (GT+150MW*2+ST+150MW)	450	450	450	Private	IPP	2002/11/26
11	Meghnaghat/Meghnagat IEL (100MW)	100MW CRPP (5 Yrs) IEL , 12x8.6MW	100	100	100	Private	IEL	2011/5/8
12(new)	Meghnaghat CCPP(Summit power) 208MW	205MW (2*100MW) , SC GT	205	205		Private		
under construction	Meghnaghat 300-450 MW CCPP Unit-2 (315MW)	(ST:115MW to be 012) : GT:203MW				Private	N/A	2014
13	Madanganj/Madanganj (Summit) 102MW	102MW (6x17.0MW)	102	100	100	Private	QRPP 3yrs, Summit power	2011/4/1
14	Keranigenj (Powerpac) 100MW QRPP	100 MW (8x14.4MW)	100	100	100	Private	RPP 5years, Power pack	2012/5/27
15	Narshingdi/Narsindi (REB Doreen)	22MW (8x2.5MW)	22	22	22	Private	SIPP, REB, Doreen Generation and systems	2008/12/21
16a	Siddhirganj Power Station (ST) 210MW	210 MW Steam Turbine	210	150	150	Public	BPDB	2004/9/1
16b	Siddhirganj Power Station (GT-1 & GT2) 210MW	BPDB 2* 120MW / PGB 210MW (2x105 MW) C/T	210	210	210	Public	BPDB	#1:2011/12/1, #2:2012/2/5
17	Siddhirganj (Desh) 96MW QRPP	96MW (96x1.2MW)	100	98	96	Private	QRPP 3yrs, Desh energy	2011/2/17
18	Siddhirganj / Siddhorganj (Dutch-Bangla) 100 MW	100MW (12x8.3MW)	100	100	100	Private	RPP 5rrsoon Dutch Bangla power	2011/7/21
19	Pagla (DPA Power QRPP) 50MW	50MW (100x0.5MW) DPA Power	50	50	50	Private	QRPP 3yrs	2010/11/24
20	Gangnagar , (Narayanganj) 100MW PP (Orion)	102MW	102	102		Private	IPP	2014/6/2
21	Summit Power Ltd (Dhaka) (disaggregated follows)	6*8.67MW+2*6.97MW*18*8.73MW	146	146	146	Private	SIPP, REB	2006/12/16
retired	Madhabdi 35 MW REB	N/A	N/A	N/A	N/A	Private	REB, Summit power	
retired	Ashulia 45 MW REB	N/A	N/A	N/A	N/A	Private	REB, Summit power	
retired	Maona 33 MW SIPP	N/A	N/A	N/A	N/A	Private	REB, Summit power	2009
retired	Rupganj 33 MW SIPP	N/A	N/A	N/A	N/A	Private	REB, Summit power	2009/6/9
22	Gazipur 50MW (RPCL)	52MW (8*8.9MW)	52	52	52	Public	IPP, RPCL	2012/7/1
23	Tongi Power Station (105MW)	105MW Gas Turbine	105	105	105	Public	BPDB	2005/5/18
Dhaka area								
24a	Raujan,Chittagong Power Station ST: Unit-1, 210MW	210 MW S/T	210	180	180	Public	BPDB	1993/5/28
24b	Raujan,Chittagong Power Station ST: Unit-2, 210MW	210 MW S/T	210	180	180	Public	BPDB	1997/5/21
25	Raozan/ Raujan 25 MW PP (RPCL)		25	25	25	Public	RPCL	2013/5/3
26(COD)	Baraka-Patanga/Patenge 50MW(Barekefulla)		50	50		Private	IPP	
27(on test)	Chittagong Energy pack		no data			Private	IPP	
28	Karnafuli Hydro Power Station	40MW; Unit-1	40	240	30	Public	BPDB	1962
28	Karnafuli Hydro Power Station	40MW; Unit-2	40		40	Public	BPDB	1962
28	Karnafuli Hydro Power Station	50MW; Unit-3	50		50	Public	BPDB	1982
28	Karnafuli Hydro Power Station	50 MW; Unit-4	50		50	Public	BPDB	1988
28	Karnafuli Hydro Power Station	50 MW; Unit-5	50		50	Public	BPDB	1988
29a	Chittagong Sikalbaha ST (60MW)	60MW	60	40	40	Public	BPDB	1984
29b	Sikalbaha Peaking GT (150MW)	150MW	150	150	150	Public	BPDB	2010/8/18
30	Sikalbaha (Energis)	35MW	no data	35		Private	RPP	
retired?	Shikalbaha RPP 55MW	55 MW (4x12.5MW+2x11.9MW+1x3MW)	55		53	Private	RPP 3yrs	2010/6/5
31	Hathazari 100MW peaking PP	100MW (11x8.9MW) Peaking PP	98	98	100	Public	BPDB	2011/12/23
32	Sangu, Dohazari-Kalaish 100MW peaking	102MW (6x17MW)	102	102	100	Public	BPDB	2011/12/30 or 2012/1/1
33	Julda(Julda (Acorn) 100MW(8*13.45MW)	100MW (8x13.45MW)	100	100	100	Private	RPP 5years, Acorn Infra,Service	2012/5/26
34	Barabkunda/Berobkundo SIPP 22MW	22MW (8x2.9MW)	22	22	22	Private	SIPP, PDB	2009/5/23
35	Molancha, Ctg EPZ (United) 36MW	36MW (5*8.73MW+3*5.54MW ?)	36		30	Private		
Chittagong area								
36a	Ashugonj Power Station Unit-1,-2 , 64MW*2	128MW (64MW*2)	128	97	55	Public	APSCL	1970
36b	Ashugonj Power Station Unit-3, 150MW	150MW ST	150	135	140	Public	APSCL	1986
36c	Ashugonj Power Station Unit-4, 150MW	150MW ST	150	129	150	Public	APSCL	1987
36d	Ashugonj Power Station Unit-5, 150MW	150MW ST	150	134	140	Public	APSCL	1988
36e	Ashugonj GT-2 (56MW)	56MW	56	40	40	Public	APSCL	1986
36f	Ashuganj/ashugonj Engines 50MW	54MW (18x3.0MW)	54	85	53	Public	APSCL	2011/4/30
37	Ashugonj RPP (Precision) 55MW	55MW (11x5MW)	55	55	55	Private	RPP 5yrs	2010/7/3
38	Ashuganj Aggekko 99MW	99MW (99x1.1MW) ←増出力(80MW:82*1.1MW)	99	99	80	Private	RPP 5years, Aggreko	2011/5/31 ?
39	Ashuganj United Power 53MW (14*4MW)	53MW (14x4MW)	53	53	53	Private	RPP 3years, United Ashuganj power	2011/6/23
40	Ashuganj (Midland) 51MW	51MW (6*9.34MW)	51	51		Private		2011/12/6
41	Brahmanbaria (Aggreko) 85MW	85MW (86*1.1MW) ←増出力(70MW:72*1.1M)	85	85	70	Private	QRPP 5yrs, Aggreko	2011/6/30 ?
42	Titas Daudkandi/Doudkandi 50MW peakingPP	52MW (6x8.92MW)	52	52	52	Public	BPDB	2011/10/29
43	Chandpur CCPP 150MW	163MW (GT:106MW, ST:57MW)	163	163	163	Public	BPDB	2012/GT mar/ST:2012/7/1
44	Feni (Doreen) 22MW	22MW (8X 2.94MW) , Feni	22	22	22	Private	SIPP, BPDB	2009/2/16
45	Feni Mohipal (Doreen) 11MW	11MW (4*2.9MW)	11	11	11	Private	SIPP, REB, Doreen Generation and systems	2009/4/22
46	Jangalia, Summit, 33MW(4*8.73MW)	33 MW (4x8.73MW)	33	33	33	Private	SIPP, BPDB, Summit power	2009/5/12
47(new)	Lakdhanvi-52MW	52MW	52	52		Private	IPP	
48	Summit power, Comilla 25MW	26MW (3*3.67MW+2*6.97MW)	25	25	25	Private	SIPP, REB	
Comilla area								

Serial Number of PGCB	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity 2012-2013 (MW)	Sector	Producer (Source: PGCB)	Commercial Operation Date
49	RPCL CCPP (Mymensingh CCPP) 210MW	210MW (4*35MW+70MW)	210	202	197	Private	IPP	1999/11/20
50	Tangail (Doreen) 22MW	22MW (8*2.9MWor 2.5MW?)	22	22	22	Private	SIPP, BPDB	2008/11/12
Mymensingh area								
51a	Fenchuganj Comb. Cycle (CCPP-1) 97MW	BPDB 97MW (GT:2x52MW, ST:33MW)	97	80	90	Public	BPDB	1994-95
51b	Fenchuganj Comb. Cycle (CCPP-2) 104MW	GT:2x35MW, ST:35MW	104	90	104	Public	BPDB	2011/10/26
52	Fenchuganj/Fenchuganj (Barakatullah) 51 MW	51MW (19*2.6MW)	51	51	51	Private	RPP 15yrs	2009/10/18
53	Fenchuganj Energyprima 44MW	44MW (12*3.3MW + 5*2MW)	44	44	44	Private	RPP, energy prima	2012/2/15
54	Hobiganj (Confidence-EP) 11MW	11MW(4*2.9MW)	11	11	11	Private	SIPP, REB	2009/1/10
retired	Shahjibazar Power Unit-5,6 ,38MW	38 MW	38	N/A	0	Public	BPDB	
55	Shahjibazar GT: Unit- 8,9 , 70MW	BPDB/PGCB 70MW (2*35MW)	70	66	66	Public	BPDB	2000
ECREC Approved	Shahibazar conversion 105MW	ST35MW 増設計画	N/A					2017/June
56	Shahjibazar (Shahibazar, Sahzinazar) 86MW	86MW (32x2.90MW)	86	86	86	Private	RPP 15yrs	2009/2/9
57	Shahjibazar (, Sahzinazar) , Energyprima) 50MW	50MW (27x2.0MW)	50	50	50	Private	RPP 5yrs	2008
58	Sylhet 150 MW	BPDB 150MW / PGCB 142MW	150	142	142	Public	BPDB	2012/3/28
under evaluation	Sylhet conversion 150MW→225MW	add 75MW	N/A			Public	BPDB	2017/Jan
59	Sylhet 20MW GT	20MW	20	20	20	Public	BPDB	1986
60	Sylhet (Energyprima), Kumargoan, 48MW	48MW (26x1.95MW)	48	50	50	Private	RPP 5yrs	2008
61	Shahjahanulla/ Shajahanulah power Com 25MW	3*9.34MW	25	25				2013/11/1
62	Sylhet (Desh) , Kumargao/kumkargoan , 10MW	10MW (6*1.95MW)	10	10	10	Private	RPP 15yrs	2009/3/15
Shihat area								
63	Bheramara GT Unit-1, -2,-3 , 90MW	60MW (3*20MW) GT	60	46	16	Public	BPDB	1976/76/80
64	Bheramara (Quantum) 105MW	BPDB 110MW/ PGCB:105MW (12x8.5MW+2x6MW+2x18MW)	105	105	105	Private	RPP 5yrs	2010/12/31
65	Bheramara HVDC Interconnector 500MW (直流送電)	500MW	500	500				2013/11/1
66a	Khulna ST 110MW	110 MW Steam Turbine	110	55	55	Public	BPDB	1984
66b (Uttered in 2013)	Khulna ST 60MW	60 MW Steam Turbine	60	N/A	30	Public	BPDB	1973
67	Khulna (KPCL-1) 110MW	110MW (19x6.5MW)	110	110	110	Private	IPP	1998
68	Khulna (KPCL-2) ,Summit power , 115MW	115MW (7x17MW) , QRPP (5 Yrs)	115	115	115	Private	IPP,KPCL	2011/6/1
69	Faridpur 50MW peaking	54MW (8*6.69MW), Peaking PP	54	54	54	Public	BPDB	2011/11/6
70	Khulna 150MW GT	158MW(GT)	158	158		Public	NWPGCL	2013/9/23
(70b controlled)	Khulna 150MW GT→ 225MW (ST75MW,CCPP)	75MW(ST)	N/A			Public		2015/Dec
retired	Khulna RPP(Aggreko) 40MW	40MW (50x0.80MW)	40	N/A	40	Private	RPP 3yrs	2008
74	Khulna Aggreko 55MW	55 MW (71*0.85MW)	55	55	55	Private	QRPP 3yrs	2010/8/10
71	Gopalganj/Gopalgonj/ Gopanlgonj 100MW peaking PP	109MW (16*6.58MW)	109	109	109	Public	BPDB	2011/9/29 or 2013/11/16?
72	Noapara/ Nowapara (Quantam) 105MW	101MW (5x9.9MW+6x9.5MW+2x9.2MW)	101	101	101	Private	RPP 5years,Quantum power system	2011/8/26
73	Noapara/ Nowapara (Khanjahan Ali) 40MW(5*8.5MW)	40MW (5*8.5MW), QRPP (5 Yrs)	40	40	40	Private	RPP, khan lahan Ali	2011/5/28
Khulna area								
75	Barisal GT : Unit-1 20MW	20 MW Gas Turbine	20	30	16	Public	BPDB	1984
75	Barisal GT : Unit-2 20MW	20 MW Gas Turbine	20		16	Public	BPDB	1987
76	Bhola (Venture) 33MW	34.5 MW	33	33	33	Private	RPP 5yrs	2009/7/12
Barisal area								
77a	Baghabari GT 71MW	71MW Gas Turbine	71	71	71	Public	SBU, BPDB	1991
77b	Baghabari GT 100MW	100MW Gas Turbine	100	100	100	Public	SBU, BPDB	2001
ECREC Approved	Baghabari 100MW conversion→ 150MW	add 50MW → 150MW	N/A					2017/June
78	Baghabari 50MW peaking PP	52MW (6*8.9MW)	52	52	52	Public	BPDB	2011/8/29
79 (retired in 2013)	Westmont GT, Baghabari	2x45MW	90	N/A	70	Private	IPP	1999
80	Bera Peaking 70MW	71MW (9*8.29MW)	71	71	71	Public	BPDB	2011/10/28
81	Amnura 50MW, Sinha Power	50MW (7*7.79MW),	50	50	50	Private	RPP 5years, Sinha power	2012/1/15
82	Katakhali, Rajshahi (Northern) 50 MW	50MW (6*8.92MW)	50	50	50	Private	RPP, NPSL	2012/5/23
83	Katakhali 50MW Peaking PP	50MW (6*8.2MW)	50	50		Public	BPDB	2012/12/1
84 COD	Sirajganj/Sirajigonj CCPP (150→225MW完工) NWPGCL	210MW (GT:150MW, ST:75MW)	210	210		Public	NWPGCL	GT 2012/9/1→2014/May?
85	Santahar 50MW peaking	50MW (6*8.2MW)	50	50		Public	BPDB	2012/12/1
86	Bogra (GBB) 22MW	22MW (6*4MW)	22	22	22	Private	RPP 15yrs	2008
87	Bogra Energyprima 20MW	20MW (5*3.3MW+5*2MW)	20	20	20	Private	RPP 3yrs, energy prima	2011
88	Ullapara (Summit) 11MW	11MW (4*2.9MW)	11	11	11	Private	SIPP, REB, Summit power	2009/3/2
89(COD)	Netore 52MW / Raj Lenka /Rajshahi	52MW (6*8.92MW)	52	52				2014/1/24
Rajshahi area								
90	Barapukuria ST : Unit-1,2 , 250MW	2x125MW	250	200	200	Public	BPDB	2006
91	RangpurGT 20MW	20MW Gas Turbine	20	20	20	Public	BPDB	1988
92	Syedpur/Saidpur GT 20MW	20MW Gas Turbine	20	20	20	Public	BPDB	1987
93	Thakurgaon (R2) 47MW	BPDB:55MW / PGCB:47MW(20x1.5MW+21x1.1MW)	47	40	47	Private	RPP 3yrs	2010/8/2
Rangpur area								

Source: JICA Survey Team

Figure 18-1 List of Existing Power Plants

Serial Number of PGCB	Plant name	Configuration	Original installed capacity (MW)	Derated capacity at 2015/01 (MW)	Generation Capacity 2012-2013 (MW)	Sector	Producer (Source: PGCB)	Commercial Operation Date
test run	Ghorasal/ Ghorashal, Narsingdi/Narsindi 100 MW PP	108MW	108			Private	IPP	2014/july→
under construction	Munshiganj (Kathpotti) 50 MW PP	53MW	53			Private	IPP	2014/sep→
under construction	Chittagong (Patenga/potiya) 100 MW PP	108MW	108			Private	IPP	2014/oct→
under construction	Bhola 225 MW CCPP : SC GT 125MW ←150MW ?	GT 125MW ←150MW ?	150			Public	BPDB	2014/Nov→
under construction	Ashuganj 225MW CCPP : SC GT Umit 150MW	GT 150MW	150			Public	APSCL	2014/dec→
under construction	Ashuganj 225MW CCPP : SC ST Unit 75MW	ST 75MW	75			Public	APSCL	2015/June
under construction	Bibiana #2 341MW CCPP(Summit) : SC GT Unit	222MW(GT)	222			Private	BPDB	2015/jan
under construction	Kodda, Gazipur 150 MW PP	150MW	150			Public(BPDB-RPCL)	BPDB	2015/Feb
under construction	Jangalila, Comilla, 52MW peaking	52MW	52					2015/Mar
under construction	Ashuganj (South) 450 MW CCPP	373MW (COGT)	373			Public	APSCL	2015/June
contructed	Co'xbazar 60MW PP	60MW	60			Private		2015/June
under construction	Ashuganj 195MW Modular PP	195MW	195			Public	APSCL	2015/June
under construction	Siddhirganj 335MW CCPP : GT 200MW	200MW GT	200			Public(EGCB)	EGCB	2015/June
under construction	Siddhirganj 335MW CCPP : ST 135MW	135MW ST	135			Public	EGCB	2016/march
under construction	Bibiana #2 341MW CCPP : SC ST Unit	119MW(ST)	119			Private	BPDB	2015/July
under construction	Bhola 225 MW CCPP : SC ST 70MW	ST 70MW	70			Public	IPP	2015/Aug
contructed	Keraniganj 100MW PP (re-losate from khulna)	100MW	100			Private	IPP	2016/jan
under construction	Narayanganj 53MW	53MW	53			Private	REB	2016/jan
contructed	Manikganj 55MW PP	55MW	55			Private	REB	2016/march
Approved by Purchase Committee	Fenchuganj 50 MW PP	50MW	50			Private	IPP	2016/march
LOI	Munshiganj (Kathpotti) 50 MW PP	50MW	50			Private	IPP	2016/June
under construction	Bosila, Keraniganj, 108MW CCPP(CLC power)	108MW(GT)	108			Private	IPP	2016/June
under construction	Nebabganj/ Nababgonj 55MW PP	55MW	55			Private	REB	2016/June
PPA	Kusiara 163MW CCPP	163MW	163			Private	IPP	2016/June
contructed	Chapai nababganj 104MW PP	104MW	104			Public	BPDB	2016/June
tender	Kaptai Solar 8MW	8MW	8			Public	BPDB	2016/June
Tender	Hatiya hybrid (Diesel Generator/solar) 7MW	7MW	7			Public	BPDB	2016/June
Approved by Purchase Committee	Sorishabari 3MW solar	3MW	3			Private	IPP	2016/June
contructed	Shahjibazar CCPP : GT216MW	GT 216MW	216			Public	BPDB	2016/June
contructed	Shahjibazar CCPP : ST 116MW	ST 116MW	116			Public	BPDB	2017/march
NOA	Sikalbaha 225 MW CCPP : GT	150MW(GT)	150			Public	BPDB	2016/Sep
NOA	Sikalbaha 225 MW CCPP : ST	75MW(ST)	75			Public	BPDB	2017/June
NOA	Sirajganj #2, 225MW CCPP : SC GT	150MW	150			Public	NWPGCL	2016/Sep
NOA	Sirajganj #2, 225MW CCPP : SC ST	70MW	70			Public	NWPGCL	2017/June
PPA	Sirajganj 367MW CCPP : SC GT	249MW GT	249			Private	IPP	2016/Sep
LOI	Sirajganj 367MW CCPP : SC ST	118MW ST	118			Private	IPP	2017/June
PSS/IEE evaluation	Dhorola 30MW solar park	30MW	30			Private	IPP	2016/dec
under evaluation	Bibiana south 383MW CCPP ,SC GT	GT 252MW	252			Public	BPDB	2017/jan
under evaluation	Bibiana south 383MW CCPP ,SC ST	ST 131MW : combined 383MW	131			Public	BPDB	2016/jan
contructed	Ashuganj (North) CCPP 381MW	381MW	381			Public	APSCL	2017/jan
2014→2017	Ghorasal 363MW CCPP : SC GT Unit 254MW	254MW GT	254			Public	BPDB	2017/march
2015→2018	Ghorasal 363MW CCPP : SC ST Unit 109MW	109MW ST	109			Public	BPDB	2018/jan
2015→2017	Bheramara 414MW CCPP : SC GT Unit 260MW	260MW GT	260			Public	NWPGCL	2017/march
contructed	Bibiana #3 CCPP 400MW GT:274MW	274MW GT	274			Public	BPDB	2017/march
contructed	Bibiana #3 CCPP 400MW ST:126MW	126MW ST	126			Public	BPDB	2018/jan
contructed	Barapukuria 275MW, Unit 3	274MW ST	274			Public	BPDB	2018/jan
contructed	Maowa, Munshiganj 522MW coal fored pp(Orion)	522MW	522			Private	IPP	2018/jan
contructed	Khulna 630 MW Coal fired pp (Orion)	630MW	630			Private	IPP	2018/jan
N/A	International Grid Connection	500MW	500					2018/Dec
LOI	Chittagong 282MW Coal fired PP (Import coal)	282MW	282			Private	IPP	2019/march
LOI	Dhaka 282MW Coal fired PP (Import coal)	282MW	282			Private	IPP	2019/march
PPA	BIFPCL, Rampal, Coal fired PP 1,320MW	1,320MW	1320			Public	BIFPCL	2019/June
	Chittagong 1000MW CCPP(LNG)	1,000MW	1000			Public	BPDB	2019/Dec
LOI	Chittagong 612MW Coal fired PP S.alam group (Import coal)	612MW	612			Private	IPP	2020/Jan
LOI	Dhaka 635MW coal fired pp (Orion)	635MW	635			Private	IPP	2020/jan
preliminary	LNG based 1,000MW CCPP	1,000MW	1000			Public	BPDB	2020/June
FS	Moheskhali 1,200MW coal fired PP (JV Huadian/ECA)	1,200MW	1200			Public	BIFPCL	2021/June
LOI	Chittagong 612MW Coal fired PP S.alam group (Import coal)	612MW	612			Private	IPP	2025/jan
FS finish	Matarbari 1,200MW coal fired PP	1,200MW	1200			Public	CPGCL	2021/Dec
	BPDB and CHHKLChina JV ,Chittagong,Co'x Bazar	1,320MW	1,320			Public	BCFPCL	
	Patuakhali , Barisal Patuakhali	1,320MW	1,320			Public	CMC-NWPGCL	
	Moheskhali PP ,Chittagong,Co'x Bazar	1,320MW	1,320			Public	-	
	1,320MW PP with South Korea (Weat Generation Power Compa	1,320MW	1,320			Public	WGPC	
	Chittagong-Anowara PP , Chittagong, Anowara	1,320MW	1,320			Public	-	
	Munshiganj 600-800MW PP	800MW	800			Public	-	
	Ashuganj Coal- based pp , Barisal	1,320MW	1,320			Public	APSCL	
	Barapukuria 300MW financed by ECA, Rangpur,Dinajpur	300MW	300			Public	BPDB	
	Bashkhali 600MW, chittagong (Bangladesh Machine Tools Factor	600MW	600			Private	BMTFL	
	Mirersorai Chittagong 150MW Commercial pp (Chittagong powe	150MW	150			Private	BSRM	

Source: JICA Survey Team

Figure 18-2 List of Planned Power Plants

(1) O&M target site selection

To ascertain the O&M situation in Bangladesh as a whole, the JICA survey team carried out screening with the following selection criteria. The team also considered the rehabilitation target site and combined cycle power generation remodeling plan target site.

(2) Screening criteria and grounds

(a) BPDB owned

Grounds: BPDB is the largest generation public company in Bangladesh, and thus, cooperation can be expected for the JICA survey team investigation

(b) Operation period: more than 10 years, less than 30 years

Grounds: 10 years of experience in O&M is preferable.
A unit older than 30 years may have large-scale malfunctions regardless of the application of the remodeling plan, therefore, 10-20 year long stable operation may not be expected after the completion of the remodeling works.

(c) Larger than 100MW

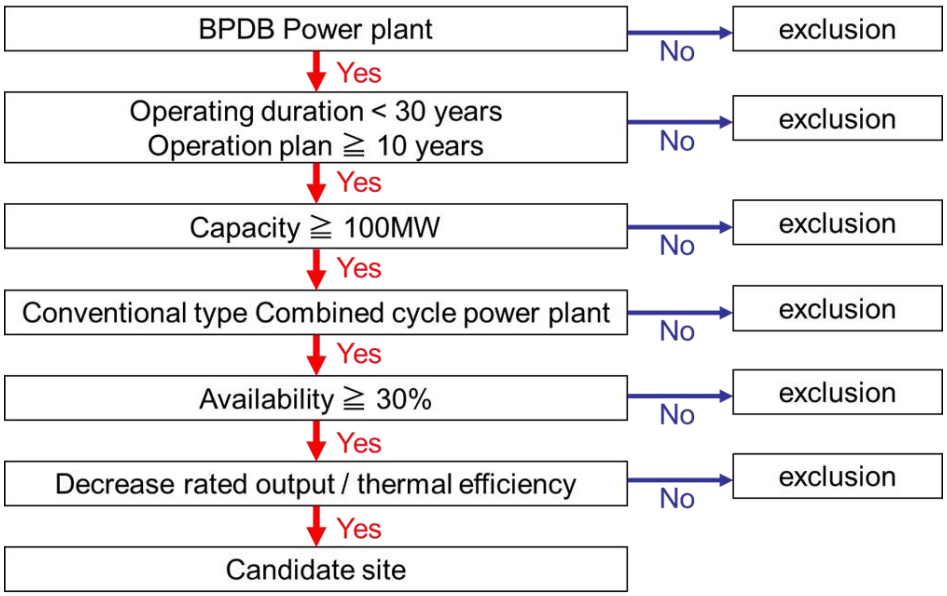
Grounds: There is little to expect from the rehabilitation effect on a small power unit.

(d) Availability more than 30%

Grounds: This means the plant is very useful, and will continue to be vital in the future.

(e) Lowered output or efficiency

Grounds: A large expect can be expected.



Source: JICA Survey Team

Figure 18-3 Site Selection

After site selection, the JICA survey team submits the target site list and discusses it with working group members. Finally, the target site list is decided.

BPDB Annual Report 2012-2013

Name of powerplant	For		COD (Year)	Type	Fuel	Installed	Derated	Plant factor	Efficiency (NET)	
	O&M	C/C				(MW)	(MW)	(%)	(%)	
Rauzan #1		○	1993	ST	Gas	210	180	23.94	27.98	*1
Rauzan #2		○	1997	ST	Gas	210	180	15.80	28.89	*1
Ashuganji #3、#4、#5	○	○	1987/87/88	ST	Gas	450	430	88.56	33.88	
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	30.32	
Barapukuria #1,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	27.56	
Chandpur	○		2012	CC	Gas	163	163	49.68	37.27	
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	53.33	21.16	
Ghorasal #3,#4	○	○	1987/89	ST	Gas	420(210*2)	360	69.53	31.09	
Ghorasal #5,#6	○	○	1995/99	ST	Gas	420(210*2)	380	33.72	28.76	
Tongi		○	2005	GT	Gas	105	105	38.38	25.93	
Baghabari		○	2001	GT	Gas	100	100	87.52	28.29	
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.53	
Fenchuganj	○		2011	CC	Gas	104	104	49.08	30.06	
Sylhet		○	2012	GT	Gas	150	142	51.96	29.16	

*1) Rauzan power station 1)lack of gas causes low availability
2)large scale of its generation capacity
Because of above reasons, Rauzan power plant also listed in candidate plants list.

Source: JICA Survey Team

Figure 18-4 Target Site List

After site investigation, the JICA survey team writes down the next section.

18.3 Actual O&M Situation

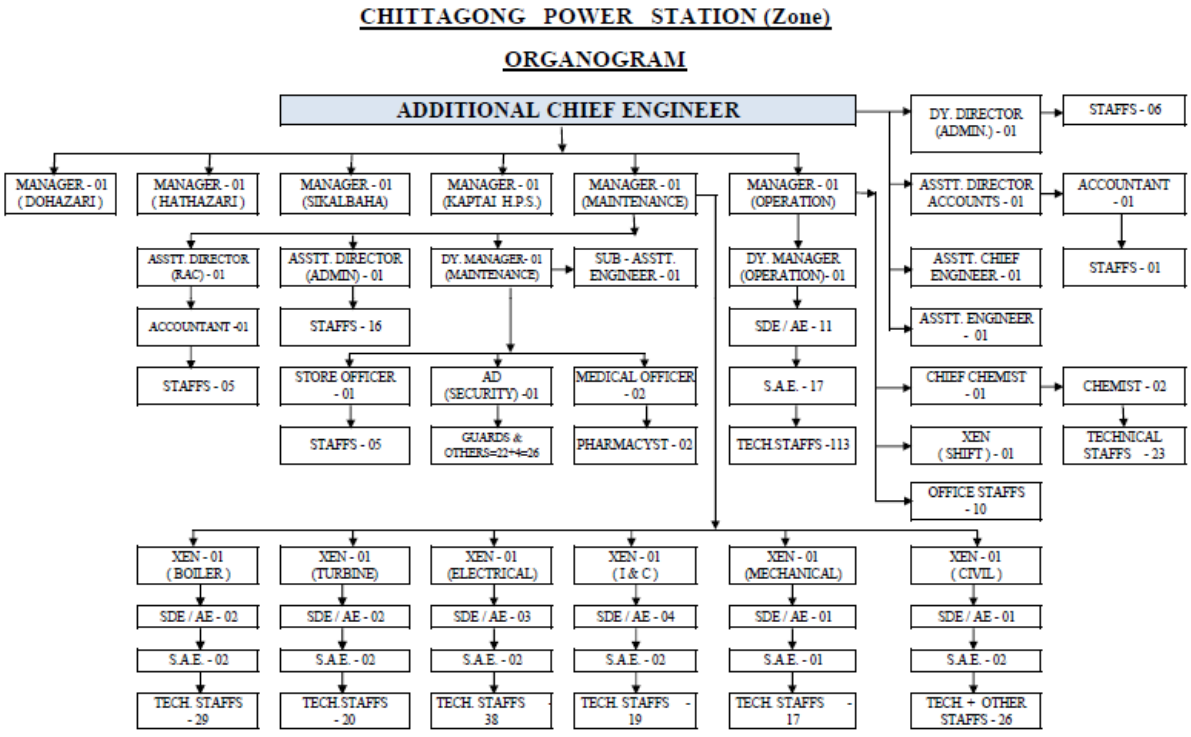
18.3.1 Power station situation

(1) Rauzan thermal power station (main fuel : natural gas)

Basic information	:	COD unit 1: 1993, unit 2: 1997
Capacity (COD)	:	210MW, 210MW
Capacity (Now)	:	180MW, 120MW

Organization chart:

Source: Rauzan thermal power station



Source: Rauzan thermal power station

Figure 18-5 Rauzan Organization Chart

Table 18-1 Rauzan Thermal Power Station

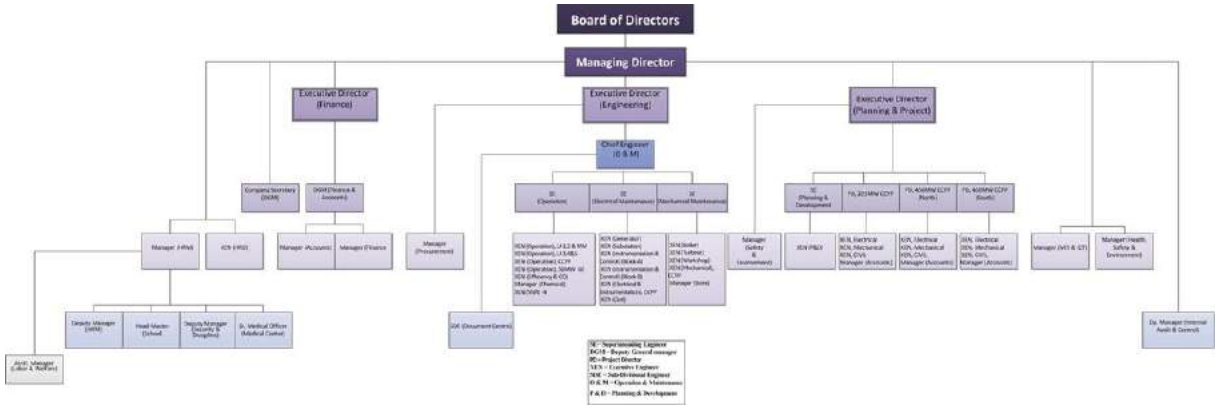
Maintenance plan	Unidentified
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Cannot get shutdown permission because of lack of power supply
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Manufacture
Safety for equipment	Firefighting system
Safety for staff	Has safety rules *there is a human accident data book
Efficiency management	Monthly average efficiency calculated by SAE
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	13 staff/shift (10 operators for 2 units, shift-leader, shift sub-leader, supervisor), 3 shifts
Patrol for site	Unidentified
Plant condition report	Operator checks and records every 2 hours
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*No root cause analysis for unit 2 explosion and there are also no countermeasures *Does not reach rated output
Capacity limitation	Yes
Future plan	Unit 2 has a plan for large scale repair at next outage by Chinese manufacturer
Peculiar information	These plants can operate until facility replacement parts disappear
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	They have not received enough gas, but they believe gas will be supplied

Source: JICA Survey Team

(2) Ashuganj thermal power station (main fuel : natural gas) units 3, 4 and 5

Basic information	:	COD unit 3: 1986, unit 4: 1987, unit 5: 1988
Capacity (COD)	:	150MW, 150MW, 150MW
Capacity (Now)	:	135MW, 129MW, 134MW

Organization chart:



Source: Ashuganj thermal power station

Figure 18-6 Ashuganj Organization Chart

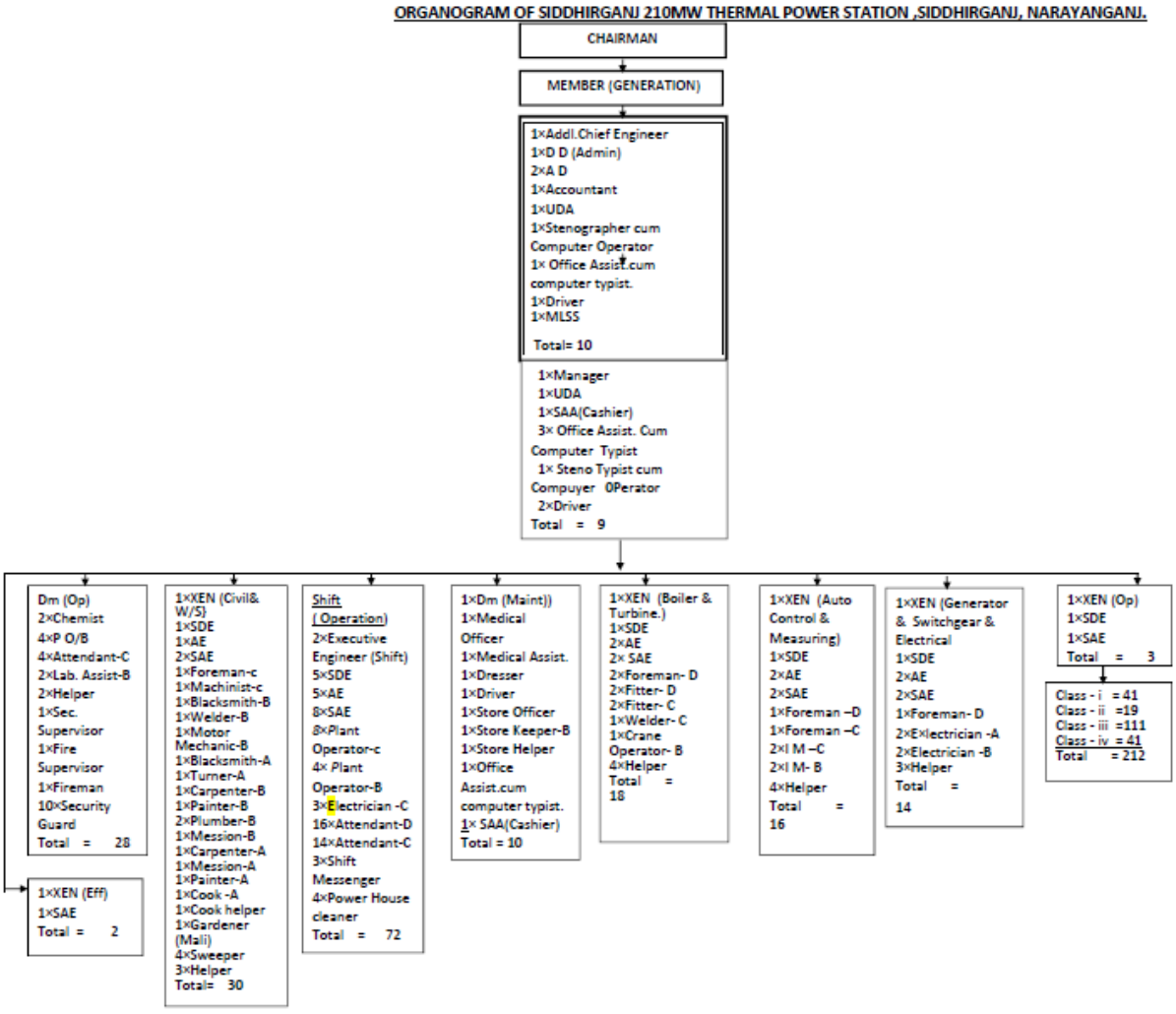
Table 18-2 Ashuganj Thermal Power Station

Maintenance plan	Chief engineer
Maintenance plan basic idea	Few days' short stop maintenance and every 3 months maintenance
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Cannot get shutdown permission from Power div
Manufacture support for daily	Unidentified
Daily maintenance	Maintenance staff
Major inspection	Unidentified
Safety for equipment	Firefighting system
Safety for staff	Health and safety section was established in 2013. *in emergency, contact hospital and head office (*there is no communication chart)
Efficiency management	Monthly average efficiency calculated by efficiency section
Fuel analysis	No analysis
Environmental regulation	No (there is no emission monitor)
Organization for operation	6 staff / shift, 4 groups, 3 shifts
Patrol for site	Every 2 hours
Plant condition report	Operation group makes operation log sheet. It includes unit start up/shut down events and trip events
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*Does not reach rated output *High pressure heater tube leak
Capacity limitation	Yes
Future plan	Combined cycle power generation remodeling plan sequentially
Peculiar information	None
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	No

Source: JICA Survey Team

(3) Siddhirganj thermal power station (main fuel : natural gas)

Basic information : COD 2004
Capacity (COD) : 210MW
Capacity (Now) : 150MW
Organization chart:



Source: Siddhirganj thermal power station

Figure 18-7 Siddhirganj Organization Chart

Table 18-3 Siddhirganj Thermal Power Station

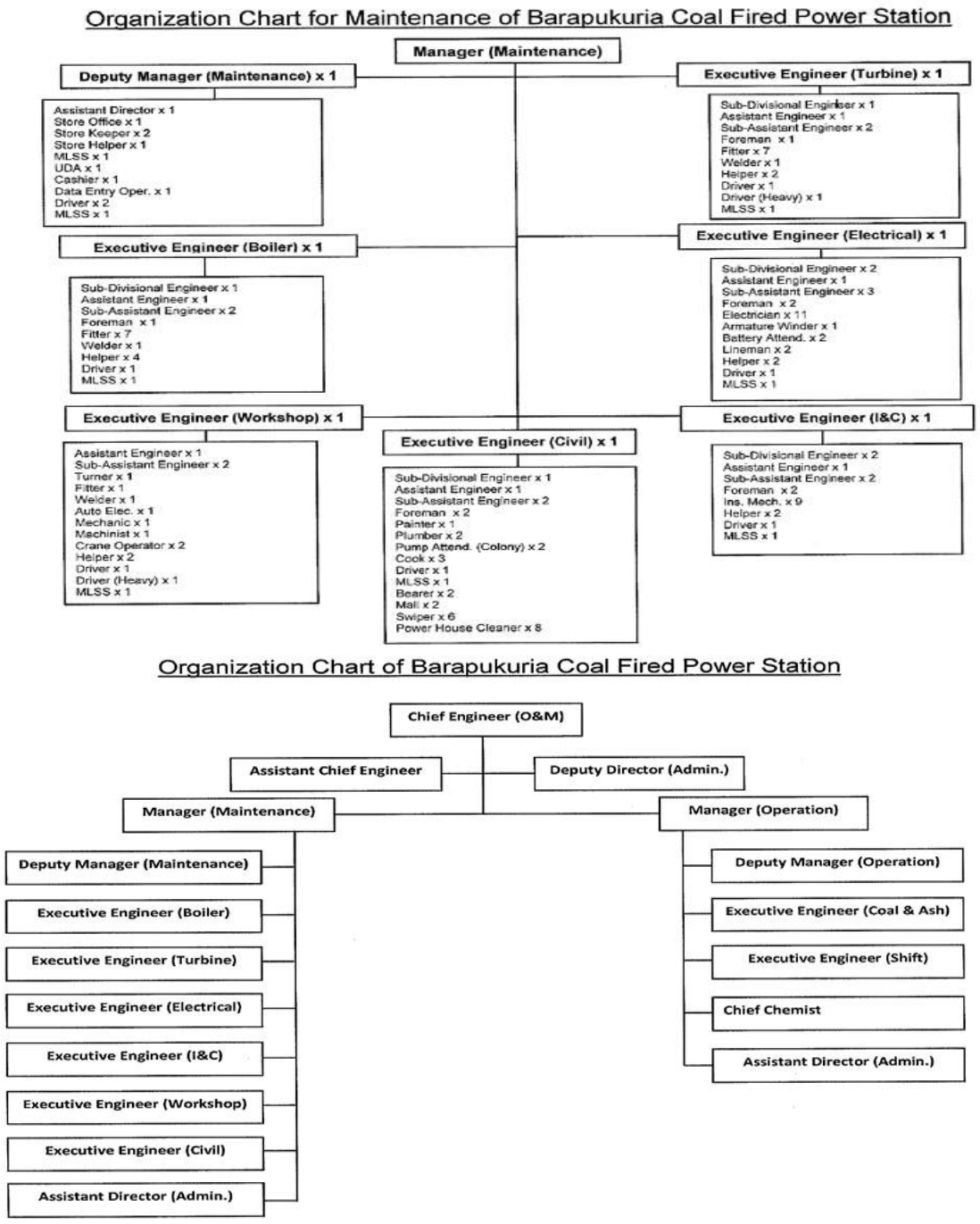
Maintenance plan	Unidentified
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Unidentified
Reason to disturb it	Unidentified
Manufacture support for daily	Yes (Russian company)
Daily maintenance	Maintenance staff *there is a workshop
Major inspection	Unidentified
Safety for equipment	Firefighting system
Safety for staff	No record
Efficiency management	Monthly average efficiency only
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	9 staff/shift (operator *4, Engineer *5) 4 groups/3 shifts Others:11 staff for local (day shift)
Patrol for site	Once/shift
Plant condition report	Operation group makes operation log sheet every hour. *auxiliary equipment switch over test (there is a monthly schedule)
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output
Capacity limitation	Yes - 150MW (Generator has trouble)
Future plan	None
Peculiar information	Unidentified
Staff issues	Unidentified
Training system	Unidentified
Uneasiness concerning natural gas supply	Uneasy *the generation output is 110MW degree because of shortage of gas supply

Source: JICA Survey Team

(4) Barapukuria thermal power station (main fuel : Coal)

Basic information : COD 2005
Capacity (COD) : 250MW (125MW*2)
Capacity (COD) : 180MW

Organization chart:



Source: Barapukuria thermal power station

Figure 18-8 Barapukuria Organization Chart

Table 18-4 Barapukuria Thermal Power Station

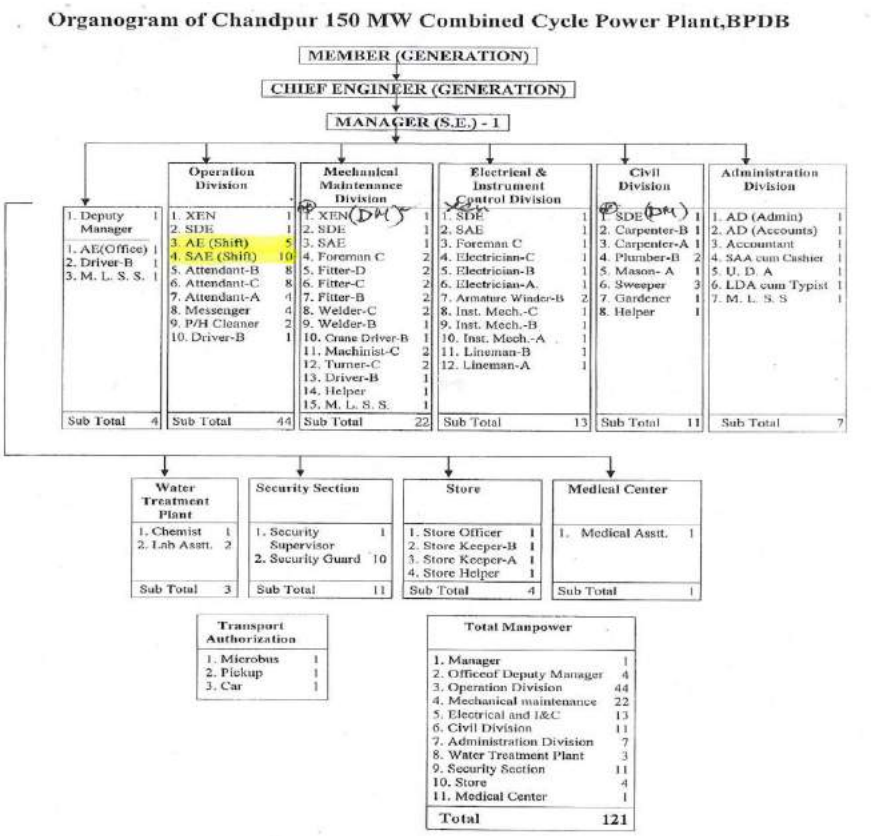
Maintenance plan	Executive engineer, approved by manager
Maintenance plan basic idea	Boiler inspection every 2.5 months, major inspection every 4 years *They have a 3 year maintenance plan
Feasibility of maintenance plan	*Boiler minor inspection will be held as scheduled *major maintenance has never been carried out since COD.
Reason to disturb it	BPDB: budget issue Power Div: shutdown permission issue
Manufacture support for daily	Unidentified
Daily maintenance	Maintenance staff *they have spare parts based on 10 years' experience
Major inspection	Main equipment (boiler, turbine): manufacture other portions: maintenance staff
Safety for equipment	Firefighting system
Safety for staff	BPDB guideline only *there are no individual rules, and no safety section in power station. *if a person is injured, they submit a report to BPDB head office
Efficiency management	Monthly average efficiency only *No performance test
Fuel consumption	2,400ton/day for 2 units
Fuel analysis	*they do analysis every day, but if heat value is not over/under 6,100kcal/kg +/-10%, then they use 6,100kcal/kg, the same as the construction period value.
Environmental regulation	Nox: 150ppm、Sox: 277ppm
Organization for operation	4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	*Operation group makes operation log sheet. *auxiliary equipment switch over test
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *because coal includes small stones, it breaks coal mill equipment
Capacity limitation	180MW (because mill cannot operate at rated speed)
Future plan	None
Peculiar information	Bituminous coal (6,100kcal/kg +/-10%) They cannot inspect boiler equipment by themselves
Staff issues	Unidentified
Training system	OJT and using BPDB training center

Source: JICA Survey Team

(5) Chandpur thermal power station (main fuel : natural gas)

Basic information : COD 2012
Capacity (COD) : 163MW
Capacity (Now) : 163MW

Organization chart:



Source: Chandpur thermal power station

Figure 18-9 Chandpur Organization Chart

Table 18-5 Chandpur Thermal Power Station

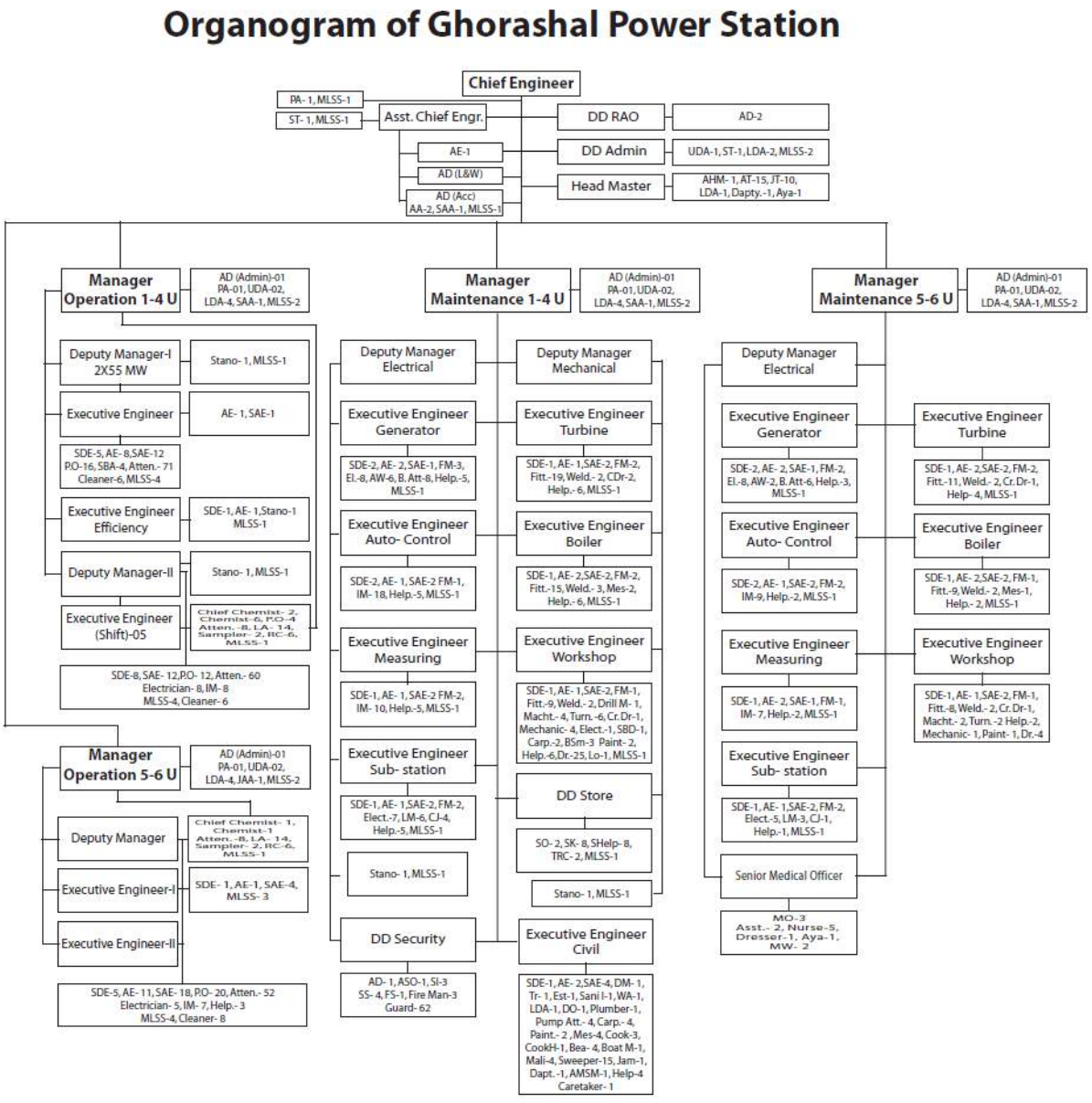
Maintenance plan	Executive - electrical engineer, - operator, - mechanical engineer -> plant manager Finally, BPDB approves
Maintenance plan basic idea	No original maintenance plan *just finished warranty period
Feasibility of maintenance plan	Ignorance *because, during construction period, they have priority over other plants
Reason to disturb it	-
Manufacture support for daily	None *they consider making a contract with manufacture
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff + overseas expert company (Indian engineering) *Indian engineering company cooperates with Tongi thermal power station
Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, and also helmets and gloves, but nobody cares *There is no penalty for not following a manual ・Staff can take lectures at BPDB training center
Efficiency management	Monthly average efficiency calculated by operation sector *performance test carried out during commissioning period only *managed by performance acceptance committee
Fuel analysis	No analysis *using fixed value that was established in commissioning period because same gas field's gas has same content
Environmental regulation	No regulation
Organization for operation	9 staff /shift (engineer *3, skilled technician) 5 groups, 3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	None
Capacity limitation	None
Future plan	None
Peculiar information	None
Staff issues	Because salary is low, the human resources they developed flow out to other power stations *short of staff
Training system	OJT *every member of staff goes to training center at Tongi twice/year *the contents are mainly lectures
Uneasiness concerning natural gas supply	Unidentified

Source: JICA Survey Team

(6) Ghorasal thermal power station (main fuel : natural gas)

Basic information : COD unit 4: 1989, unit 5: 1995
Capacity (COD) : 210MW, 210MW
Capacity (Now) : 180MW, 190MW

Organization chart:



Source: Ghorasal thermal power station

Figure 18-10 Ghorasal Organization Chart

Table 18-6 Ghorasal Thermal Power Station

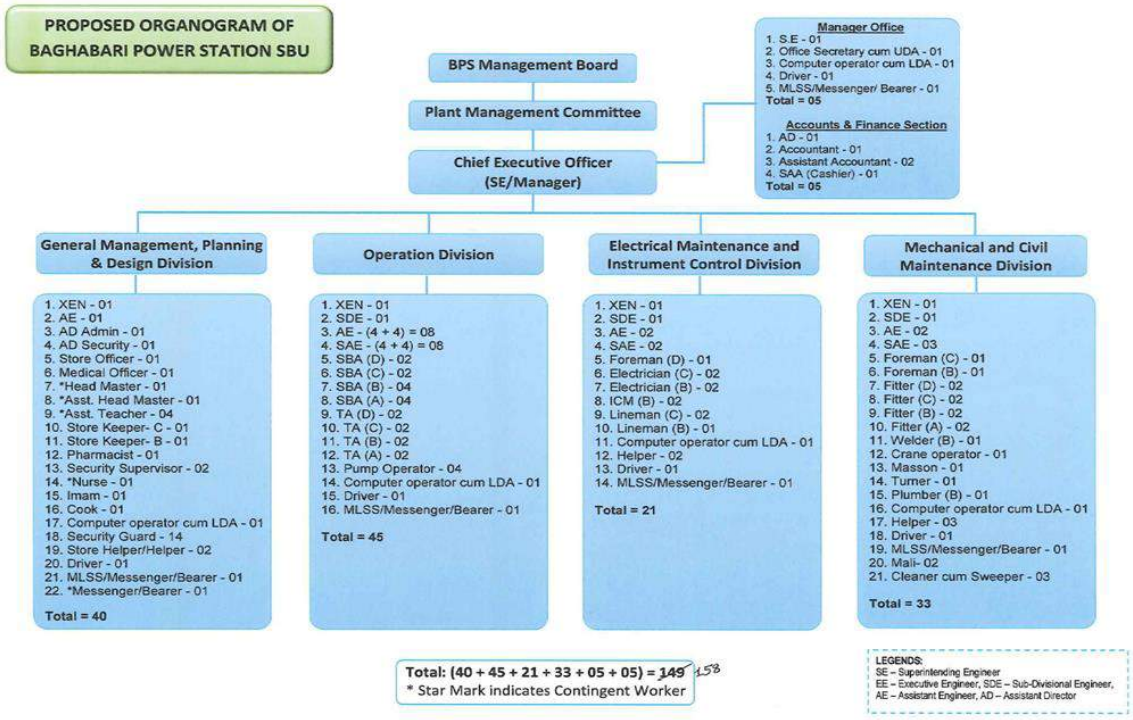
Maintenance plan	4 section managers make, -> plant manager approves, BPDB approves finally
Maintenance plan basic idea	Make every year
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Unidentified
Manufacture support for daily	None *No contract, no support *basically, there is no contract
Daily maintenance	Maintenance staff + workshop
Major inspection	Main: Maintenance staff, Some portion: manufacture
Safety for equipment	Firefighting system
Safety for staff	BPDB guideline
Efficiency management	Calculated by efficiency division every day *Monthly average report to head office *No performance test
Fuel analysis	No analysis
Environmental regulation	Unidentified
Organization for operation	Engineers: 5 groups/3 shifts Technicians: 4groups/3 shifts 5 officers, 25 staff /2 units Total of 20 officers and 100 staff for 4 control rooms; Units 1 & 2, units 3 & 4, units 5 & 6 and network
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *Overhaul need for 25 year old plant *DCS and exciter have to be replaced
Capacity limitation	Yes
Future plan	Unit 5 will have overhaul from Feb 2016 Units 3 & 6 have a repowering plan with duck burner in flue gas duck Unit 7 is under construction (target 365MW)
Peculiar information	None
Staff issues	No problem
Training system	OJT They have training center *the contents are mainly lectures *every member of staff attends a 60 hour lecture per year
Uneasiness concerning natural gas supply	No

Source: JICA Survey Team

(7) Baghabari thermal power station (main fuel: natural gas)

Basic information : COD unit 1: 1991, unit 2: 2001
Capacity (COD) : 71MW (Flame 7B), 100MW (Flame 9E)
Capacity (Now) : 71MW, 100MW

Organization chart:



Source: Baghabari thermal power station

Figure 18-11 Baghabari Organization Chart

Table 18-7 Baghabari Thermal Power Station

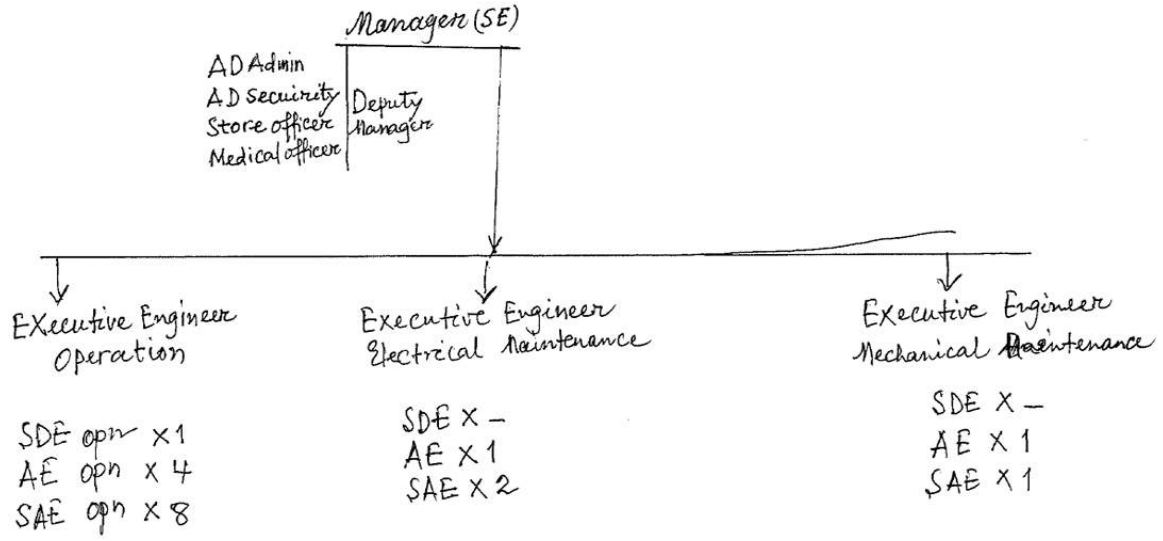
Maintenance plan	Engineer + Plant manager > BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	*Approve -> purchase order -> shutdown permission; this flow takes a long time *BPDB does not allow LTSA contracts. Before periodic maintenance, they have to buy every needed spare part and consumable part. It also takes a long time
Manufacture support for daily	None *need contract with manufacture
Daily maintenance	Maintenance staff
Major inspection	CI: maintenance staff HGPI, MI: GE
Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, and also helmets and gloves, but nobody cares
Efficiency management	Calculated by shift engineer every day *Monthly average report to head office *No performance test
Fuel analysis	No analysis Getting analysis data from gas company *the analysis data is similar to EPC analysis data during commissioning period
Environmental regulation	Every 2 years, they have DOE survey
Organization for operation	5 staff/shift (Shift engineer *1, service assistant *1, assistant (electric) engineer *1, turbine attendant *1, data sampling *1) 4 groups (total 20 staff)/3 shifts
Patrol for site	Unidentified
Plant condition report	Electric engineer, turbine engineer make each part of a daily log sheet
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	None
Capacity limitation	None
Future plan	Unit 2 has combined cycle power generation remodeling plan (100MW→150MW)
Peculiar information	None
Staff issues	No problems
Training system	OJT No curriculum for training BPDB training is theory lecture mainly
Uneasiness concerning natural gas supply	Unidentified

Source: JICA Survey Team

(8) Shahbazar thermal power station (main fuel: natural gas)

Basic information	:	COD 2000 (GT 2 units)
Capacity (COD)	:	35MW (Flame 6B)*2
Capacity (Now)	:	35MW*2

Organization chart:



Source: Shahijbazar thermal power station

Figure 18-12 Shahjibazar Organization Chart

Table 18-8 Shahjibazar Thermal Power Station

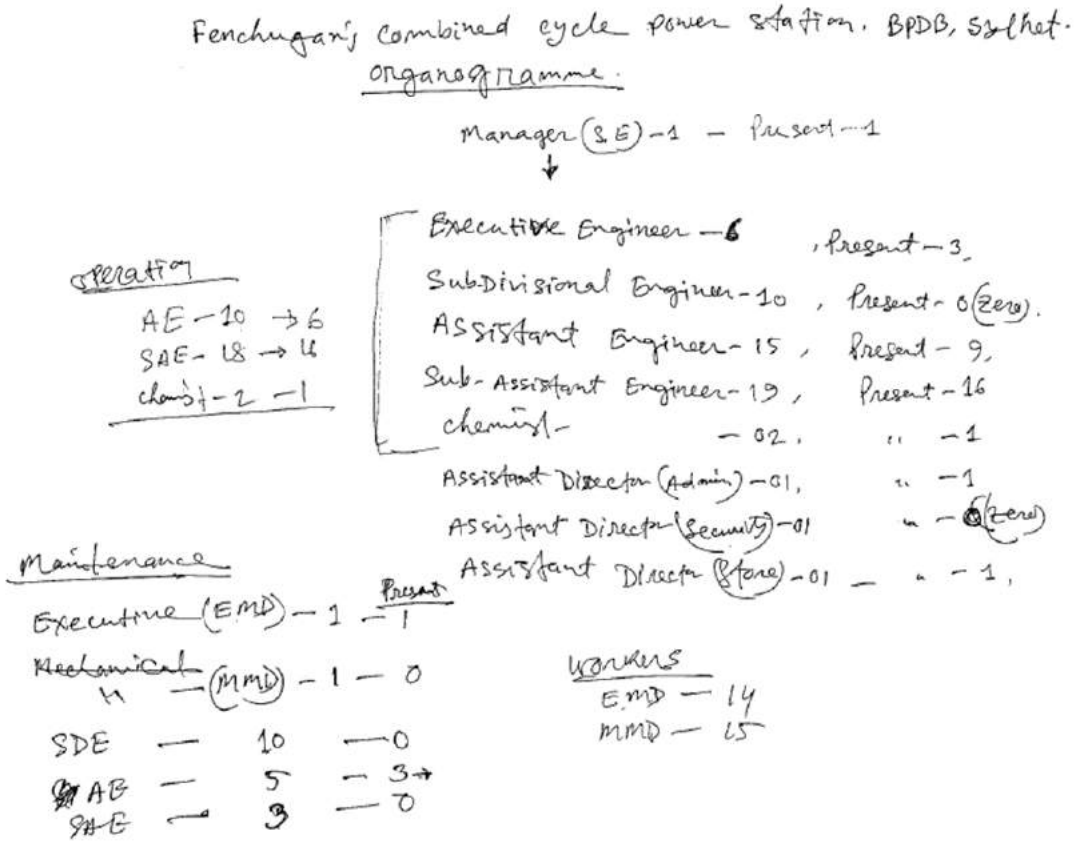
Maintenance plan	Maintenance staff, -> plant manager coordinate, finally BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Have to wait for shutdown permission from Power Div
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	CI, HGPI: Maintenance staff MI: manufacture support
Safety for equipment	Firefighting system
Safety for staff	At the time of introduction, training only *they have a concept
Efficiency management	Monthly average efficiency only *No performance test
Fuel analysis	No analysis
Environmental regulation	No regulation (no CEMS)
Organization for operation	5 staff/shift (chief *1, sub chief *1, operator *3) 4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *basic information
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Before major inspection they have to purchase all needed spare parts, so cannot proceed as scheduled
Capacity limitation	None
Future plan	70MW -> 105MW (add ST)
Peculiar information	Considering combined cycle power generation remodeling plan, because it can generate more with same amount of gas, and improve efficiency
Staff issues	None
Training system	OJT *need maintenance/operation skill improvement
Uneasiness concerning natural gas supply	Unidentified

Source: JICA Survey Team

(9) Fenchuganj thermal power station (main fuel: natural gas)

Basic information	:	COD unit 1: 1995, unit 2: 2011
Capacity (COD)	:	97MW, 104MW
Capacity (Now)	:	62MW, 66MW

Organization chart:



Source: Fenchuganj thermal power station

Figure 18-13 Fenchuganj Organization Chart

Table 18-9 Fenchuganj Thermal Power Station

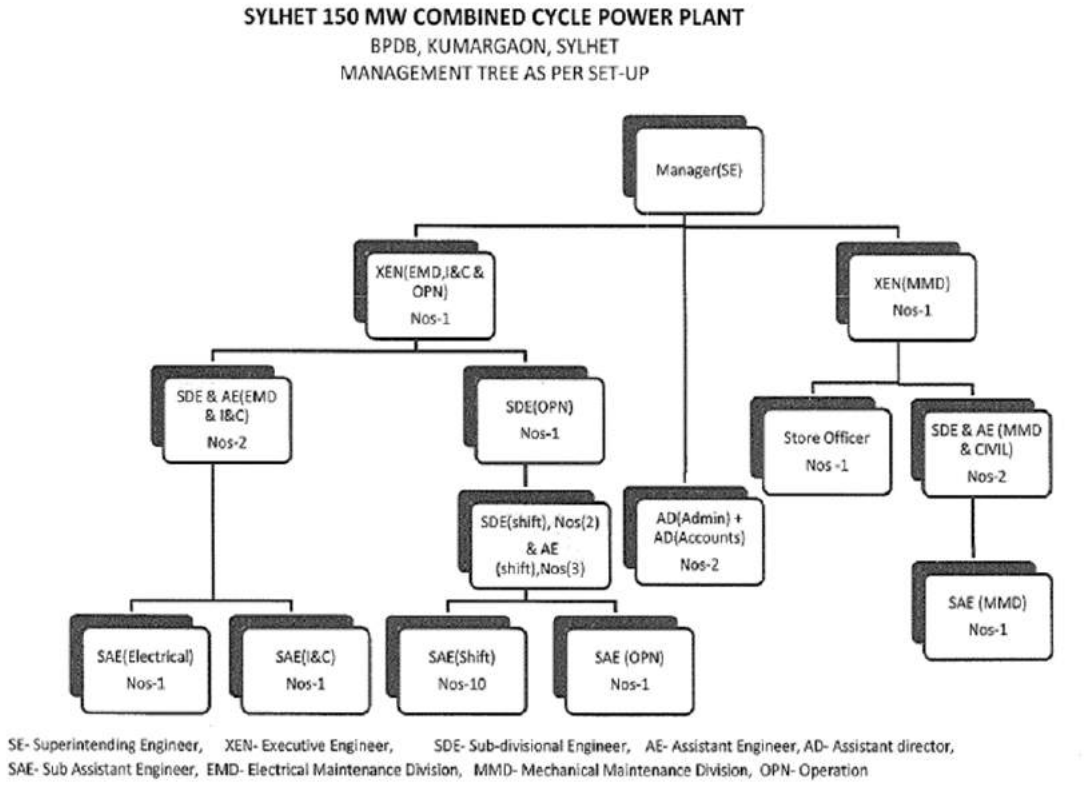
Maintenance plan	Chief engineer -> BPDB approves
Maintenance plan basic idea	Unidentified
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	Waiting for shutdown permission from Power Div *BPDB approval -> parts purchase -> shutdown permission
Manufacture support for daily	None *when trouble happens, they correspond with neighboring power plant staff
Daily maintenance	Maintenance staff
Major inspection	CI, HGPI: maintenance staff MI: GE
Safety for equipment	Firefighting system
Safety for staff	Have a concept, but there is nothing actually implemented
Efficiency management	Monthly average efficiency only *No performance test
Fuel analysis	No analysis
Environmental regulation	No regulation
Organization for operation	5 staff/shift (chief *1, sub-chief *1, operator *3) 4 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *hand writing is official
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	Does not reach rated output *unit 1 is made by a Japan team There is no problem with the facilities, which have already passed 20 years. *unit 1 has 2 GTs, and they basically needed major inspection at 48,000 hours, but they have already passed 65,000 hours because inspection could not proceed as scheduled. Therefore, combustion temperature has to be decreased and, as a result, output also goes down. *unit 2, which is made by a China team, is only 5 years past COD, but it has a lot of trouble. *2 GTs did not change combustion; therefore, they have to decrease combustion temperature. They do not have LTSA, and they cannot change combustion periodically.
Capacity limitation	Already passed gas turbine maintenance timing. To prevent gas turbine trouble, they have to decrease combustion temperature; therefore, both units' output decreases.
Future plan	Next year, first major overhaul for unit 1 (already operated 20 years)
Peculiar information	4 gas turbines have decreased combustion temperature GT1: 22MW, GT2: 26MW, GT3&4: 22MW
Staff issues	Staff need to move every 2-3 years; therefore, difficult to keep skilled staff
Training system	OJT
Uneasiness concerning natural gas supply	No *because near the gas field

Source: JICA Survey Team

(10) Sylhet thermal power station (main fuel : natural gas)

Basic information : COD 2012
Capacity (COD) : 150MW
Capacity (Now) : 150MW

Organization chart:



Source: Sylhet thermal power station

Figure 18-14 Sylhet Organization Chart

Table 18-10 Sylhet Thermal Power Station

KPI	None
Maintenance plan	Staff -> BPDB approves
Maintenance plan basic idea	No plan *because they had a warranty period to 10 November 2014
Feasibility of maintenance plan	As scheduled during warranty period
Reason to disturb it	No
Manufacture support for daily	Yes *they have an LTSA (to 2019) and, during major inspection, Ansaldo will support them (includes 6 engineers) Expect GT, if they have contract to manufacture, they can get support
Daily maintenance	Staff + SEC (EPC) advisor
Major inspection	CI, HGPI: maintenance staff MI: not decided yet (because just finished warranty period)
Safety for equipment	Firefighting system
Safety for staff	They have BPDB guideline, but nobody cares *There is no penalty for not following a manual
Efficiency management	Monthly average efficiency only *no management
Fuel analysis	No analysis *using fixed value that was established in commissioning period
Environmental regulation	No regulation (no monitor) *requirement to EPC : under Nox 30ppm
Organization for operation	7 staff/shift (Shift in charge *1, shift supervisor *2, operator *4) 5 groups/3 shifts
Patrol for site	Unidentified
Plant condition report	Operation group makes operation log sheet *hand writing is official
Report for Head office	Monthly report made by operator (handwritten) Operation group makes operation log sheet
Equipment issues	Air quality is bad; need air filter replacement frequently. *3 years' experience. They know that the quality of Chinese products is bad, but Japanese products are expensive. It is difficult for them to buy Japanese products
Capacity limitation	None
Future plan	They have combined cycle power generation remodeling plan (150→225MW) *Now at final stage of this plan.
Peculiar information	Base load plant *during rainy season, they need to keep about 70MW; easy to control system frequency
Staff issues	None
Training system	OJT *BPDB has a training center, and every member of staff attends a 60 hour lecture per year. *the contents are mainly lectures, with no real machines.
Uneasiness concerning natural gas supply	None

Source: JICA Survey Team

18.3.2 Summary of actual O&M situation

To summarize the information on the power stations which the JICA survey team visited, mentioned above:

Table 18-11 Summary of BPDB Thermal Power Stations

Maintenance plan	According to manual and experience ➔ BPDB approval
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb it	
－Budget approval	Waiting for BPDB budget approval
－purchase	After approval of budget, start bidding, sign contract, then get equipment and parts
－shutdown permission	Waiting for shutdown permission from Power Div
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff and manufacture (for major equipment)
Safety for staff	Only have BPDB guideline *there is no periodic education on safety
Efficiency management	Nobody cares *only calculate average for one month *no periodic performance test
Fuel analysis	No analysis
Environmental regulation	No regulation *there is no regulation now, but DOE plans to devise this in the near future
Report for Head office	Monthly report made by operator (handwritten)
Equipment issues	*Does not reach rated output *There are many problems, but information sharing, such as the cause correspondence, is limited
Staff issues	* Shortage of human resources in BPDB, and their being used in a variety of positions worsens this problem
Training system	*OJT *Only theoretical lectures in training center *Need maintenance/operation skill improvement

Source: JICA Survey Team

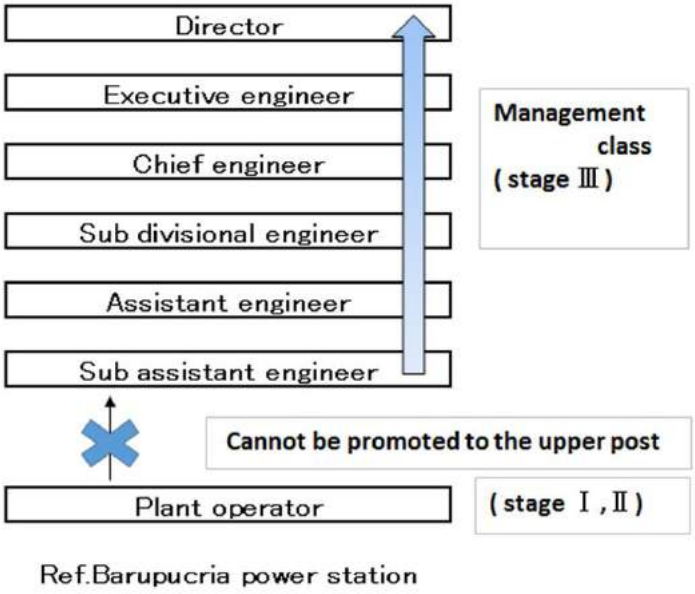
The JICA study team has divided the things it gathered in the list mentioned above into “staff”, “facilities, repair plan”, “budget” and “information” and organized the information.

18.3.3 Staff

(1) Curriculum and organization in a power station in Bangladesh

Curriculum in Bangladesh as follows:
Stage Ⅰ: from kindergarten to standard Ⅹ
(SSC: Standard Secondary Certificate: graduate high school level in Japan)
Stage Ⅱ: Ⅺ～ⅫⅡ (HSC: Higher Secondary Certificate; graduate professional school level)
StageⅢ: Admission for undergraduate

Organization of thermal power station as follows:



Source: JICA Survey Team

Figure 18-15 Education and Organization

The upper figure is an example from Barapukuria, but all power stations are thought to be similar.
Depending on education before the entering a company, some people cannot attain the engineer post.

(2) Lack of education, shortage of staff

BPDB has 6 training centers, but these are basically only for lecture training. The contents of the training centers' lectures are theory and the experience of seniors. And there is no training with actual equipment. The place that people can experience real duties is the power station only. Only a few power stations have training centers and are educating staff; the others cannot educate their staff with training facilities.
In addition, staff at the power station is conclusively lacking for the personnel required. It was supposedly the case that one held an additional post of three posts depending on the power station. In addition, some staff whom they trained transfer to other BPDB power stations.

(3) Safety for staff

They have the BPDB guideline, but nobody cares. One of reasons is that there is no penalty for not following a manual, and then there is the cultural side. In addition, consciousness of safety is very low, probably because the power station shutdown period will not be very long.

18.3.4 Facilities, repair plan

(1) Periodical maintenance and feasibility of parts replacement

Because maintenance cannot proceed following the plan, many power stations worry about their facility. Gas turbine equipment is a particular problem, because hot gas path parts need periodic replacement, but this cannot be done; thus, they have to decrease the firing temperature to protect the equipment and this causes power output decrease. One of reasons is that they do not have an LTSA agreement with the manufacturer and there is a delay in budget approval.

(2) Shutdown permission

Because of the delay in getting shutdown permission from Power Div (sometimes, it takes 2-3 years), it also causes delays in periodic maintenance.

(3) Does not reach rated output

Some power stations have to operate with malfunctions.

(4) Efficiency

Do not care about power plant efficiency. Consciousness of maintaining efficiency and efficiency improvement is not felt. Therefore, they do not care about fuel gas analysis. But everyone wants to introduce the newest high efficiency power plant.

(5) Manufacturer support

Without a contract, manufacturers do not support them or submit related information.
If a malfunction happens, every power station performs trouble correspondence with neighboring power station staff.

18.3.5 Budget

(1) It takes a long time for budget approval, so power plant maintenance cannot proceed.
(2) BPDB does not allow LTSA with manufacturers.

18.3.6 Information

(1) Trouble addressing depends on own experience.
(2) Without a contract, manufacturers do not submit related information.
(3) Do not have other power stations' information except via direct contact.

18.3.7 Summary

The summary of the above survey results are shown in the table below.

Table 18-12 Summary

Staff	*Lack of education and only theoretical lecture curriculum *Low safety awareness *Discrimination towards the post due to education before entering a company
Facilities, repair plan	*Does not reach rated output *Cannot proceed with periodic maintenance as scheduled *Delay in shutdown permission *No manufacturer support *Do not care about power plant efficiency
Budget	*Delay in budget approval *No permission for LTSA
Information	*Trouble addressing depends on own experience *There is no information submitted *There is no positive information sharing among power stations

Source: JICA Survey Team

18.4 Problems

The details of the problems found in the survey results are explained in the following subsections.

18.4.1 Staff

The existing training center only has a lecture curriculum, and there is no training using concrete facilities. The staff has to do On the Job Training (OJT). Therefore, staff only get knowledge through the OJT. Thus, there is no place where they can learn what they must not do, and also no chance to learn what they cannot do on the site. In other words, there is no place to experience what happens when they go too far. And some power stations have a training center, but there are shortages of information for education and organization. In conclusion, there is no effective curriculum or facility. So, the construction of a facility that possesses concrete facilities and an education curriculum is needed. This facility should not only be for BPDB power station staff, but also loaned out for a fee to other companies. This would improve the Bangladesh power sector's O&M skills.
The details of the training facility are explained in 18.6 Training Center.

18.4.2 Facilities, repair plan

Almost all power stations mentioned the delay in maintenance work. Through the site visits, the JICA survey team found that during the process of making the maintenance plan to implementing it, there were 2 key points: one of them is BPDB budget approval, and the other one is shutdown permission from Power Div.

(1) Approval of maintenance plan and budget

BPDB has to check all of the plants' maintenance plans and budget. But every power plant submits its plan and budget one by one. It is thought that it is hard to make an objective, rough estimate of the necessary expense for BPDB as a whole beforehand. As a result, after ascertaining the whole plan and budget, they approve each power plant's plan, and this causes delays in approval. In conclusion, a maintenance plan for several years for all power stations is not gathered in objective form and this is

an issue.

(2) Shutdown permission

It seems that Power Div does not have all power plants' maintenance plans; therefore, there are few judgment grounds to shut down a power station in a particular time. It is necessary to coordinate with individual power stations and to judge accordingly and, as a result, judgment for the shutdown permission is late.
The above 2 items cause time delays.

(3) Does not reach rated output

There are several kinds of reasons, like lack of power supply, inability to shut down and repair, lack of information for repair work, inability to get manufacturer support and the long time taken to purchase needed parts and, because of these reasons, many power units cannot reach rated output.

(4) LTSA

Regarding gas turbine plants, many power stations are not allowed to make LTSA contracts with manufacturers. The purposes of LTSAs are as follows: on-time parts supply, emergency correspondence, and measures for technical issues. However, because these power stations do not have LTSAs, they depend on past experience to deal with malfunctions. Combustion also needs replacing every 1-2 years, but because combustion needs budget approval and shutdown permission they have to wait, they cannot replace things on time, and then they have to operate at a decreased output.

(5) Efficiency

They do not care about power plant efficiency. In the near future, Bangladesh needs to import LNG from overseas. This means that fuel prices are getting high, and generation costs are getting high. The Bangladesh government plans to introduce high efficiency thermal power units, improve average thermal efficiency, and reduce fuel costs. Japan also does the same, so it is a good idea, but there are some problems. For example, they do not analyze every day and every hour efficiency, and do not carry out performance tests just after maintenance work is done. These items are needed to ascertain the change in situation after the maintenance operation period. In Japan, because almost all fuel has to be imported, fuel cost reduction is a very important issue in every sector; thus, each sector has its own targets and takes measures. Bangladesh also needs targets and to take measures.
Bangladesh faces the following problems.

Severe condition of power supply:
-> Power plant cannot shut down but has to operate
  -> Power plant stops suddenly
    -> Power supply decreases
      -> Other power plants have to operate

Due to this, it is in a "negative spiral".

18.4.3 Budget

Budget and plan approval takes a long time as mentioned above, and this issue is caused by information not being gathered in an "objective" manner. Therefore, BPDB approves each power station's maintenance plan and budget only after fixing all of the plant maintenance plans.
The issue of LTSAs also exists. Because an LTSA includes a technical issue treatment fee, it is more expensive than only purchasing needed parts, but it includes a "certain supply of periodic replacement

parts" and "needed parts will be supplied when emergency trouble happens". Considering the actual situation, LTSA is a useful and efficient countermeasure for stable operation.

18.4.4 Information

Actual conditions depend on past experience and measures taken for malfunctions. They cannot get manufacturer support and there is no positive information sharing among power stations. It also means that power station staff's technical levels stop at some point, because they cannot get any more information. If they can share trouble-related information, they can learn suitable countermeasures and prevent the trouble from happening again. To achieve this, they need an information sharing strategy.

18.4.5 Problem Analysis

Almost all power stations mentioned the delay in maintenance work, which is mainly caused by a delay in BPDB approval of maintenance plan/budget, and a delay in shutdown permission from Power Div. BPDB has to check all of the plants' maintenance plans and budget. But every power plant submits its plan and budget one by one. It is thought that it is hard to make an objective, rough estimate of the necessary expense for BPDB as a whole beforehand. It is also found that Power Div. does not have all power plants' maintenance plans; therefore, there are few judgment grounds to shut down a power station in a particular time. It is necessary to coordinate with individual power stations and to judge accordingly and, as a result, judgment for the shutdown permission is delayed. The survey results include some more problems such as the run-to-failure policy, the absence of manufacturer's support, and the procurement delay of spare parts.

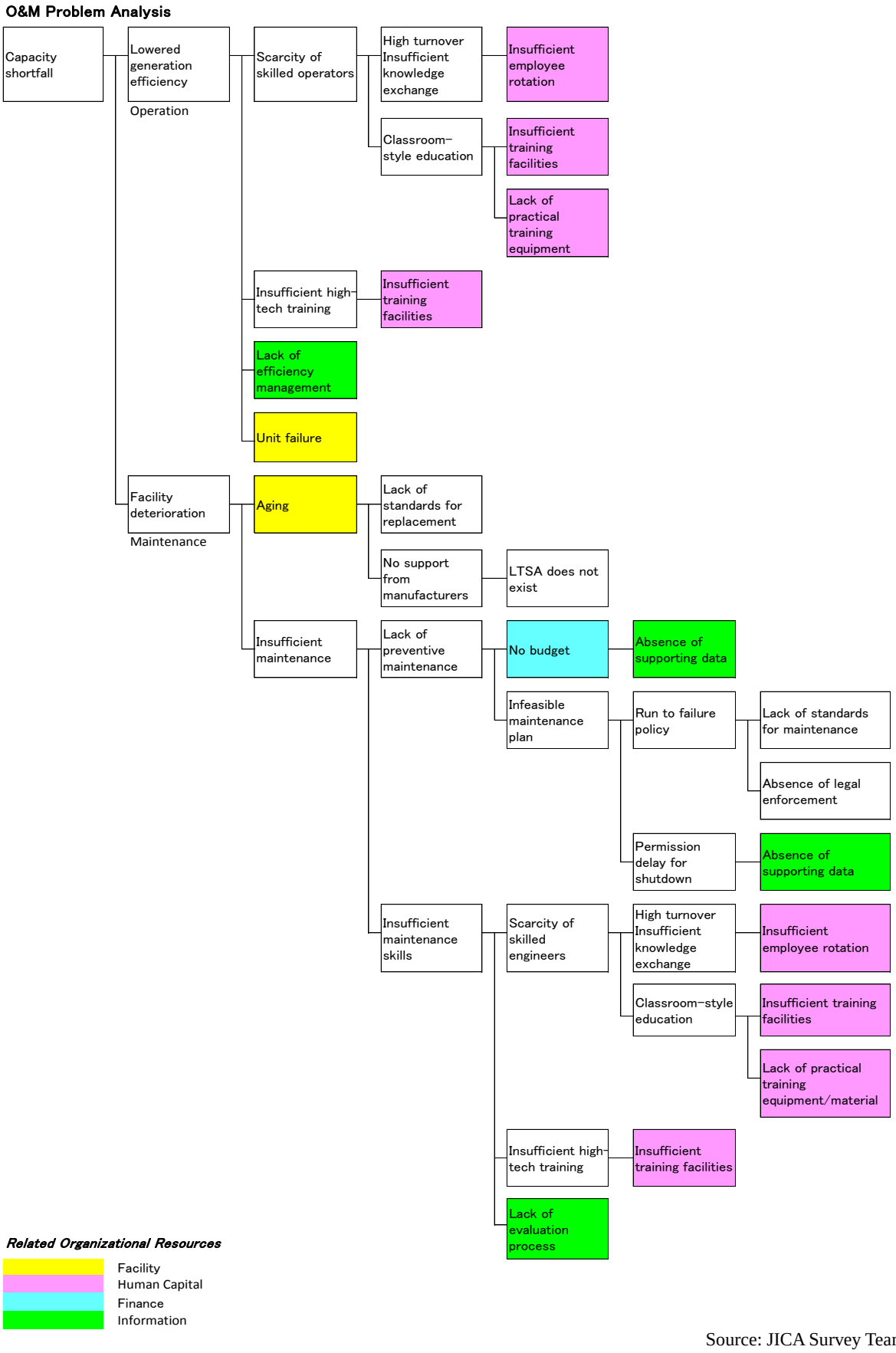
The problems are categorized into Human Capital, Facility, Finance, and, Information which are commonly referred to as organizational resources in management of an enterprise. As shown in the table below, the problems exist across the organizational resources.

Table 18-13 Summary

Human Capital	- Classroom-style education, no opportunities to lean dos and don'ts - Low awareness of safety
Facility	- Capacity shortfall - Infeasible maintenance plans - Permission delay for shutdown - Low awareness of efficiency
Finance	- Budget approval delay - No LTSA policy
Information	- No support from manufacturers - Lack of knowledge sharing among power plants

Source: JICA Survey Team

The figure below shows the problems and the causes in an analytical way based on the problem tree analysis technique.



Source: JICA Survey Team

Figure 18-16 Problem Tree Analysis

Table 18-14 Problems in Organizational Resources

Core Missions and Areas	Human Capital	Facility	Finance	Information
Generation Capacity	—	Unit failure. Aging.	—	—
Daily Operation	Insufficient employee rotation. Lack of practical training equipment. Insufficient training facilities.	—	—	Lack of efficiency management.
Maintenance & Repairs	Insufficient employee rotation. Lack of practical training equipment and material. Insufficient training facilities.	—	No budget.	—
Maintenance Planning and Budget Creation	—	—	No budget.	Absence of supporting data for maintenance plan and shutdown permission. Lack of evaluation process.

Source: JICA Survey Team

Some of the problems remain untouched in the tree, which are:

- Lack of standards for replacement
- LTSA does not exist
- Lack of standards for maintenance
- Absence of legal enforcement

These are firmly connected with the legal framework which should be enacted by the government. The problems exist out of the target organizations or the scope of operations and maintenance of power facilities. The details of the legal framework are explained in the previous section. However, regular maintenance can be applied before the legal basis is established.

In the next subsection, solutions to the problems are shown along with implementation proposals.

18.5 Solutions

18.5.1 Outline of solution proposals

As a facility enhancement solution for the capacity problem, this Study proposes rehabilitation and conversion to combined cycle. It also proposes the following plans to facilitate regular maintenance which requires information management and plant crew trainings.

Table 18-15 Solution Proposals

Core Missions and Areas	Human Capital	Facility	Finance	Information
Generation Capacity	—	Steam turbine rehabilitation & conversion to combined cycle. Scheduled maintenance.	—	—
Daily Operation	Training center equipped with simulators and hi-tech training materials. Work rotation.	—	—	Collection of unit data and fuel data, and efficiency monitoring.
Maintenance & Repairs	Training center equipped with real machines and hi-tech training materials. Work rotation.	—	Mid-to long-term maintenance budget.	—
Maintenance Planning and Budget Creation	—	—	Procurement based on maintenance plan. Financial efficiency monitoring and cost optimization	Database for budgeting, shutdown planning, investment decision making and evaluation.

Source: JICA Survey Team

The team proposes the following feasible plans to implement the solutions above, which are considered to be effective in facility enhancement, human capital development, and, strategic use of plant information for maintenance planning and budget creation.

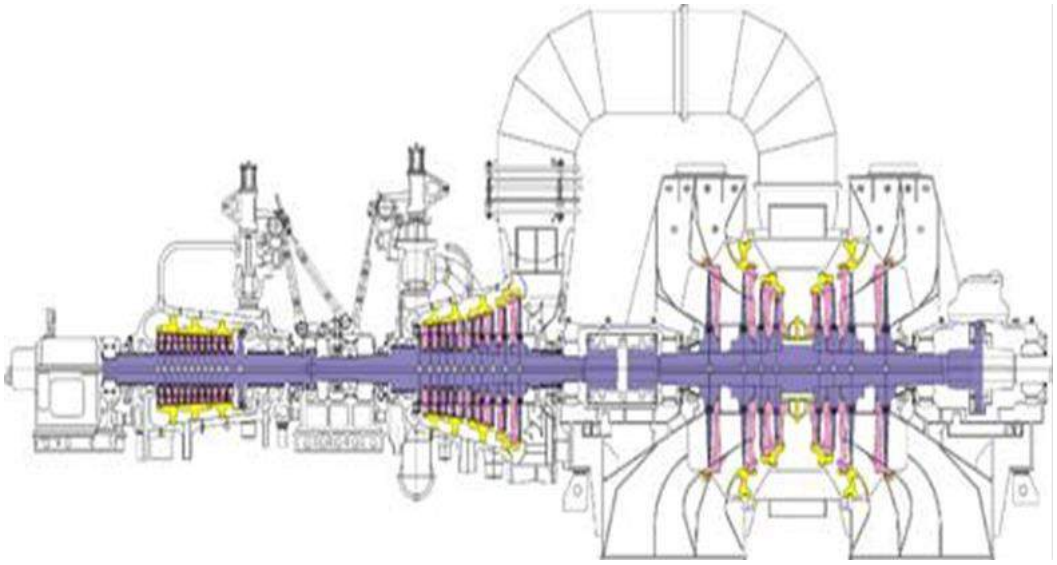
(1) Facility enhancement

Here, the JICA survey team suggests measures for the issues of “Does not reach rated output” and “efficiency improvement”. For recovering output or efficiency, the rehabilitation of facilities or combined cycle power generation remodeling are effective. Firstly, we introduce Japanese technology.

(a) Steam turbine rehabilitation

There are many steam turbine products made by the turbine manufacture, LMZ, in the former Soviet

Union, in Bangladesh. These LMZ steam turbines are already aged, and the original design efficiency is lower than that currently. In the LMZ series, Japanese manufacturers have rehabilitation experience of LMZ210 that was designed in the 1960s. The content of rehabilitation is mainly using the newest design blade. They have rehabilitation experience in Bulgaria, in 2010 and 2011, and finished the work successfully. Each steam turbine improved its output about 10-15MW. Therefore, rehabilitation is suitable for LMZ210MW and is a good selection.



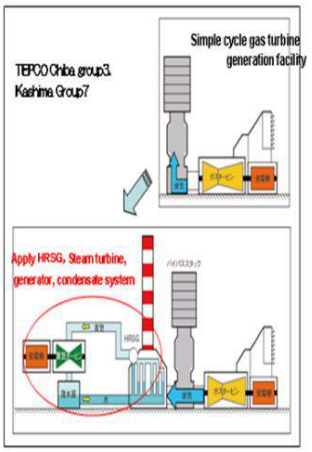
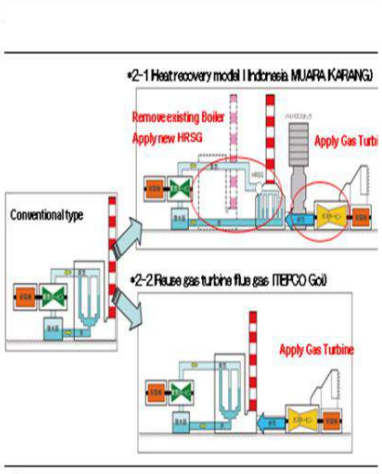
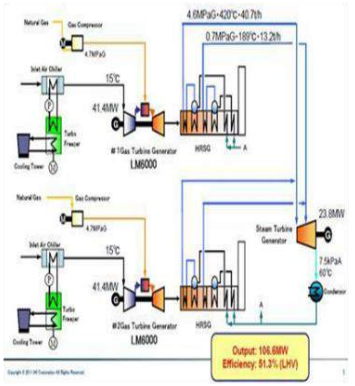
Source: JICA Survey Team

Figure 18-17 Steam Turbine Rehabilitation

Detailed study is mentioned in 18.6 Rehabilitation.

(b) Combined cycle power generation remodeling plan

For high efficiency and output reinforcement of the existing power stations, remodeling to combined cycle is one of the ideas. For combined cycle remodeling, there are two types of combined cycle applicable (CASE 1 and CASE 2) and the scrap & build model (CASE 3). CASE 1 is "Adoption of the bottoming system model" (HRSG, Steam turbine, generator and condensate system), and CASE 2 is "Adoption of Gas turbine model". A bottoming system model has been adopted at TEPCO's "Chiba thermal power station group No.3" and "Kashima thermal power station group No.7". As for "Adoption of gas turbine model", there are two types of model. One of them is the Heat recovery model (*2-1) which entails removing the existing boiler and installing a gas turbine and HRSG. The other one is the exhaust reuse model (*2-2) which entails installing a gas turbine, and the existing boiler reuses the exhaust gas of the gas turbine. The former (*2-1) has been adopted at "MUARA KARANG Power plant" in Indonesia, and the latter (*2-2) has been adopted at TEPCO's "Goi thermal power station unit No.6".

CASE 1	CASE 2	CASE 3
adoption of bottoming system model	adoption of gas turbine model	Scrap and build model
		

Source: JICA Survey Team

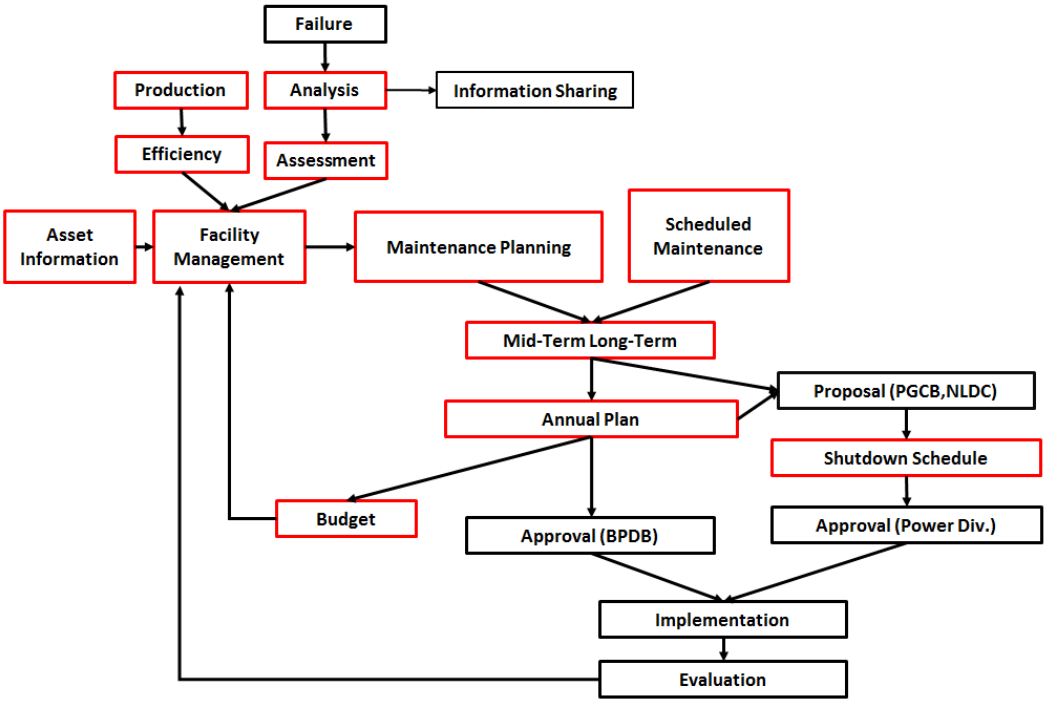
Figure 18-18 Combined Cycle Power Generation Remodeling Plan

Detailed study is mentioned in 18.7 Combined cycle power generation remodeling plan.

(2) Strategic use of plant information

For power station administration, information becomes important over all of the maintenance plan, budgets and techniques for facilities. Through the site survey, lack of information sharing and poor management causes many problems in various places. The generation company must understand the importance of information management and use this knowledge throughout its operations. To achieve this, they must utilize the visualization of data, timely data collection and data sharing, and it is necessary to promote the PDCA cycle of the business. To promote information utilization, they can manage things like a periodic inspection schedule and the budget for shutdown timing for each power plant, and can prevent blackouts and power supply over/under. This will also allow effective management for the power plants.

The following figure shows a sample from Japan. The red boxes show an example of effectively utilizing information.



Source: JICA Survey Team

Figure 18-19 O&M Best Practice Supported by Information Sharing System

In addition, Japanese utilities adjust the gap between supply and demand by coordinating it with the power grid control system section when making the maintenance plan. The following figure shows the flow of maintenance plan - supply-demand gap ascertainment before the adjustment.

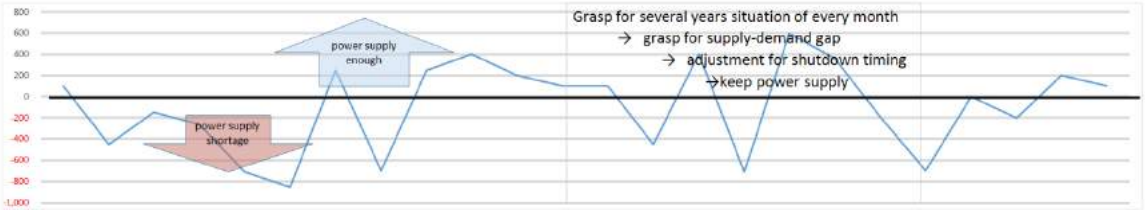
Maintenance plan for several years

maintenance plan	Year1												Year2											
Plant	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Plant A ; 450MW	0	0	0	0	-SD-	-SD-	0	0	0	0	0	0	0	0	0	-SD-	0	0	0	0	0	0	0	0
Plant B ; 660MW	0	0	0	-SD-	-SD-	-SD-	0	0	0	0	0	0	0	0	0	-SD-	0	0	0	0	0	0	0	0
Plant C ; 350MW	0	0	0	0	0	0	0	-SD-	-SD-	0	0	0	0	0	0	0	0	0	0	-SD-	0	0	0	0
Plant D ; 200MW	0	0	0	-SD-	-SD-	0	0	0	0	0	0	0	0	0	0	-SD-	0	0	0	0	0	0	0	0
Plant E ; 100MW	0	0	0	0	-SD-	-SD-	0	0	0	0	0	0	0	0	0	0	-SD-	0	0	0	0	0	0	0
Plant F ; 600MW	0	0	0	0	0	0	0	-SD-	0	0	0	0	0	0	0	0	0	0	0	-SD-	-SD-	-SD-	0	0
Plant G ; 550MW	0	0	0	0	0	0	-SD-	-SD-	0	0	0	0	0	0	0	0	0	0	-SD-	-SD-	0	0	0	0
Plant H ; 550MW	0	-SD-	-SD-	0	0	0	0	0	0	0	0	0	0	-SD-	0	0	0	0	0	0	0	0	0	0
Plant I ; 400MW	0	0	0	0	0	-SD-	0	0	0	0	0	0	0	0	0	0	0	-SD-	-SD-	0	0	0	0	0

Compare with demand forecast, ascertain supply-demand gap

power supply ability	Year1												Year2											
Plant	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Plant A ; 450MW	450	450	450	450	0	0	450	450	450	450	450	450	450	450	450	0	450	450	450	450	450	450	450	450
Plant B ; 660MW	660	660	660	0	0	0	660	660	660	660	660	660	660	660	660	0	660	660	660	660	660	660	660	660
Plant C ; 350MW	350	350	350	350	350	350	350	0	0	350	350	350	350	350	350	350	350	350	350	0	350	350	350	350
Plant D ; 200MW	200	200	200	0	0	200	200	200	200	200	200	200	200	200	200	0	200	200	200	200	200	200	200	200
Plant E ; 100MW	100	100	100	100	0	0	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	100
Plant F ; 600MW	600	600	600	600	600	600	600	0	600	600	600	600	600	600	600	600	600	600	600	0	0	0	600	600
Plant G ; 550MW	550	550	550	550	550	550	0	0	550	550	550	550	550	550	550	550	550	550	0	0	550	550	550	550
Plant H ; 550MW	550	0	0	550	550	550	550	550	550	550	550	550	550	0	550	550	550	550	550	550	550	550	550	550
Plant I ; 400MW	440	440	440	440	440	0	440	440	440	440	440	440	440	440	440	440	440	0	0	440	440	440	440	440
total of supply	3,900	3,350	3,350	3,040	2,490	2,250	3,350	2,400	3,550	3,900	3,900	3,900	3,900	3,350	3,900	2,590	3,800	3,460	2,910	2,400	3,300	3,300	3,900	3,900
demand forecast	3,800	3,800	3,500	3,300	3,200	3,100	3,100	3,100	3,300	3,500	3,700	3,800	3,800	3,800	3,500	3,300	3,200	3,100	3,100	3,100	3,300	3,500	3,700	3,800
Supply-demand(MW)	*100*	*-450*	*-150*	*-260*	*-710*	*-850*	*250*	*-700*	*250*	*400*	*200*	*100*	*100*	*-450*	*400*	*-710*	*600*	*360*	*-190*	*-700*	*0*	*-200*	*200*	*100*

Making graph



Source: JICA Survey Team

Figure 18-20 Illustration

Before the adjustment of the maintenance plan, making a graph like that shown above and reviewing the maintenance plan is needed to proceed with periodic maintenance. Of course, it also needs to be shared with PGC. To forecast several years into the future, the budget plan needs to be connected to the maintenance plan.

The significance of information management is explained in 18.8 Information Strategy.

(3) Human capital development

The human capital development proposal includes a new training facility with a practical training system (Training Center). The Training Center is purported to provide trainees with:

- High-tech education for new power facilities.
- Practical training courses and opportunities to experience real operations and maintenance practices.
- Education for certifications in compliance with laws and regulations.

In order to meet the training demand, the study mentions about inviting trainees to Japan during the construction of the training facility.

The details of the proposal for human capital development are explained in 18.9 Training center.

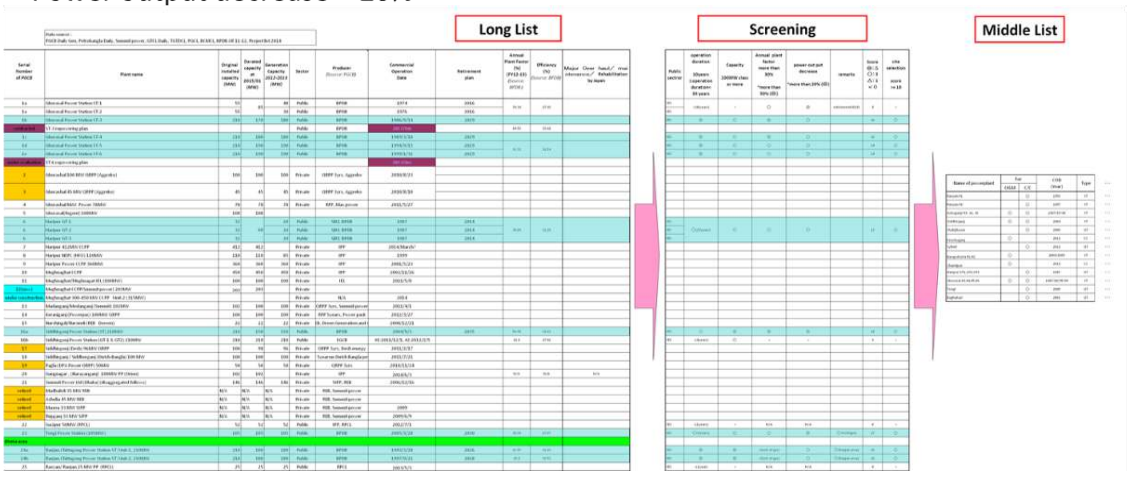
18.6 Rehabilitation

18.6.1 Rehabilitation considerations

According to 18.2.1 (1) O&M target site selection, target sites were selected. The following is an illustration of the selection.

Long list (all of the Bangladesh power plants) to middle list, according to the following conditions

- Public owned
- 10 years < operation duration < 30 years
- Capacity > 100 MW
- Power output decrease > 20%



Source: JICA Survey Team

Figure 18-21 Long-Mid List Selection Illustration

Middle List (21 plants of 12 sites) to short list, according to the following conditions

- Land space
- Grid capacity
- Gas supply

Middle List

Name of powerplant	For		COD (Year)	Type	Fuel	Installed	Derated	Plant factor	Efficiency (NET)	Working group	Donor	visited	visit plan
	O&M	C/C				(MW)	(MW)	(%)	(%)				
Rauzan #1		○	1993	ST	Gas	210	200	21.55	31.26	×		2014/11/29	-
Rauzan #2		○	1997	ST	Gas	210	180	15.80	32.53	×			
Ashuganj #3, #4, #5	○	○	1987/87/88	ST	Gas	450	390	97.64	36.16			2014/11/30	-
Siddhirganj	○	○	2004	ST	Gas	210	150	56.98	32.63			2014/12/3	-
Barapukuria #1,#2	○		2009/2009	ST	Coal	250(125*2)	200	75.37	31.47				2015/3/8-3/9
Chandpur	○		2012	CC	Gas	163	163	49.68	39.38				2015/3/23
Tongi		○	2005	GT	Gas	105	105	38.38	27.07	○			2015/3/24
Ghorasal #3,#4,#5,#6	○	○	1987/89/95/99	ST	Gas	420(210*2)	360	69.53	33.68	×	○		2015/3/25
Shahjibazar		○	2000	GT	Gas	70(35*2)	66	76.36	25.63		○		2015/3/29
Fenchuganj	○		2011	CC	Gas	104	104	49.08	31.95				2015/3/30
Sylhet		○	2012	GT	Gas	150	142	51.96	29.86		○		2015/3/31
Baghabari		○	2001	GT	Gas	100	100	87.52	28.36		○		2015/4/1
Haripur GT1,GT2,GT3		○	1987	GT	Gas	32*3	60	38.09	21.26				2015/4/2

Short List

Select 3-4 sites for Conversion / Rehabilitation

○ : World Bank "A Power Sector Investment Strategy Framework for Bangladesh, July 2014"

JICA Survey Team will investigate ADB and other donor in next site survey

Source: JICA Survey Team

Figure 18-22 Mid-Short List Selection Illustration

Because they are adopting the LMZ 210MW type steam turbine, Ghorasal #4 & #5 and Siddhirganj were selected as steam turbine rehabilitation candidate sites, and budget and calculation of the cost-effectiveness were estimated as follows.

18.6.2 Cost-effectiveness

Estimated cost for steam turbine replacement is about 30 million US dollars, and its output will increase about 10MW. Estimated operation years will be 30 years, but other equipment will not be replaced; therefore, we are using boiler operation years. Generally, the operation period of a boiler is 30 years; thus, the estimated operation period is 30 years - boiler operation years.

	Site name	Target unit	COD	capacity condition				output increase	Estimated Cost	Unit price	Efficiency		Manufacture support	Remaining plant life after rehabilitation (plant life time 30years)	Year cost
				installed	de-rated	remarks	New								
				A	B	C	D	D-C	Mill dollar	mill dollar / MW	after	now			Mill dollar
ST rehabilitation	Ghorasal	Unit4	1989	210	180	180	190	10MW	30	3.0	improved	37.8 (*3) / 28.8 (*2)	Toshiba	5	0.60
	Ghorasal	Unit5	1994	210	190	190	200			3.0				9	0.33
	Siddhirganj	Unit1	2004	210	110	110(gas limitation)	120			3.0		33.8 (*1)		19	0.16

Source: JICA Survey Team

Figure 18-23 Cost-effectiveness of Turbine Rehabilitation

Estimated cost to increase power output is 3 million US dollars/MW. Considering Boiler operation years, investment cost per year is as follows.

Ghorasal unit 4	0.6 million US dollars/year
Ghorasal unit 5	0.33 million US dollars/year
Siddhirganj	0.16 million US dollars/year

However, when the JICA survey team visited the power station, the staff mentioned that Siddhirganj's Power unit generator has a problem and it has a 150MW limitation. Unless the generator is repaired, there is no point in pursuing steam turbine rehabilitation. Therefore, it is excluded as a target.

18.6.3 Power station comments

According to the above idea, the JICA survey team got some comments from Ghorasal power station.
*Currently, unit 4 is under overhaul, and unit 5 will start overhaul from next February.
Therefore, they are not thinking of rehabilitation with huge expense.
*They need the idea that the output greatly increases, like unit 3 and unit 6
An answer on turbine rehabilitation where Japanese technology could be utilized was not provided.

18.7 Combined Cycle Power Generation Remodeling Plan

18.7.1 Combined cycle power generation remodeling examination

According to 18.2.1 (1) O&M target site selection, target sites were selected the same as for turbine rehabilitation. Based on the target power station selection, the JICA survey team carried out further target narrowing. The characteristics of each plan, CASE 1, CASE 2 and CASE 3, and narrowing method are as follows:

(1) CASE 1 Adoption of the bottoming system model

Adoption of the bottoming system model is adopting HRSG, Steam turbine, generator and condensate system in the existing gas turbine plant. Operation years of the existing gas turbine is the important point. The JICA survey team found that BPDB already has plans to upgrade gas turbines currently in operation to combined cycle power generation. If the gas turbine has already been operating for 10 years or more, maintenance and modification is needed for the gas turbine itself before combined cycle remodeling. Because of the basic philosophy of site selection, the JICA survey team selected an operation period of more than 10 years; therefore, an old gas turbine's combined remodeling plan needs gas turbine rehabilitation, and so, the adoption of a bottoming system has technical and cost difficulties.

(2) CASE 2 Adoption of gas turbine model

Adoption of the gas turbine in the existing boiler-turbine plant. Before the site visits, the JICA survey team regarded Ghorasal power station unit 3 – unit 6 and Ashuganj power station units 3, 4 and 5 as target candidates for combined remodeling. However, Ghorasal power station already has a plan for combined cycle remodeling for unit 3 and unit 6, and unit 4 and unit 5 do not have enough space to adopt gas turbines. In addition, Ashuganj power station has a scrap and build plan until 2023: they will scrap units 3, 4 and 5, then build combined cycle power generation plants in sequence. For Siddhirganj power station, although there is enough space to build, because steam turbine generation has a problem the steam turbine generation needs to be repaired first. Therefore, the JICA survey team decided to remove it as an examination candidate.

(3) CASE 3 Scrap & build (S&B) model and build & scrap (B&S) model

This case means to scrap the existing power plant first, then build a new combined cycle power generation plant. First of all, the scrap and build (S&B) plan is not suitable for Bangladesh, because scrapping the existing power generation plant first causes severe conditions for the Bangladesh power grid system.
This plan needs more than 2 years from shutdown and scrap to start of power generation. Therefore,

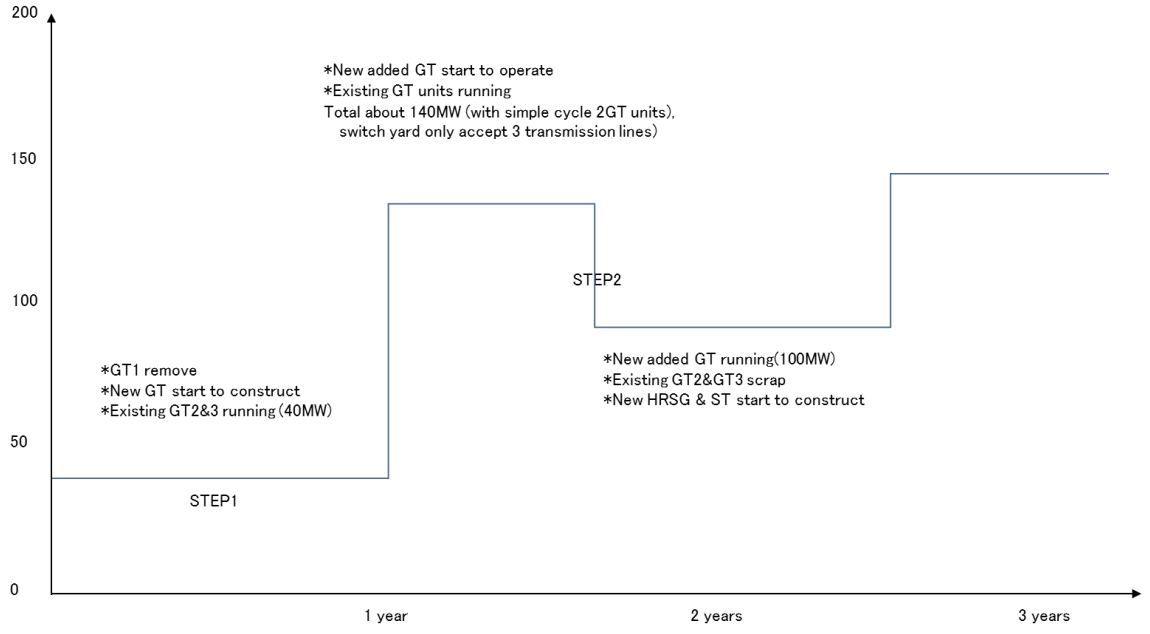
the JICA survey team proposes the build and scrap (B&S) model - that is, construct a new gas turbine and start operation first, then scrap the existing power plant and construct a new HRSG and steam turbine next. It is a very severe situation to build a new gas turbine next to an operating Power plant, and it is also risky to construct new equipment because the underground situation is not clear. However, thinking about the current situation in Bangladesh, it is an unavoidable method.

Combined cycle power generation remodeling case	Target site	Target unit	Propriety	reason
Adoption of the bottoming system model	Shahibazar	35MWGT	×	Gas turbine is too old to remodel
	Baghabari	100MWGT	×	Gas turbine is too old to remodel
	Sylhet	150MWGT	×	They have combined cycle power generation remodeling plan
Adoption of Gas turbine model	Ghorasal	unit4,5	×	No space
	Ashuganj	unit 3,4,5	×	will be retired till 2023 and they have CCGT construction plan
	Siddhirganj	unit1	×	Generator problem
Scrap & build (S&B) / build & scrap (B&S) model	Fenchuganj	unit 1,2	○	-
	Haripur	1,2,3GT	○	-

Source: JICA Survey Team

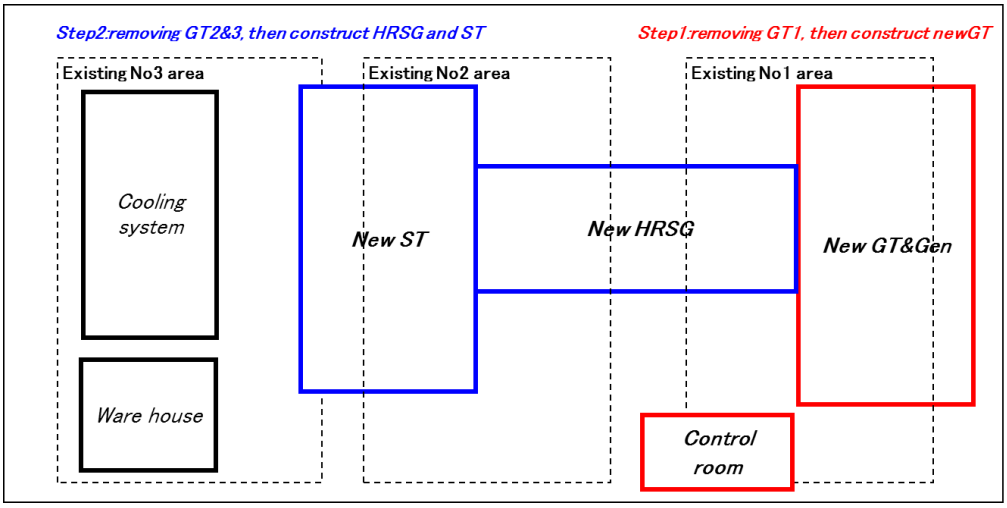
Figure 18-24 Application Judgment by Each case

Below is an illustration of the Haripur B&S construction schedule and the layout for Haripur and Fenchuganj.



Source: JICA Survey Team

Figure 18-25 B&S Schedule with Power Output



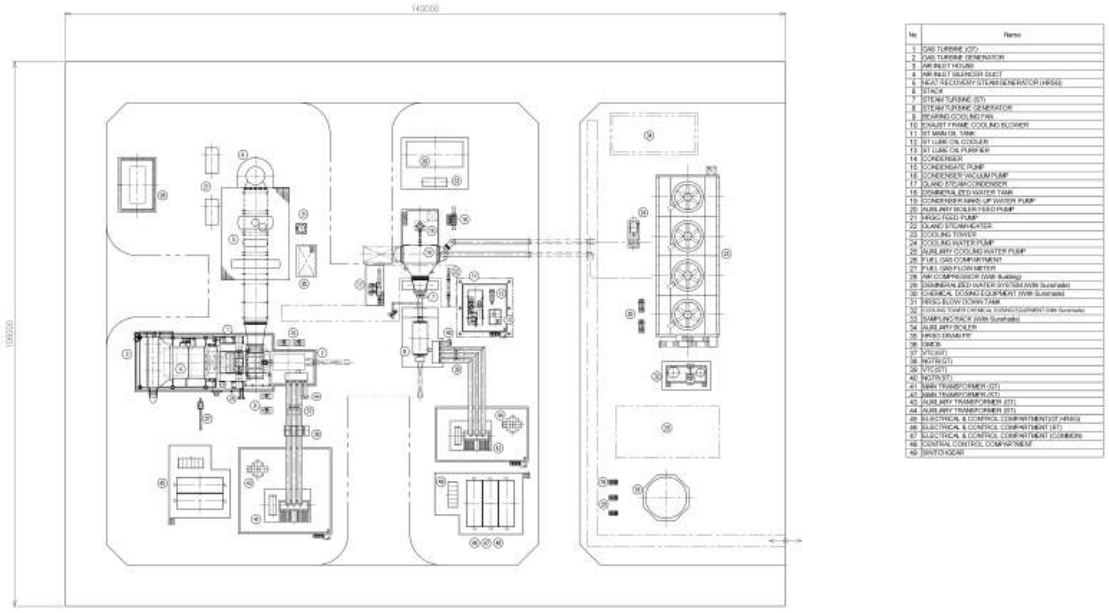
Source: JICA Survey Team

Figure 18-26 B&S Image on Old Haripur Area



Source: JICA Survey Team

Figure 18-27 Haripur Layout



Source: JICA Survey Team

Figure 18-28 150MW Combined Cycle Layout Image

18.7.2 Frequency instability problem in Bangladesh and small class gas turbine combined cycle generation plant

One of the problems that the electricity sector in Bangladesh has is that the band of the frequency is big (more than 50Hz +/-1Hz). To stabilize this frequency instability problem, it is very effective, due to the following reasons, to install the latest combined cycle plant.

Reasons:

(1) It is a very short time from long term shutdown to startup complete.
(2) High efficiency during low load operation.

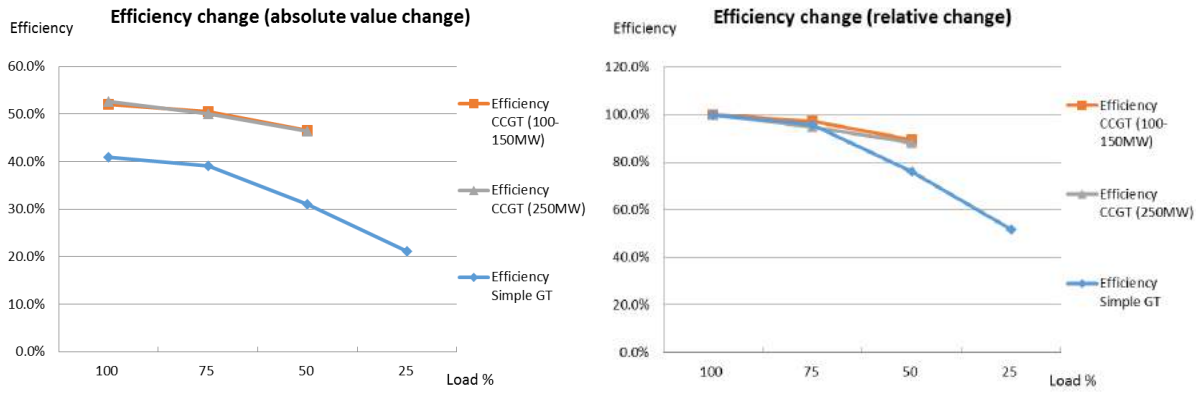
(1) First of all, concerning the startup period, it only takes 2 hours just after cold start up to full load operation, as per the following figure. This means that if you know demand peak just 2-3 hours before, you only order start up for this small combined cycle plant and the plant startup finishes just on time.

Plant capacity	Hot start	Cold start	efficiency
400MW Class CCGT	1hour	6hours	50%
250MW Class CCGT	< 1hour	4hours	50%
100-150MW Class CCGT	0.5hour	2-3hours	50%
Simple GT	0.5hour		40%(new) 30%(old)

Source: JICA Survey Team

Figure 18-29 Short Start Time Characteristics and Efficiency

(2) The following figure shows efficiency change with load % between 100-150MW, 250MW and simple cycle units. The newest combined cycle plants can maintain high efficiency compared with a simple cycle gas turbine plant and a 100-250MW unit can maintain high efficiency during load change.



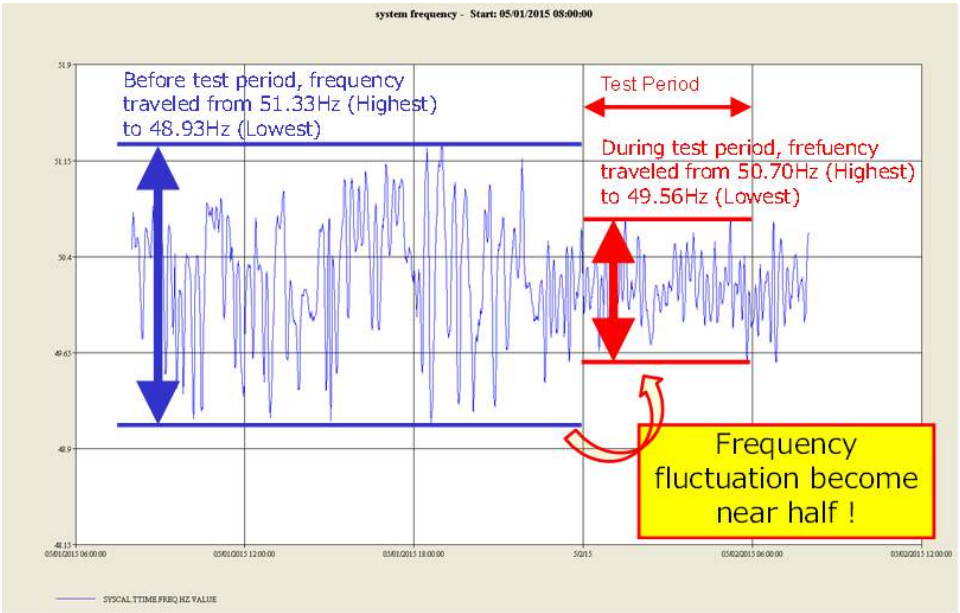
Source: JICA Survey Team

Figure 18-30 Efficiency Comparison

From this, it is very significant to install a 100MW class combined cycle power generation plant to solve frequency instability.

18.7.3 Cost-effectiveness

One of the problems that the electricity sector in Bangladesh currently has is that the frequency band is very big (more than 50Hz +/-1Hz). One of the methods to resolve this is to make a 100-250MW combined cycle unit and adjust the system frequency. We can see by the results of the test at Khulna power station, carried out on May 2nd 2016 at a 150MW capacity unit, that it is useful for adjusting the frequency fluctuation.



Source: JICA Survey Team

Figure 18-31 Frequency Fluctuation Record during Test Operation in Khulna Power Station

Although, simple cycle gas turbine can adjustment its power output, but not efficiently (please see Figure 18-30 Efficiency Comparison) .Because its efficiency is to suddenly decrease with a load drop. Therefore combined cycle is advantageous.
On the other hand, combined cycle needs a slight start-up period (a few hours) from cold start mode condition. Therefore, it is necessary to have accurate demand forecasting for several hours ahead and for the start order to be given promptly when the load control center judges it is necessary. Cold start mode is caused by around a 1 week shutdown period. As unit capacity gets larger, the steam turbine also gets larger, and if the steam turbine is large the start-up time will be long. Therefore, 150-200MW class combined cycle would be suitable for Bangladesh.
Power unit capacity and expense will be examined in the feasibility study.

18.8 Information Strategy

18.8.1 Presumptions

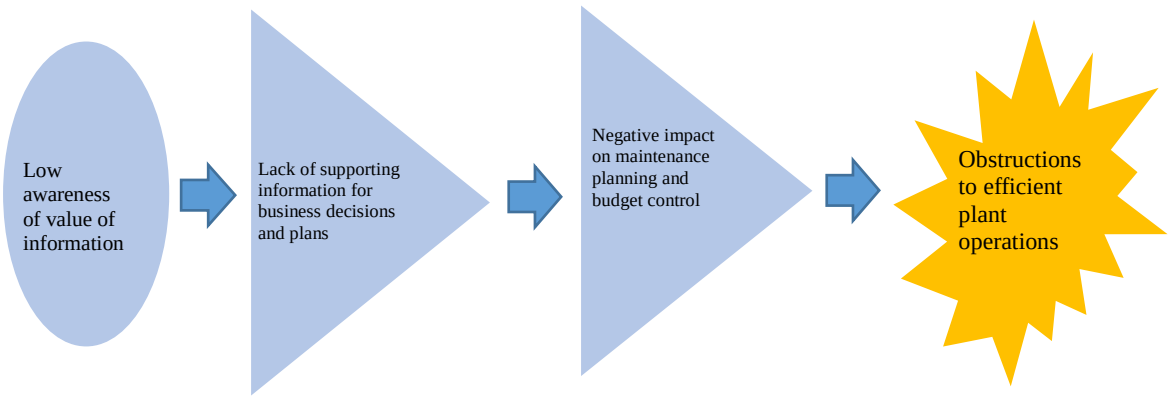
As mentioned in the previous sections, some of the problems in operation and maintenance can be solved by installing new facilities and rehabilitating ongoing facilities. This section explains that the main problems the country faces can be broken down into smaller problems, some of which are caused by lack of information. Based on the survey results, the JICA team made a hypothesis that the following descriptions of the current situation may be connected with the risk factors which cause the problems.

Table 18-16 Conventional Information Management Practices and Risk Factors

Category	Current Situation	Risk Factors	Affected Performance Factors
Acquisition of Plant Data	No data logger Manual meter reading	Human errors Time inaccuracy	Accuracy
Recording of Plant Data	Paper based	Human errors Overheads	Accuracy
Delivery of Plant Data	Verbal conversation	Miscommunication	Accuracy
Other Information Handling	Paper documentation	Document loss Data obsolescence Access/reference inconvenience	Accuracy Efficiency Responsiveness
Reporting	One month delay in monthly report writing	Slow decision making Negative Impact on maintenance planning and scheduled shutdown	Efficiency Readiness Responsiveness

Source: JICA Survey Team

According to the survey results, the descriptions of information handling show how information management is typically performed at the power plants. However, the overall impression of the results implies that there is a big problem in the mindset of the plant workers, who are satisfied with the conventional way of information handling. Lack of motivation for improvement in their work performance can be the biggest problem when the risk factors may cause negative outcomes in terms of accuracy, efficiency, responsiveness and readiness. The figure below shows how the efficiency in plant operations is affected by the low awareness of information handling.



Source: JICA Survey Team

Figure 18-32 Current Situation and Obstructive Factors

18.8.2 Information management strategy

In response to impending demand growth, the power sector of Bangladesh is trying its best to keep the facilities operating. The plant operators know that their facilities are deteriorating faster than those which are properly maintained. A problem lies in the absence of sufficient information to answer a simple question: How much faster?
The survey results are mainly based on information gathered through interviews and meetings with the sector representatives. The findings indicate that there are some challenges in information management. In particular, lack of supporting data for practicing preventive maintenance, planning and creating a feasible budget are the key problems which need to be addressed in priority.
Power generation companies nowadays are familiar with a range of activities, each of which is driven by the economic value of the significance of managing information. As measurable achievements are always expected, it is clear that continuous performance monitoring is key to successful plant operations. An integrated strategy for information management through the entire lifecycle of a power plant is required to facilitate effective data acquisition and sharing. This section explains how to implement information management in a modern power sector, and shows an overview of the conceptual model of information management for a power plant in Bangladesh.

18.8.3 Goal and objectives

(1) Goal of information management in power generation sector of Bangladesh

Our goal is to achieve the best practice for a modern power sector in the field of Operation and Maintenance by facilitating a business process cycle to run towards improvement based on measurable achievement.

(a) Set a framework for effective information management for business efficiency
(b) Enforce information management strategy throughout the organization to strengthen organizational capacity
(c) Enforce improvement cycle by monitoring and measuring results

(2) Rationale

In general, commercial entities engaging in business process improvement set a performance framework in which efficiency and productivity are continuously monitored and analyzed. The survey results indicate that effective use of operation data can be the key to successful plant management in terms of reliability and economic efficiency. It appears that, at least in some power plants, paper based

document handling is replaced by computer file operations and email systems. However, all the processes are managed in isolation and the information is not shared with other business units and power plants across the organization. For example, in one of the power plants, computers are used to write monthly reports for the management team. It takes about a month to complete a report because the information sources are dispersed through various processes and their timings are different. Another example is a disruption between the planning phase and field activities. Most of the power plants answer positively to a question about the significance of scheduled maintenance while many of them keep failing to actually implement it.

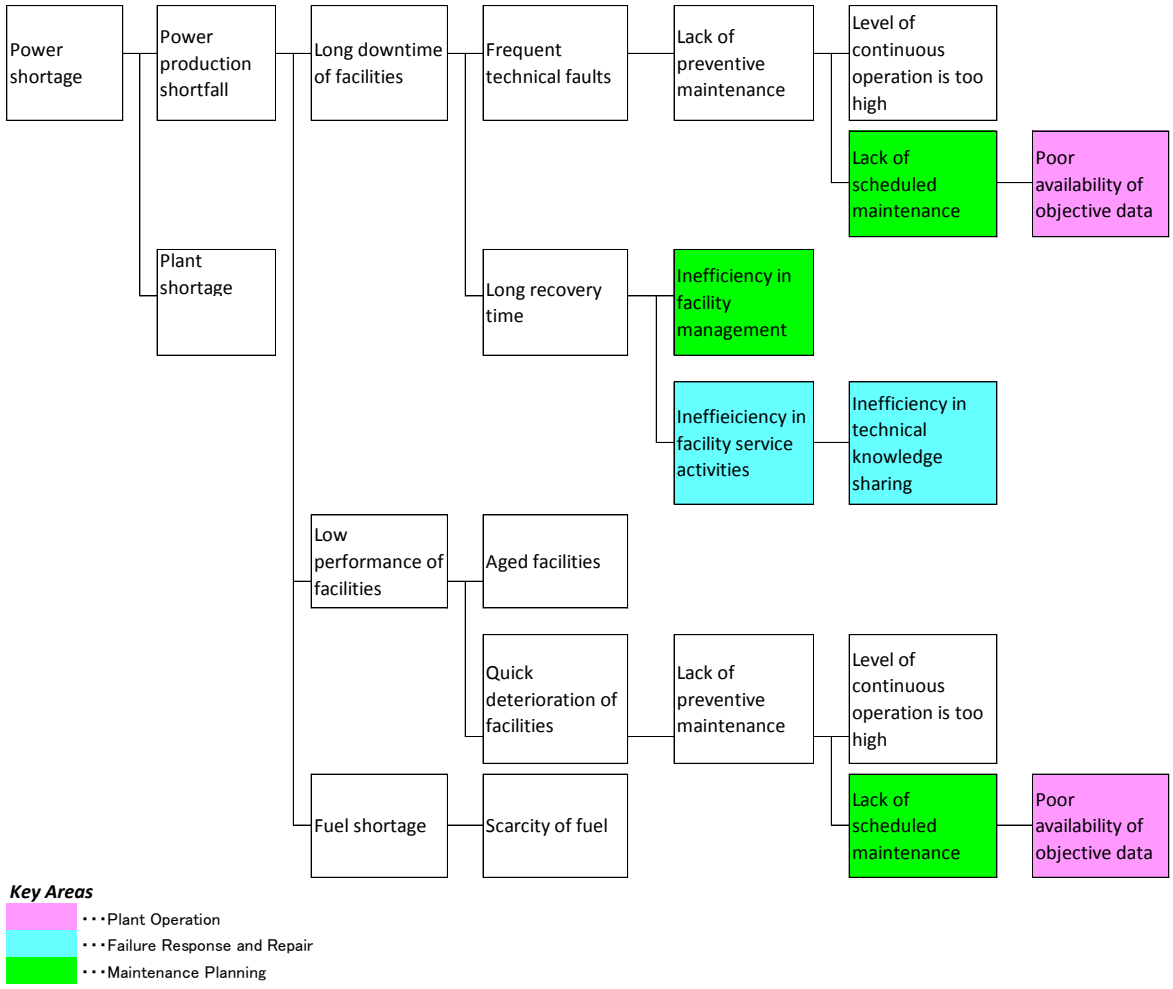
Typically, organizations have a hierarchical structure with multiple divisions, each of which is responsible for a specific activity such as plant operation, maintenance, procurement, administration or planning. Analytical use of accumulated information from daily and monthly reports enables the planning division to estimate future costs for maintenance of and repairs to the facilities which can be more accurately budgeted, while condition based maintenance enables scheduled shutdown for maintenance. Scheduled maintenance also contributes to procurement efficiency. The results of improvements should be observed as changes in various performance indicators.

As mentioned above, replacing paper documents with computer files only makes limited improvements in business efficiency. It is necessary to build a platform for information management integrated across the organization, from field activities to corporate management, from procurement to production, so that making efficient and effective use of information can be achieved.

Competitive business practices often demonstrate how they enforce the improvement cycle, a series of continual steps of Plan, Do, Check, Act. In order to achieve the goal, the business objectives must be aligned with the organizational strategy for information management. In implementation of the cycle, the Plan phase defines key performance indicators and sets baselines as measurable achievements. In the Do phase, performances are measured throughout the organization. The Check phase is for evaluation of the results. If there is any difference between the expected results and the actual results from the activities, corrective actions are taken in the Act phase. Information management strategy depicts the ‘what’, ‘when’, ‘where’, ‘who’, ‘how’ and most importantly ‘why’ of information handling through the cycle. Some of the ‘whys’ are answered in the problem analysis as shown below.

(3) Challenges

Based on the survey results, a problem tree analysis was performed in order to find the key problems which have caused the current situation. The main problems the country faces today are broken down into manageable factors. The key problems fall into three areas from the viewpoint of business processes: Maintenance Planning, Plant Operation, and Failure Response and Repair.



Source: JICA Survey Team

Figure 18-33 Problem Tree Analysis and Key Problems

The biggest problem the country faces today is power shortage, which is presumably caused by:

(a) The number of power plants is too small, or the total capacity of the plants is too little.
(b) The production level of each power plant is not sufficient.

The former is a factor for which we can expect solutions out of the scope of information management. The latter is caused by:

(a) The facilities are not fully operating.
(b) Performance of the facilities is low.
(c) Fuel shortage hinders power plants from achieving maximum performance capacity.

The first one is caused by long downtime. The second one is perhaps caused by aged facilities. However, some of the factors can be improved by the application of proper maintenance. The problem of fuel shortage is not within the scope of information management. However, if the fuel sources change in the future, efficiency in procurement and inventory control can be improved by implementing information management.
As for maintenance, which appears three times in the breakdown, we focus on the significance of preventive maintenance, which requires effective handling of data and documents, knowledge and planning skills. Failure response plays a large role in the downtime of a power plant. By organizing historical data which contains a lot of lessons to learn, the crew can take appropriate actions quickly.

The findings from the tree analysis are meaningful leads to envisage higher efficiency in the activity areas. For example, most of the power plants have difficulty applying preventive maintenance because facility data is not effectively collected. Although preventive maintenance needs a large amount of data for the physical state assessment of facilities, most of the power plants do not have an elaborate information platform to handle a wide variety of types of data which keeps growing.
Another example of a finding is process disruption. In failure response, looking up failure history is a common practice. However, the case records are stored in a software application in an isolated manner. Maintenance and repair activities involve various administrative tasks such as staffing, scheduling, purchasing and hiring contractors. At some power plants, it takes a long time for approval when a procurement request is filed. In this case, the obstacle between maintenance and procurement is the lack of plan and budget.
The three activity areas are actually the core processes of the power generating business and do not operate independently. Therefore, it is pointless to single out a problem from the activity areas and try to fix it. Poor information management and process disruption are the obstructive factors in many cases observed in the organization.
The table shows the obstructive factors found from the survey results. Efficiency is measured by the performance indicators commonly used by many companies. The organization perceives the performance of the processes through its key performance indicators which are, from an enterprise perspective, aligned with the organization's resources. This means that improvements in the activities' performances are measureable and quantitatively assessable.

Table 18-17 Obstructive Factors Found in the Survey

	Enterprise Resources		
	Human Asset	Facility	Finance
Obstructive Factors Found from Survey	Inefficient use of historical data Poor communication between business units	Heavy dependence on manual handling, paper based handling of data Weak interaction between engineering and administrative fields, or business units in the organization Poor management of process cycle	Weak awareness of cost due to lack of up-to-date supporting data Traditional governance on expenditure due to lack of forecast
Performance Factors Possibly Affected	Failure Responsiveness Employees skills	Performance Indicators in Power Generation (Reliability, Availability) Facility Lifecycle	Financial Indicators (ROE, ROI)

Source: JICA Survey Team

Although, from the managerial point of view, the primary objective of indicators is to have a clear view of the operational performance and set standards for the organization, it is not realistic to cover all the performance factors across the power plants. It also requires the management team to set a framework to define meaningful indicators and keep tracking them. While most of the power generation companies focus on reliability, availability, safety and efficiency, other areas such as environmental impact should be considered in compliance with government regulatory changes. In the implementation effort on information management and sharing, designing a flexible system is crucial to embrace such changes in the business environment.

(4) Conclusion

Survey results indicate that there are some problems in the three core activities of the power

generation business: plant operation, failure response, and maintenance planning. The problems are mainly caused by the absence of sufficient information and process disruption. Regardless of the level of management, activities need objective data to support improvement efforts.
The management team and the business units of the organization can achieve their improvement goals by carefully choosing meaningful performance indicators from a wide variety of types of information. Therefore, an integrated strategy for information management through the organization is necessary. This can be implemented by setting a framework for data acquisition and sharing, and interaction between business processes. Once the processes are established and the information for sharing is defined, it is very easy for the activities to make a plan, take an action, measure the efficiency and apply the results in decision making. This improvement cycle should be enforced across the organization so that the processes of the activities can work together by sharing information, which will bring higher efficiency in the overall activity of the organization. And then, the achievement will be perceived as the effective use of enterprise resources such as human assets, facilities and money.

18.8.4 Integration of information management strategy

(1) Key processes

The key problems (factors) identified and categorized in the tree analysis affect the performance of the organization as a whole. The table below shows how the problems are connected with the organizational performance from the point of view of enterprise resources. The activities in the colored cells of the table correspond to the colored boxes in the problem tree.

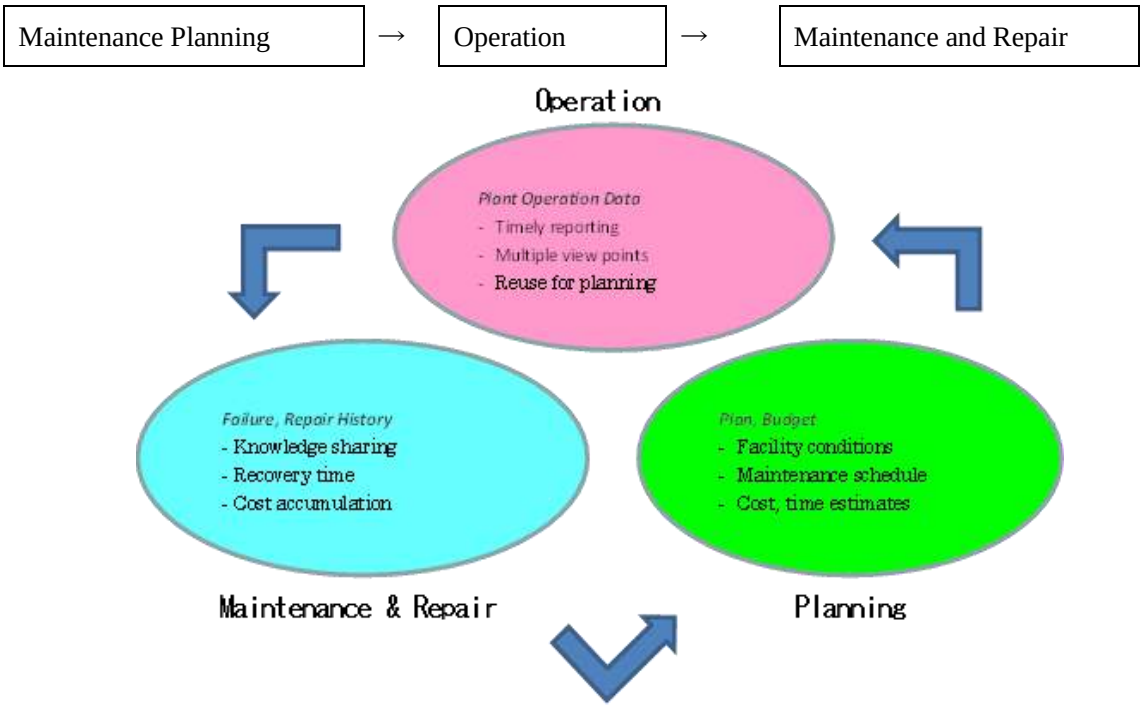
Table 18-18 Key Problems in the Three Key Activity Areas

Activity/Resource	Human Asset	Facility	Finance
Plant Operation	―	Data loggers and information networks do not exist at some power plants.	―
Maintenance Planning	There is some need for technological enhancement.	Generally, facilities often keep performing until a forced outage occurs. Spare parts' inventory control is respectively implemented at power plants.	Budgeting and procurement planning processes are complicated. Maintenance plans often fail.
Failure Response and Repair	Although failure records are available, knowledge and know-how is not available to share.	Activities are not linked with facility conditions. Activities are not linked with procurement.	Total cost of owning the failed equipment is not managed. Past repair costs are not traced.

Source: JICA Survey Team

(2) Process cycle and data

The three activity areas are the key processes (or core processes) of the power generation business, which typically has a business process cycle as below.



Source: JICA Survey Team

Figure 18-34 Business Process Cycle in the Power Generating Business

The cycle has a fixed time period and occurs at different levels of management. Its focuses are broken down into detailed parameters and shared across the power plants and other business units. The frequency of monitoring and controlling varies depending on the level of management. Monthly reporting to the head office creates a control point at plant level while daily walkthrough reports are firstly delivered to the relevant manager who has span of control in the engineering field. The most important point is that those business process cycles across the hierarchy and structure of the organization are synchronized. Our objective is to set a framework for information management integrated through the organization, so that the management team and all of the business units can achieve their performance goals, which are measured by key performance indicators regardless of the level of management or the profession.
In order for the cycle to keep moving towards improvements, selection of appropriate data (parameters) is the key. The following are the data areas corresponding to the business process and the challenges the processes have followed by improvement ideas for the data areas.

(a) Plant Operation Data

Inefficient reporting processes often hinder quick managerial analysis and decision making, which is caused by the fact that information management relies heavily on manual handling. Timely reporting and analytical re-use of plant operation data lead to the efficient management of a modern power sector.
Switching from paper based reporting to information systems, aiming for:

- Timely, accurate, analytical, visualized presentation of plant performance
- Re-use of data for planning and budgeting

(b) Failure, Repair History

Although a software application is used for failure management at some power plants, it is not

integrated with other systems. The management process is isolated and also handled manually. It is not easy to allocate optimal resources to the failure response team. History data, accumulation of know-how and lessons learned should be organized and shared by the field crew and transferred to other business units such as the procurement division for other purposes. For example, collectively controlling spare inventory across power plants, parts sharing and having an internal purchase program can contribute to a reduction of procurement overheads. Also, assessment of failure impacts improves the readiness for possible failures.
Knowledge sharing, aiming for:

- Accumulation of knowledge to help crew solve impending problems
- Reduction of response time, recovery time
- Improvement in activity efficiency based on lessons learned from history
- Learning opportunities for field engineers
- Case studies for other plants which own similar equipment.

Integration between failure trends, activities, procurement and budget, aiming for:

- Smooth procurement of spare parts and optimum replacement
- Spare inventory optimization
- Control of Total Ownership Cost

(c) Plan, Budget

A number of research studies and analysis results suggest that corrective maintenance costs more than preventive maintenance. Although it usually takes time to recognize the effects of preventive maintenance, sufficient data will be acquired to support rationalization of planned shutdown instead of forced shutdown in response to facility failures. It is also expected that implementing scheduled maintenance and procurement contributes to financial efficiency by optimizing inventory level and budget.
Creation of feasible maintenance plan, aiming for:

- Improved readiness for possible malfunction by predicting based on facility condition
- Accurate time and cost estimates
- Budget control, optimal procurement plan and spare inventory
- Grasp of facility lifecycle cost, investment decisions
- Facility life extension by performing proper maintenance

Implementing scheduled shutdown, aiming for:

- Mitigation of impact on the grid
- Reduction of opportunity cost and start-up/shut-down cost

18.8.5 Implementation of information management system

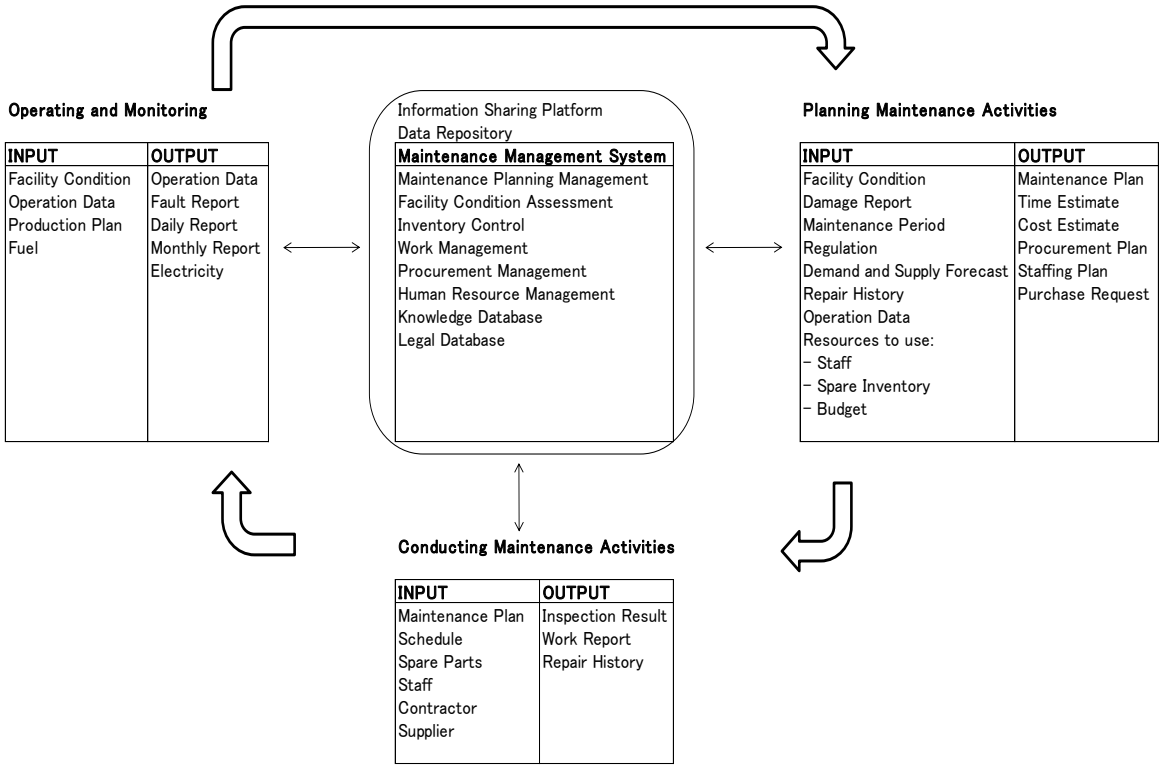
(1) Information sharing platform

The three core activity areas and data areas in the cycle have various works which are performed by either people or computers. For example, data collection can be done by receiving paper documents or computer files. Maintenance plans are created primarily based on the physical state of the facility. Requirements from laws and regulations and manufacturers' recommended maintenance periods are taken into account as well. Maintenance managers also have to care about blackout schedules, staffing and procurement. Thus, data collection involves a lot of manual work and document handling. An information sharing platform allows all business units to access the necessary data to complete their

work. Procurement managers can update purchase plans upon request from maintenance managers. The benefits of the use of an information sharing platform are:

(a) Centralized information management mitigates problems arising from data proliferation.
(b) Business processes are easily controlled and interactions are facilitated.
(c) It can be flexible and scalable.

The figure shows an example of the implementation of the maintenance process cycle on the information sharing platform. Each phase has Input and Output, of which information comes in various ways such as paper documentation, verbal conversation, and email and computer files. Therefore, it is very important for the management team to set a framework for an organization-wide information management strategy. Once the data handling rules are decided, the data repository stores the various types of information in a uniform, structured manner.



Source: JICA Survey Team

Figure 18-35 Information Sharing Framework for Maintenance Activities

Concerns in collecting data from day-to-day activities vary depending on the level of management. The information management framework defines a set of indicators aligned with the performance goals of the activities. By carefully choosing parameters and their delivery methods, effective data collection can be achieved.
The table shows an example of a set of performance factors and information sources required to measure or calculate the organizational performance on each level of management. Data acquisition and delivery methods influence how efficiently the information is collected. Manual meter reading and manual data entry into an application system can be replaced by automated data acquisition in order to reduce delays and errors in reporting processes.

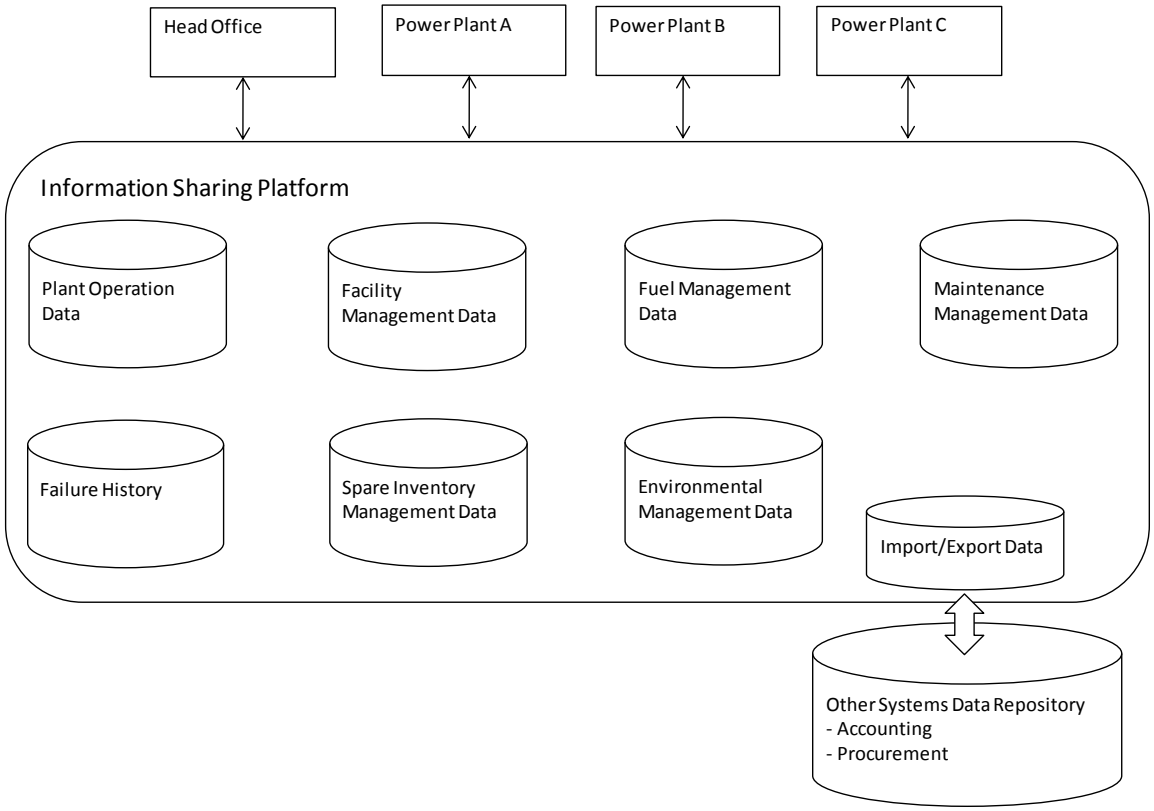
Table 18-19 Examples of Performance Indicators and Data Sources

		Performance Factor	Example of Information Source – Data Delivery Method	Data Acquisition Method
ENTERPRISE LEVEL	Financial Performance	Financial Performance Indicators	Accounting Data – Computer Files from Accounting System	Manual Data Entry
	Facility Condition	Reliability Availability Efficiency	Plant Operation Data – Computer Files from Data Loggers Damage Report – Paper Document Walkthrough Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing
	Human Asset	Number of Incidents Number of Qualified Employees Turnover	Human Recourse Data – Computer Files from HR Periodical Report – Paper Document from Power Plants	Manual Data Entry Manual Report Writing
PLANT LEVEL	Productivity	Production Consumption Thermal Efficiency	Plant Operation Data – Computer Files from Data Loggers Periodical Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing
	Maintenance Efficiency	Budget Balance Downtime	Activity / Procurement Plan – Paper Document Purchase History – Computer Files from Accounting System	Manual Data Entry
	Fault Management	Fault Responsiveness Downtime	Activity Report – Paper Document	Manual Data Entry
	Environmental Impact	Emission Effluent Discharge Disposal	Emission Data – Computer Files from Data Loggers Periodical Report – Paper Document	Direct Transmission from Monitoring Devices Manual Meter Reading Manual Report Writing

Source: JICA Survey Team

The information sharing platform connects Head Office and other business units seamlessly. Information flows are orchestrated and reporting processes are simplified. Although there are some legacy systems being used in some business units, most application software products have functions to export and import data in standard formats which allow the systems to interact with the integrated information management system on the platform. This function can be extended to external organizations such as grid operators.

The figure below shows an example of a platform for information sharing. The platform provides the system users with data sharing functions through a range of user interfaces of application systems. The main functions are database access and file handling.



Source: JICA Survey Team

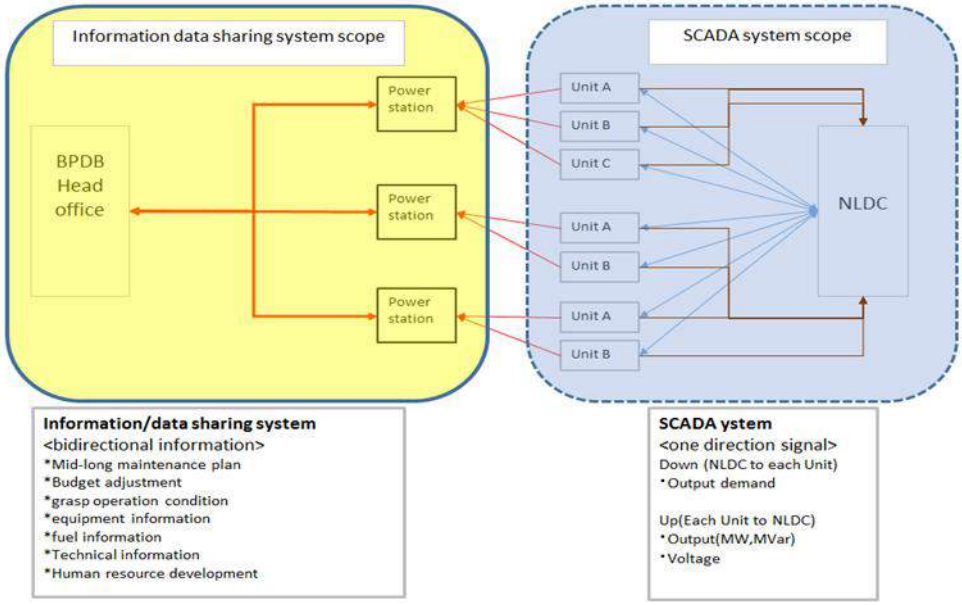
Figure 18-36 Conceptual Model of the Information Sharing Platform

(2) Integrated plant operations management system

According to the survey results, some power plants have application systems for the management of operational information which includes failure history. It is necessary to take into account such valuable information assets in the legacy systems when implementing a new system. Management of legacy data must be part of the organization-wide integration strategy for information management. ERP and EAM are examples of integrated application systems to provide data sharing functions in a uniform manner to various types of users who use the system for different purposes. One of the advantages of ERP or EAM is that data and business processes are structured based on the sector's standards. Configuration of the system includes templates for business processes and target data as well as report formats and data table formats which can be customized to meet the company's requirements. As mentioned before, the flexible and scalable platform allows the application system to embrace changes in organizational structure or policies. Interfaces with external organizations are usually available.

The figure below shows the scopes of the information management system and the SCADA system, which connects the dispatch center and the power plants.

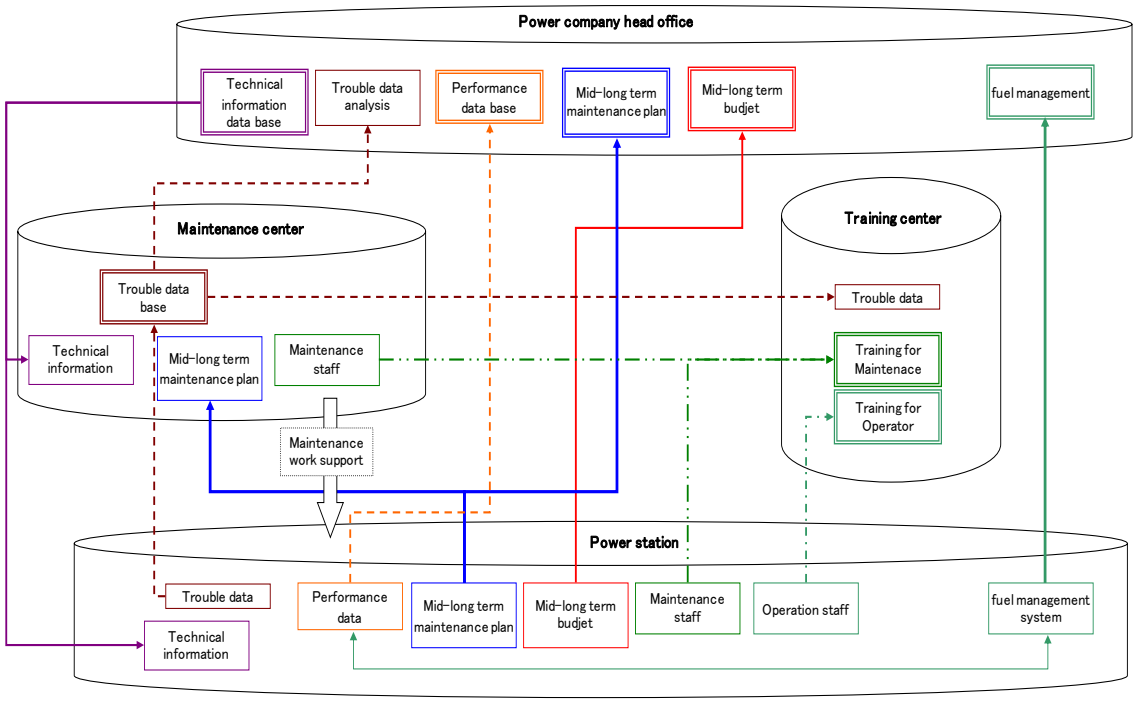
The SCADA system is an independent network system which does not share its purposes with the information management system.



Source: JICA Survey Team

Figure 18-37 Scope of Information Sharing System and SCADA System

The figure shows a conceptual model of a Thermal Power Plant Operation Management System envisioning future implementation of information sharing among current business units and new agencies, Maintenance Center and Training Center. Maintenance Center is a data repository for technical information, maintenance information, failure response support and data collection. It also provides field support services during facility inspection. Training Center provides training services to plant operators and maintenance engineers. While maintenance activities and training activities are performed separately, the improvement cycle of facility operation and maintenance as a whole can be practiced effectively by controlling the data flows on the platform. The scope of the system covers maintenance knowledge, maintenance plans, activity results and failure information, which appear in the diagram below as data flows between business units.



Source: JICA Survey Team

Figure 18-38 System Functions and Data Flows for a Power Plant in Bangladesh

(3) Application modules

The system consists of the three main components for business functions listed below. The users of the system can work concurrently through the information sharing platform by either accessing one of the modules or accessing the interface and files from other application systems which are integrated with the system.

(a) Production Management
(b) Maintenance Management
(c) Failure History Management

New modules can be added to the system for future extension. For example, if the government is going for new environmental regulations, an Environmental Management System can be introduced. Fuel Management may be added in the future if a new facility which uses coal as fuel is installed. The following explains the functions of each one of the main modules.

(a) Production Management

This module is equipped with presentation tools for visualization of plant performance. Data is mainly collected from the power generation facility. For some of the parameters used for calculation of plant performance indicators, data acquisition relies on manual entry. Key performance indicators vary depending on the level of management.

- Data acquisition frequency and report period settings
- Graphs and tables for analysis
- Data aggregation and comparison for multiple levels of management

(b) Maintenance Management

A project management tool to create plans and manage activities. By focusing on resources such as staff, materials and money, maintenance managers can monitor the efficiency of maintenance work and budget balance.

- Schedules and work progress management
- Procurement plans and budget control
- Maintenance and repair history management

(c) Failure History Management

Case database linked with facility maintenance information. Information on the failed equipment and associated information is handled in a collective manner. Preventive maintenance requires historical data for the equipment, by reference of which a decision on further investment for the equipment can be made.

- Assistance to field crew to search similar cases
- Management of cost information along with technical information
- Organized data which is reusable for training purposes.

An additional module may be considered for the future installation of new facilities as the country's energy policy shifts from natural gas to coal.

(d) Fuel Management (For Future Plans)

The users of this module can keep track of the status of the fuel from procurement to delivery. The information contains the amount of fuel unloaded and its cost. Monthly report indicates the purchase trends, which can be useful information for procurement planning.

- Management of fuel transport, reception, inventory, delivery
- Management of fuel property and quality
- Management of fuel prices and associated cost

(e) Ash Disposal Management (Matarbari and other coal fired facilities)

In order to ensure environmentally sound disposal and recycling, it is crucial to keep track of the status of the coal ash the facility generates. This module covers transport and disposal costs, from budgeting to payment to contractors. Contractors are paid based on the amount of ash processed. The system holds the qualification information of the contractor and the contract information including unit prices for disposal.

- Management of ash produced
- Management of budget, cost and payment
- Management of contract information and price

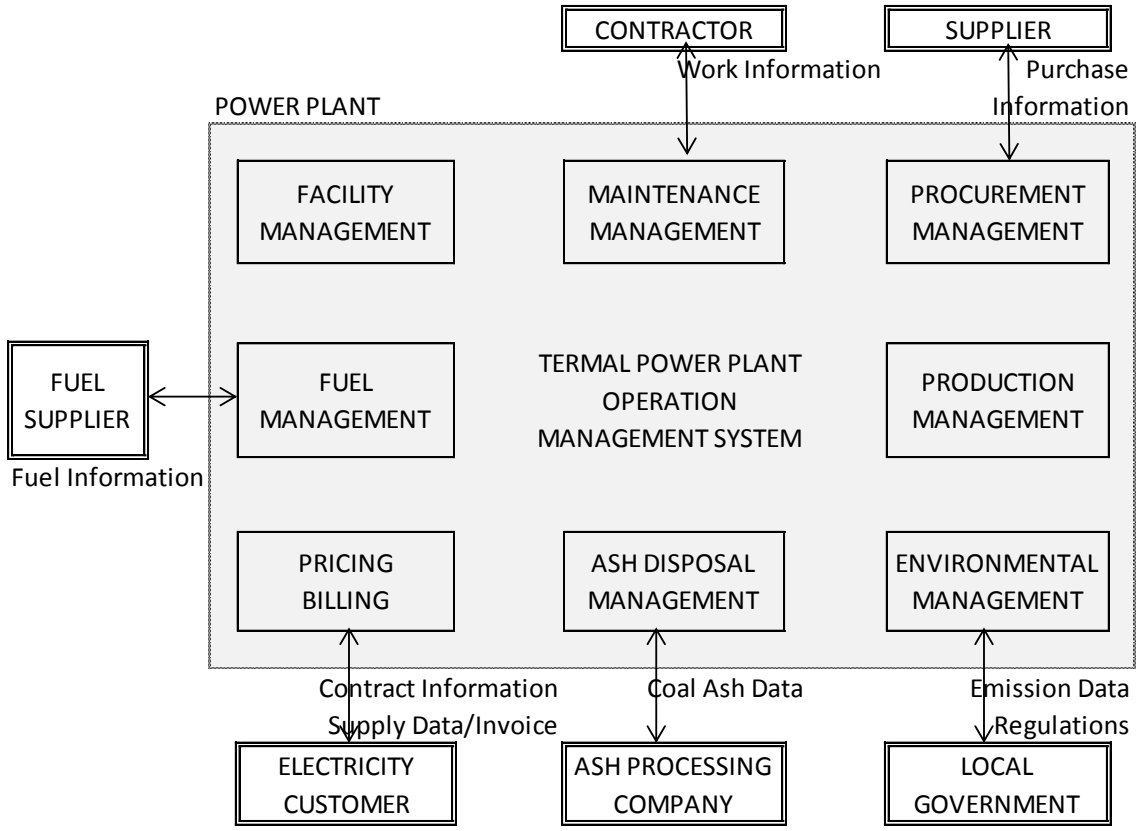
(f) Environmental Management (Matarbari and other coal fired facilities)

Emissions, effluents and waste data collected by monitoring devices. As the country's energy policy changes, the emissions associated with coal burning should be a concern in the short term. In the future, this module can be enhanced in compliance with the standards of an Environmental Management System (EMS).

- Management, analysis and assessment of monitoring data.
- Regulatory documentation and reporting.

(4) Example for further enhancement

As shown above, the system will be enhanced in the future to suit the business growth and meet the requirements from the market in Bangladesh. As a further example of best practice for information management aimed at higher reliability and efficiency, an overview of the power plant information management system at one of the leading companies in Japan is shown in the figure below.



Source: JICA Survey Team

Figure 18-39 Modern Information Management System in Japan

Over the past two decades, the company has injected efforts in information management as part of its achievements for maintaining reliability and efficiency. The challenge is to deal with the various types of facilities which are dispersed across more than 10 locations near the demand places in populated regions. On top of the inefficiency of paper based documentation, isolated systems on PCs limit the efficiency of data handling. One of the solutions to the challenge was to integrate the core business systems on an enterprise-wide network platform.

In Japan, power facilities are maintained with highly sophisticated information technology. The scope of information management includes environmental impact, safety, regulatory compliance, accountability to shareholders and social responsibility. The power sector is under severe watch by the government, and often in the center of public attention; therefore, the impact of information on its business is huge. Predictive maintenance technologies are also the key to successful operations of the high-performance large-capacity facilities. In consideration of future growth and market changes in Bangladesh, this implementation can be a good example of best practices in information management.

18.8.6 Implementation proposal

(1) Preparation for successful implementation

Strong leadership from top management is required for drawing up a plan for implementation of the integrated information management strategy. Relationships between business processes represent roles and objectives of the business units in the improvement cycle, which defines what information to share. While plant operators focus on maintaining production level, field engineers decide which piece of equipment needs to stop. Production planning and maintenance planning should be working concurrently by sharing schedules and facility condition data. The procurement manager needs to know when purchase requests will be filed from the maintenance manager because delays in supplier selection and financial arrangement lead to an overall delay in maintenance works, which may result in a longer downtime.
It might be a time consuming task to draw all the blueprints for information and process flows across the organization. Therefore, phased implementation is recommended. In a phased implementation approach, implementation is done by gradually replacing conventional business processes and data handling with new systems based on the new information strategy. The management team is expected to prioritize the business objectives and carefully select performance indicators which are to be shared on the data sharing platform. As the platform is flexible and scalable, it is a feasible way to introduce new application systems step by step.
In the preparation for the implementation, there are many points which need to be considered. The priority processes must be examined to determine which tasks can be automated and which data can be accommodated in the data repository. Strategic ICT planning includes the following points, each of which must be addressed.

(a) ICT Infrastructure
- Data Acquisition from Power Generation Facility
- Plant LAN (Local Area Network)
- Data Repository (Data Center)
- Enterprise Network

(b) Management
- Business Process
- KPI (Key Performance Indicators)
- External Organizations (Suppliers, Contractors, etc.)
- Employee Training

(c) ICT System Operation
- Legacy Systems and Data Integration
- ICT Policies and Guidelines
- ICT Education

In order to address the points listed above, further survey is expected to be carried out as shown below.

Table 18-20 Items Expected to be Addressed in Further Survey

Category	Item	Details
ICT Infrastructure	Data acquisition from power generating facility	Connectivity between facility and data acquisition devices
		Data parameters, collection periods
	Plant LAN	Local Area Network availability in power plants
	Data repository (Data Center)	Data center location, storage capacity and scalability
	Enterprise network	Network availability, connectivity among business units and multiple locations, and its security, reliability and capacity.
Management	Business process	The three core business processes, tasks and their business requirements.
	KPI	Framework setting for KPIs and other indicators.
	External organizations	Interaction with stakeholders, data sharing scope and rules. Interaction with legal framework.
	Employee training	PC users and employees' computer literacy
ICT System Operation	Legacy systems and data integration	Legacy systems and legacy data.
	ICT policies and guidelines	ICT policy setting. Guidelines for operating and maintaining the information management system.
	ICT education	ICT staffing and the required skills.

Source: JICA Survey Team

(2) Implementation options

There might be some modifications needed to the current business processes. The organization must respond to the requirements from the market, which rapidly keeps changing. The procurement policy may change to accept new suppliers or new energy sources, or to reflect new contract types of purchase or outsourcing of repair work. While the information management system can be flexible and scalable to embrace changes, conventional business processes may well remain unchanged due to the rigid structure of the organization based on roles and functions. In order for the process cycle to keep moving towards improvement, there are several options in which some part of the processes may be redesigned.

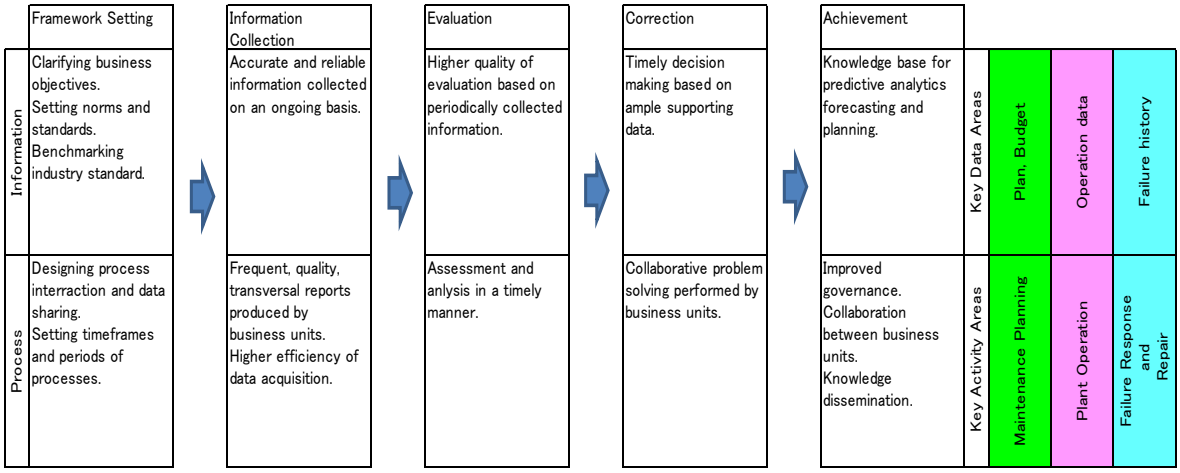
Table 18-21 Implementation Options and Process Modification Options

	Business Process Change		
System Implementation Options	No Process Change	Partial Modification	Process Reengineering
Configuration of Application System	Not realistic. Feasibility study is required to know if system best suits process. Legacy system is a burden.	Take advantage of business templates. Feasibility study is required to know which process to modify to suit the system. Data redundancy and duplication of work remain.	Take advantage of business templates. Quick implementation. Most economical but radical. Suitable for startups. Move from legacy system to new system.
Customization of Application System	Use business templates and out-of-box functions. Integrate with legacy system. Initial cost is relatively high.	Use business templates and out-of-box functions. Integrate with legacy system. Cost is relatively high.	Use business templates and out-of-box functions. Integrate with legacy system. Less expensive. Data redundancy and duplication of work remain.
Development of Tailored Application System	The processes do not need to change if they are performed through best practices. System may be inflexible and vulnerable to environmental change. Initial cost is high.	Carefully designed system can be flexible. Cost is high.	Develop system which best suits the organization. Align system to business strategy. Integration with legacy system is guaranteed. Long term ICT strategy is required.

Source: JICA Survey Team

18.8.7 Expected results

By promoting certain practices such as process interaction and information sharing, positive results will be obtained in the key activity areas. The figure below shows the sequence of intended events by implementing the information management strategy in the power generating business.



Source: JICA Survey Team

Figure 18-40 Improvement Cycle and Otcomes

As a result, the following improvements in the three core activity areas will be expected.

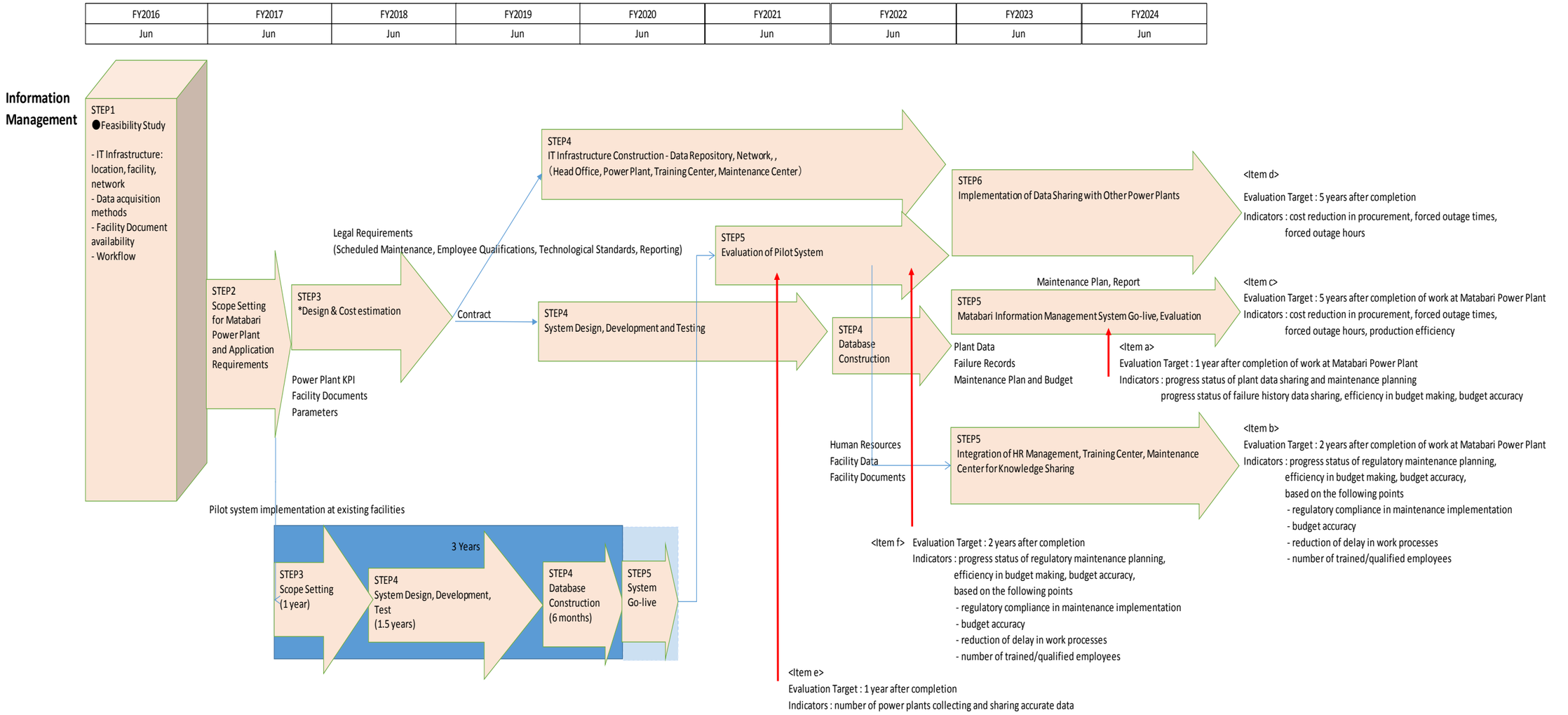
(a) Maintenance Planning
- Ensuring regulatory compliance.
- Accurate time and cost estimate for maintenance enables precise budget control, and optimization of procurement and spare inventory.
- Ascertainment of facility lifecycle cost and optimum investment decisions brings financial efficiency.
- Facility life extension by applying proper maintenance reduces total ownership cost.
- Implementing planned shutdown mitigates impact on the grid, and reduces opportunity cost and start-up/shut-down cost.

(b) Plant Operation
- Timely collected, accurate and reliable data improves the quality of evaluation and decision making, which contributes to facility assessment and maintenance planning.
- A wide variety of types of data, which is structured and assorted in a uniform manner, facilitates process interaction for problem solving and improvement.

(c) Failure Response and Repair
- Knowledge base helps field crew solve impending problems and reduce recovery times in the case of failure.
- Improvement in activity efficiency based on lessons learned from history will be achieved.
- Roll-out of maintenance techniques.
- Process interaction and data sharing with procurement leads to a reduction of total ownership cost and inventory cost.

In consideration of application of new regulations and technological standards, the information management system can bring largest benefits when it is implemented at a new facility such as Matarbari Power Station. In order to maintain the cutting edge facility to ensure the high performance

and efficient operation, sophisticated management methods should be introduced, which should embrace the dynamic changes of the business environment such as legal and market requirements. The figure below shows the implementation timeframes targeting Matarbari site along with evaluation timings and indicators for expected effects.



Source: JICA Survey Team

Figure 18-41 Implementation of Information Management System at Matarbari Power Plant

The evaluation timings and indicators are listed below.

Category : Information Management

＜Item a＞

Target Year	One year after completion of work at Matarbari
Indicators	Achievement of plant data sharing, accumulation, scheduled maintenance
Criteria	Number of parameters for KPI, maintenance plans, activities accomplished
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item b>

Target Year	Two years after completion of work at Matarbari
Indicators	Achievement of scheduled maintenance, budget process efficiency, accuracy
Criteria	Compliance: 100% (Number of qualified employees), unbudgeted expenditure: 0, process delay: 0
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item c>

Target Year	Five years after completion of work at Matarbari
Indicators	Procurement cost, forced outage, downtime, generation efficiency
Criteria	(Benchmarking) Cost reduction: 2.5%, forced outage: 0, reduction of downtime: 7.5%
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item d>

Target Year	(Pilot implementation) Five years after completion of work
Indicators	Procurement cost, forced outage, downtime, generation efficiency
Criteria	(Benchmarking) Cost reduction: 2.5%, forced outage: 0, reduction of downtime: 7.5%
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

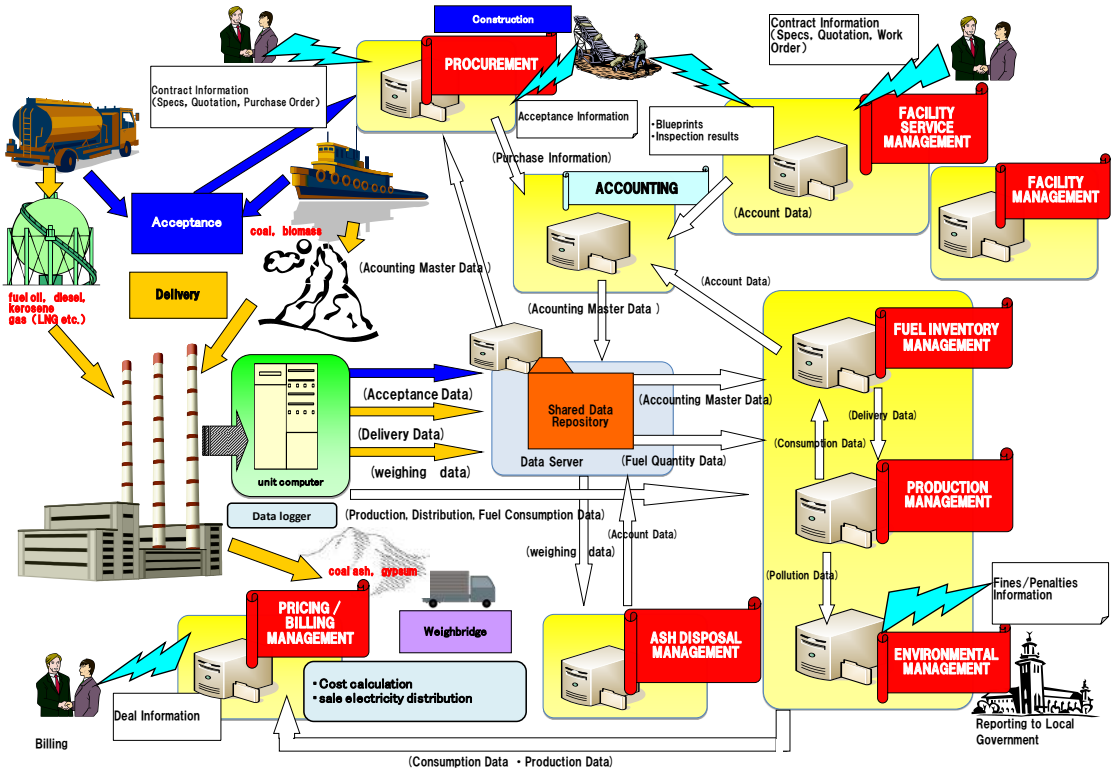
<Item e>

Target Year	(Pilot implementation) One year after completion of work
Indicators	Achievement of plant data sharing, accumulation, scheduled maintenance
Criteria	Number of parameters for KPI, maintenance plans, activities accomplished
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

<Item f>

Target Year	(Pilot implementation) Two years after completion of work
Indicators	Achievement of scheduled maintenance, budget process efficiency, accuracy
Criteria	Compliance: 100% (Number of qualified employees), unbudgeted expenditure: 0, process delay: 0
Follow-up Activity	Business process review and advisory activity
Evaluator	Feasibility Study Team

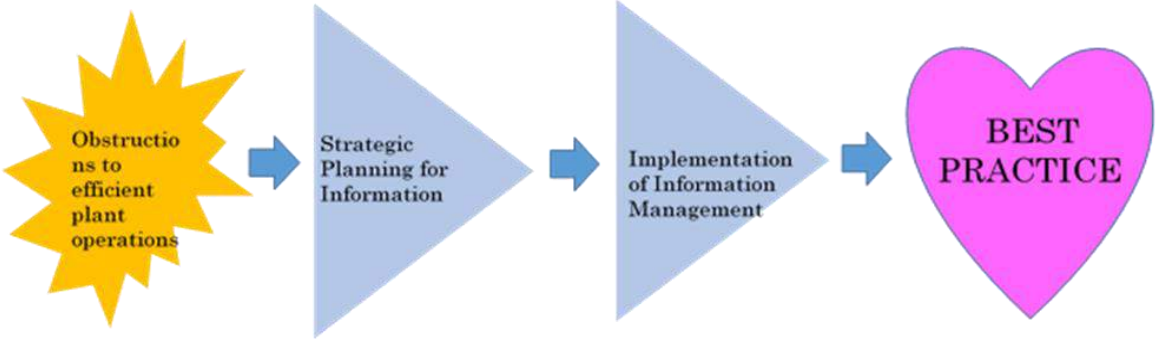
The figure below depicts an overview of the power plant information management system which is envisioned for future implementation.



Source: JICA Survey Team

Figure 18-42 Future of the Power Plant Information Management System

The study results emphasize implementation of the strategic use of information across the core business activities of the power generating business. The implementation process consists of a series of steps: Plan, Do, Check, Act. This PDCA cycle is a powerful tool to use in business performance improvement activities. The cycle can be enforced throughout the organization by information sharing and collaboration among business units. The top management is expected to create an information management strategy to define and control information flows and process interactions.
Once the processes are established and the information for sharing is defined, it is very easy to make a plan, take an action, measure the efficiency and apply the results in decision making. One of our objectives is to enforce this improvement cycle throughout the organization by implementing information sharing and collaboration among the business units.



Source: JICA Survey Team

Figure 18-43 Information Management towards a Best Practice of O&M

18.9 Training Center

18.9.1 Necessity of training center

To improve Bangladesh's O&M skills, the most necessary thing is construction of the training organization. As mentioned in 11.3.2 Summary of actual O&M situation, Bangladesh does not have an efficient training center. Therefore, it needs to have an effective training center and curriculum and also to develop instructors.
In reference to training facilities and training courses in Japan, the JICA survey team explains what is necessary for Bangladesh, as follows.

18.9.2 Training course

In Japan, to develop staff, several courses are prepared for them according to their skill level, and their knowledge level is confirmed.

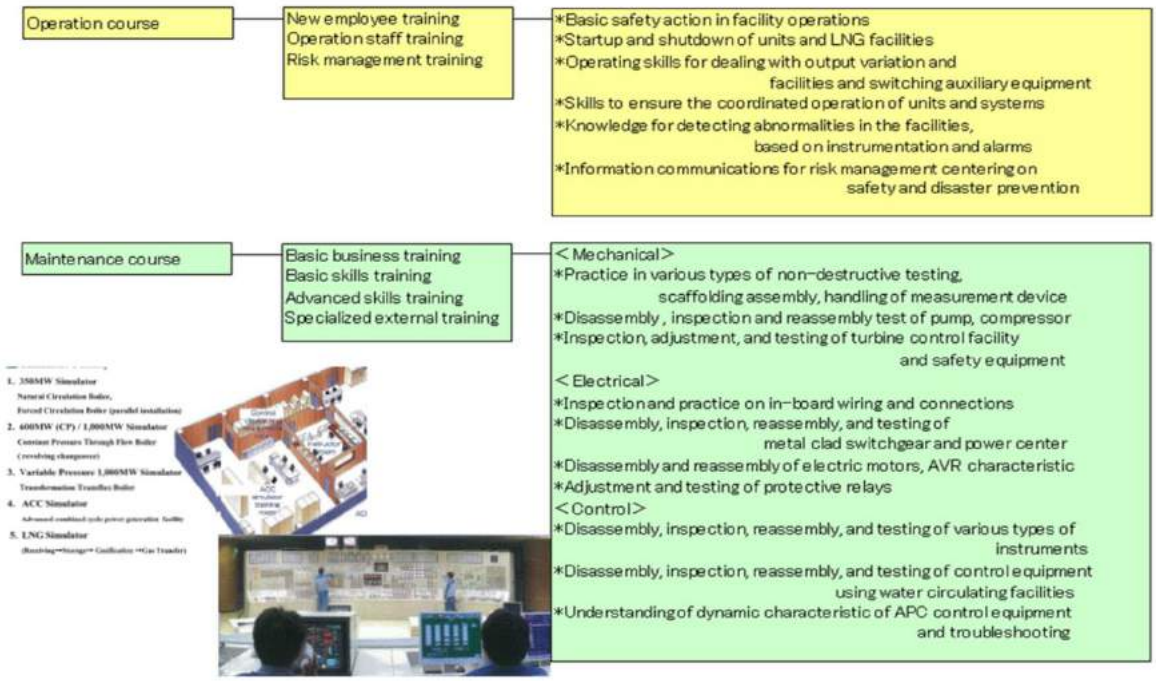
"Sample of operator training course"

(a) Training course for new employee
(b) Operator training course
(c) Risk management training course (Guide class, practitioner class, manager class)
(d) Chemical treatment, water treatment, drainage treatment training course

"Sample of maintenance course"

(e) Basic training course
(f) Applied training course (boiler, turbine, electrical, control)
(g) Special training course by manufacturer

The above courses are separated into several, more detailed courses.
And operator and maintenance staff need to be checked and authorized according to their years of experience.



Source: JICA Survey Team

Figure 18-44 Sample of Training Curriculum

18.9.3 Instructors

Instructors need a high level of skill and knowledge, and they also get a high level of education and training. Because every instructor is also an operator or maintenance staff, they also have personnel rotation between the training center and power station, getting site knowledge and feeding this back into the training content. The most important thing is to keep instructors' skill and knowledge levels high, by gathering people of ability from every power station, performing periodic personnel rotation between the training center and power station and ensuring that instructors do not forget the feeling of working at a site.

18.9.4 Training facility (simulator)

A training simulator is very useful for a training facility.
The simulator has to satisfy the following functions.

Functions for instructor

(1) Simulator execute, stop and snapshot function
(2) Initial condition setting function
(3) Variable speed control function
(4) Back track, reappearance function
(5) Malfunction
(6) Change operation condition function

Functions for trainee

Graphic screen has to show the same level screen as an operator console, and be able to operate the same as an operator console. It must also be able to show a control logic, trend graph and alarm screen.

Functions for simulator

The simulator has to simulate the following systems.

(1) Plant automatic start up and shut down control system
(2) Usual operation control system
(3) Burner control system
(4) Boiler sequence control system
(5) Turbine sequence control system
(6) Other sequence control system
(7) Plant operation simulation system after parameter tuning

Except for main facilities like boiler, turbine and generator, other facilities like a coal handling system, steam turbine, water analysis system, fire extinguishing system and so on vary with manufacturer, so the need for their inclusion in the simulator should be judged in consultation with the owner.
Of course, control logic and parameters need to be equal to a real unit control system, so that the plant simulator becomes a more realistic simulation.

18.9.5 Training facility (maintenance)

During training, maintenance staff learn how to re-assemble, adjust, fix and assemble several facilities. Therefore, when selecting a training facility, one which is the same as the facility in Bangladesh is suitable and effective.
The following facilities are those basically needed.

(1) A motor and pump
(2) Turbine feed water pump
(3) Control valve and actuator
(4) Pressure transmitter and flow transmitter
(5) A control system that has a control valve, pump and water tank in one loop
(6) A centrifugal fan or axial flow fan
(7) Non Destructive Inspection (PT, MT, UT) training facilities
(8) Rotary apparatus balance adjustment training facilities using a vibration analysis device

This is an example, and it is desirable to have the necessary facilities in the training center.

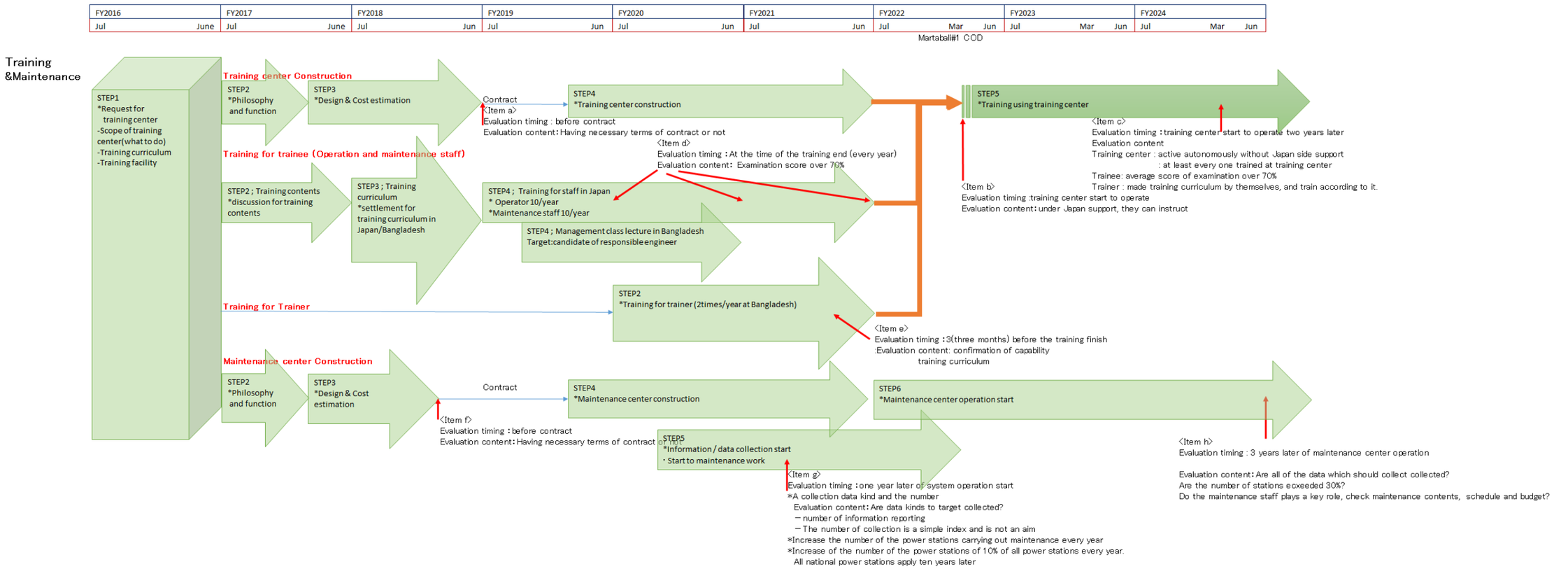
18.9.6 Important points for training center

It is important that the training center satisfies the following

(1) Curriculum from new employee to veteran
(2) Lecturer development, personnel interchange
(3) Most suitable training facility

18.9.7 Schedule for training center construction

Below is the schedule plan for O&M personnel development training center establishment when the target is the commercial operation date for Matarbari.



Source: JICA Survey Team

Figure 18-45 Training Center Construction Schedule Image

The evaluation timings and indicators are listed below.

Category: training center construction

<Item a>

Target Year	Before signing contract for training center construction
Indicators	Requirements not having any omissions
Criteria	Omission rate 0%
Follow-up Activity	Review of specifications and advice
Evaluator	The organization which carried out FS

<Item b>

Target Year	At the time when training center operation starts
Indicators	Instructors can carry out lectures by themselves
Criteria	Examination scores higher than 80%
Follow-up Activity	Re-instruction for instructors
Evaluator	The organization which carried out instructor education

<Item c-1>

Target Year	2 (two) years after training center operation starts
Indicators for training center	Technical staff of all power stations taking lectures once per year
Criteria	Attendance rates higher than 80%
Follow-up Activity	Mandatory attendance
Evaluator	The organization which carried out instructor education

<Item c-2>

Target Year	2 (two) years after training center operation starts
Indicators for instructor	Creation of training curriculum content Training schedule development
Criteria	Curriculum progress rate
Follow-up Activity	Re-instruction for Instructors
Evaluator	The organization which carried out instructor education

<Item c-3>

Target Year	2 (two) years after training center operation starts
Indicators for instructor	Examination results after attendance
Criteria	Examination scores higher than 70%
Follow-up Activity	Re-training for trainees
Evaluator	Training center instructors in Bangladesh

Category: training for trainees

<Item d>

Target Year	After the training ends (every year)
Indicators for instructor	Examination results after attendance
Criteria	Examination scores higher than 70%
Follow-up Activity	Re-training for trainees in training center in Bangladesh
Follow-up timing	After training center construction
Evaluator	The organization which carried out trainee education

Category: training for instructors
<Item e>

Target Year	Within 3 months after the training ends
Indicators for instructor	Lecture skill confirmation
Criteria	80% results in same examination as trainee
Follow-up Activity	Self-study until training center begins to be used → check according to Item b
Evaluator	The organization which carried out instructor education

Category: maintenance center construction
<Item f>

Target Year	Before signing contract for maintenance center construction
Indicators	Requirements not having any omissions
Criteria	Omission rate 0%
Follow-up Activity	Review of specifications and advice
Evaluator	The organization which carried out FS

<Item g>

Target Year	1 (one) year after starting information sharing system
Indicators	Kinds of data collected and the number of reports to head office
Criteria	No omission in data collected Number of data reports shall be deemed reference
Follow-up Activity	System repair/improvement
Evaluator	The organization which carried out FS

<Item h>

Target Year	3 (three) years after starting information sharing system
Indicators	Number increase situation of power stations
Criteria	Target of increasing number of power stations by 10% per year Amount of deviation from budget
Follow-up Activity	Improvement request to the head office
Evaluator	The organization which carried out FS

PART V ENERGY COST AND TARIFF BALANCE

Chapter 19 Financial Performance of the Power Sector

19.1 Overview of the Electricity Tariff System in Bangladesh

The Electricity Act of Bangladesh was established in 1910, during the period when Bangladesh was under the British rule. In 1937, the Electricity Rules were established as a more detailed regulation. The Electricity Act was amended afterwards to reflect the changes of governing structure, first when Bangladesh gained independence as East Pakistan and second as it gained independence as Bangladesh, it has also been amended several times afterwards.
In 2003, the Bangladesh Energy Regulatory Act was established to take over a number of provisions from the Electricity Act, including tariff setting as well as license to power generators, transmitters and distributors (public & private).
In the next year 2004, in accordance with the stipulation of the Bangladesh Energy Regulatory Act, BERC (Bangladesh Energy Regulatory Commission) was founded as the organization responsible for Bangladesh's electricity and other energy tariff policies. Major electricity tariff policies published by BERC include "the Power Pricing Framework (2004)," "the Vision 2020 - Tariff guidance," and "the BERC Electricity Tariff Regulations (including bulk supply tariff, wheeling charge and retail tariff)."

Table 19-1 Major Tariff Policies

■ Power Pricing Framework (2004)
■ Vision 2020 - Tariff guidance
■ BERC Electricity Tariff Regulations:
Generation : BST - Bulk Supply Tariff
Transmission : Wheeling Charge
Distribution : Retail Distribution Tariff

Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

Principles and methodologies for tariff fixation are set in BERC's Tariff Regulations. Principles are fixed, but may be adjusted if necessary to a certain extent. In case of dispute, the Bangladesh Energy Regulatory Commission will come up with a resolution.
BERC's interaction with the government is defined in Article 22(i) of BERC Act as its ability to extend co-operation and advice to the Government, if necessary, regarding electricity generation, transmission, marketing, supply distribution and storage of energy.
Some highlights of the "Power Pricing Framework (2004)" and "the Vision 2020" are as follows. According to the Power Pricing Framework, while the average end-user electricity tariff for each customer class is set to fully cover reasonable costs of supplying electricity, subsidy from the Government is also defined. It further defines that rates are established each for cases of peak and off-peak, fixed cost (capacity cost) and variable cost.
The Vision 2020 emphasizes the necessity of electricity tariff that reflects the cost of electricity supply, the importance of efficiency, economical use of resources, good performance and optimum investment and the need to safeguard the interests of the consumers. The Vision also states that generation, transmission, distribution and supply are conducted on commercial principles. Differential tariff will be set related to time of the day to facilitate efficient demand side management.

Table 19-2 Tariff Policies

Act/ Policy	Highlights
Power Pricing Framework, 2004	・ The electricity tariff to cover costs of supplying electricity. ・ Government subsidy ・ Differentiated rates for certain cases : Peak and off-peak Fixed cost (capacity cost) and variable cost
Vision 2020	・ Electrcity tariff that reflects the cost of supply ・ Efficiency, economical use of the resources, good performance and optimum investment are important ・ Interests of the consumers ・ Generation, transmission, distribution and supply on commercial principles ・ Time-related tariff to facilitate efficient demand side management

Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

Current electricity tariff table, which was set by BERC in 2015, is as follows. Different tariff rates are set for each type of customers.

Table 19-3 Electricity Retail Tariff Structures in Bangladesh (as of 2015)

	Consumer Category	Energy Charge (BDT/kWh)	Service Charge (BDT/month)	Demand Charge (BDT/kW/month)
1	**Category A: Residential**		1-Phase: 10.00 3-Phase: 30.00	15
	Life Line: 1-50 Units	3.33		
	a First Step: From 00 to 75 units	3.80		
	b Second Step: From 76 to 200 units	5.14		
	c Third Step: From 201 to 300 units	5.36		
	d Fourth Step: From 301 to 400 units	5.63		
	e Fifth Step: From 401 to 600 units	8.70		
	f Sixth Step: From 601 to above	9.98		
2	**Category B: Agricultural pumping**	3.82	30	40 (Applicable for approved demand more than 30 kWh)
3	**Category C: Small Industries**		70	40 (Applicable for approved demand more than 30 kWh)
	a Flat Rate	7.66		
	b Off-Peak Time	6.90		
	c Peak Time	9.24		
4	**Category D: Non-Residential (Light & Power)**	5.22	1-Phase: 10.00 3-Phase: 30.00	20
5	**Category E: Commercial & Office**		1-Phase: 10.00 3-Phase: 30.00	25
	a Flat Rate	9.80		
	b Off-Peak Time	8.45		
	c Peak Time	11.98		
6	**Category F: Medium Voltage, General Purpose (11 KV)**		400	45 (For Maximum Demand)
	a Flat Rate	7.57		
	b Off-Peak Time	6.88		
	c Peak Time	9.57		
7	**Category G-2: Extra High Voltage, General Purpose (132 KV)**		500	40 (For Maximum Demand)
	a Flat Rate	7.35		
	b Off-Peak Time	6.74		
	c Peak Time	9.47		
8	**Category H: High Voltage, General Purpose (33 KV)**		450	40 (For Maximum Demand)
	a Flat Rate	7.49		
	b Off-Peak Time	6.82		
	c Peak Time	9.52		
9	**Category J: Street Light and Water Pumps**	7.17	1-Phase: 10.00 3-Phase: 30.00	20

Source: Bangladesh Energy Regulatory Commission (BERC)

Note: "Non-residential category" includes public services such as street lighting and non-residential use such as water pumps.

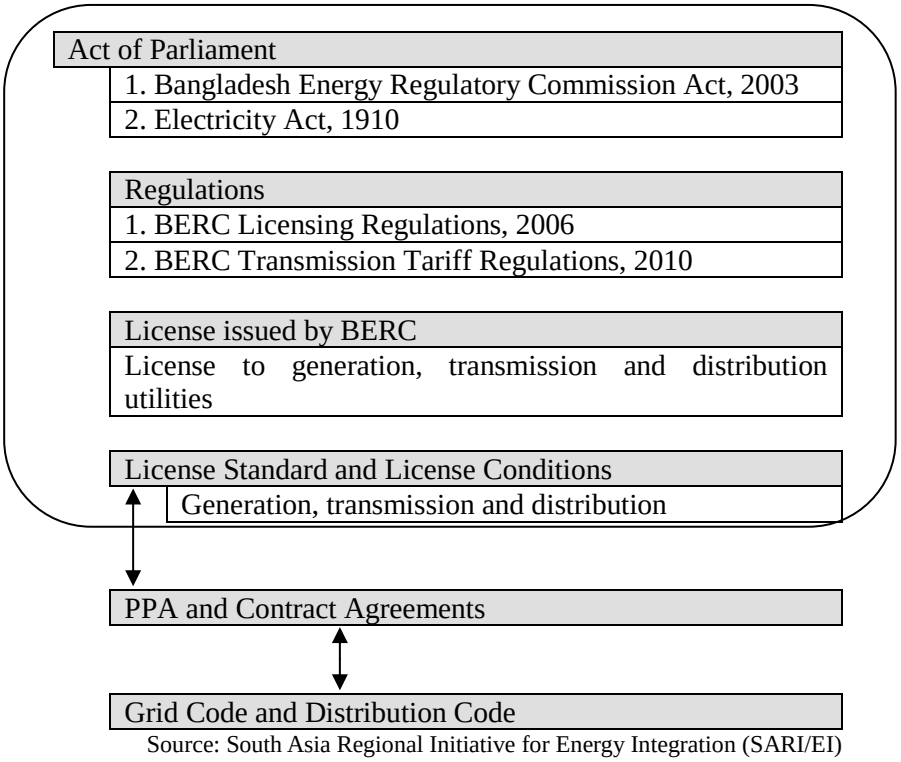
In addition, the BERC Act 2003 determines the electricity tariff issues, dispute resolutions and relationship with the government as follows:

Table 19-4 Tariff Policies

Act/ Policy	Highlights
BERC Act 2003 Tariff Issues	Article 22 : (b) to ensure efficient use, quality services, determine tariff and safety enhancement of electricity generation and transmission, marketing, supply, storage and distribution of energy; BERC Electricity Tariff Regulations
BERC Act 2003 Dispute Resolutions	Article 22 : (j) to resolve disputes between the licensees, and between licensees and consumers, and refer those to arbitration if considered necessary *licensees are utilities that have acquired their licenses. (k) to ensure appropriate remedy for consumer disputes, dishonest business practices or monopoly
BERC Act 2003 Relationship with Government	Article 34 : BERC determines tariff in accordance with government Policies. BERC consults with Government in preparing the Tariff methodologies only.

Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

According to the Electricity Act and BERC Act, the upper level regulations, BERC publishes regulations including the BERC Licensing Regulations (2006) and the BERC Transmission Tariff Regulations (2010).



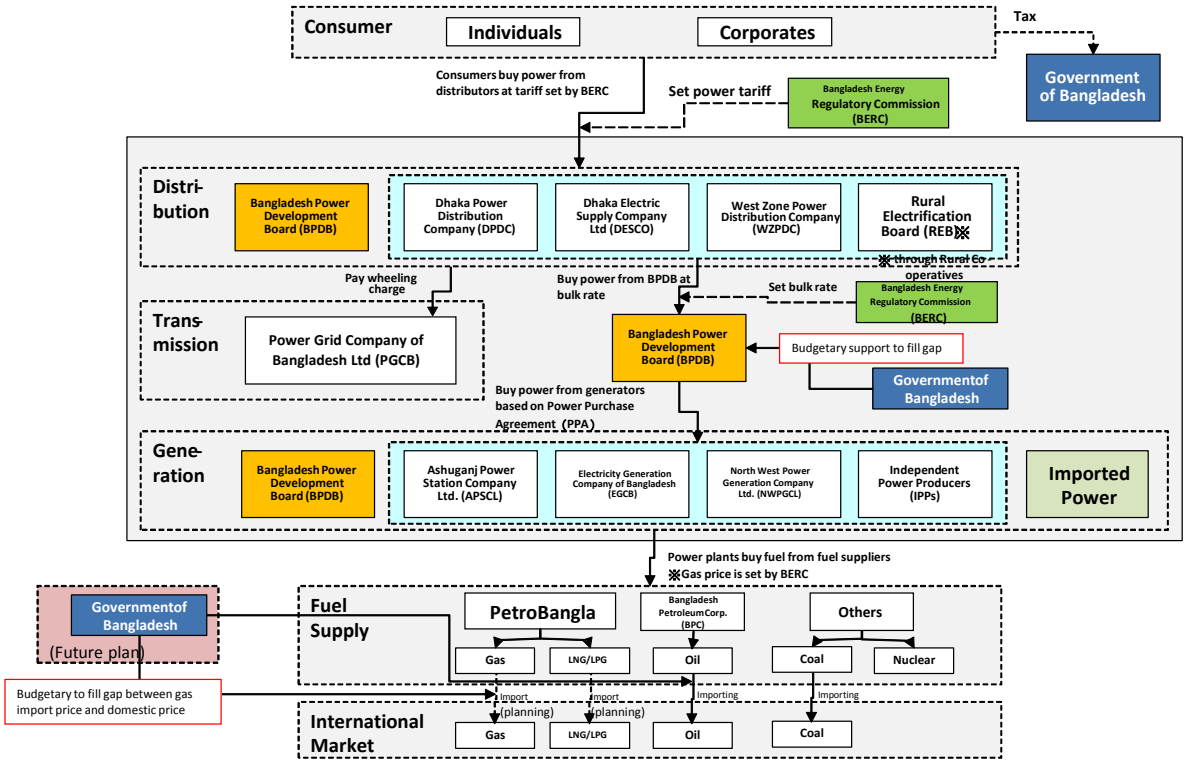
Source: South Asia Regional Initiative for Energy Integration (SARI/EI)

Figure 19-1 Hierarchy of Governance for Transmission

19.2 Overview of Funding Related to the Power Sector

Main relevant institutions of the power sector are identified and their cash flows among these institutions are investigated. In this section, the operation phase and the capital investment phase are investigated separately (see Figure 19-2 and Figure 19-3).

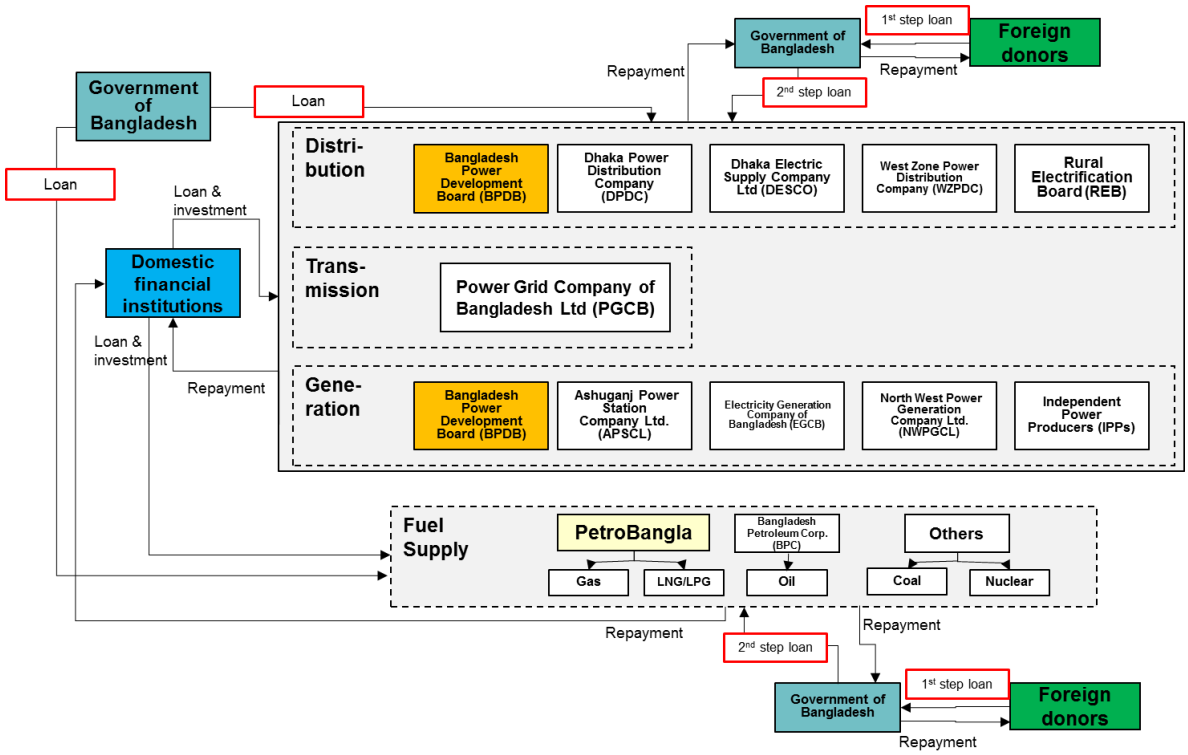
In the operation phase, the cash inflow from consumers, i.e. both individuals and corporates, to distributing entities (BPDB, DPDC, DESCO, WZPDC and REB) based on the power tariff set by BERC. These distributing entities buy power from BPDB at bulk rate which is also determined by BERC. The distribution entities pay wheeling charge to PGCB, the only entity responsible for power transmission in Bangladesh. In addition to transmission charge, BPDB as the single power buyer also purchases power from generation entities based on individual Power Purchase Agreement (PPA) between BPDB and each power generating entity. These generation entities purchase fuel (gas, oil, coal, etc.), which are required for power generation, from primary energy suppliers. In cases where the fuel needs to be procured from abroad, these primary energy suppliers purchase fuel from oversea markets.



Source: JICA Survey Team

Figure 19-2 Cash Flow of Bangladesh Power Sector for Operation Phase

In the capital investment phase, businesses in the power sector (including power generation, transmission and distribution) borrow from the government of Bangladesh (GOB) as well as financial institutions (including international donors, i.e. World Bank, Asia Development Bank, JICA, and local commercial banks). In case of international donors, loan is injected into projects in a 2-step manner. At step 1, the GOB signs a loan agreement and borrows from international donors using concessional loan from these donors. In step 2, the GOB provides loans in BDT to businesses with their own conditions. Details of these loan conditions are given in the following section.



Source: JICA Survey Team

Figure 19-3 Cash Flow of Bangladesh Power Sector for Capital Investment

19.2.1 Donors' assistance programs for the Bangladeshi power sector

Business entities in the power sector raise funds for capital investments from various sources of finance, notably the government of Bangladesh and commercial banks, as well as international donors such as World Bank (WB), Asia Development Bank (ADB), JICA, etc., also considering their financial situation. Loan condition of those sources is summarized below based on interviews and review of public documents.

(1) Overview

International development aid agencies that are main partners in the energy sector in Bangladesh are Asian Development Bank (ADB), Islamic Development Bank, and World Bank. There are also major bilateral aid partners including Japan, Germany, Kuwait, Norway, etc. The areas of support include power generation, transmission and distribution upgrading, energy sector reforms, assistance to the regulatory commission, rural electrification, power plant upgrading and capacity addition, capacity building, and planning.
Major financing projects by development partners are listed in the table below.

Table 19-5 Recent Major Financing Projects by Development Partners in the Bangladeshi Power Sector

Development Partners	Project Name	Duration	Amount (million BDT)
Abudabi, Kuwait Fund, OPEC, Saudi Arabia,	Construction of Shikalbaha 225 MW Duel-Fuel Combined Cycle Power Plant	2012-2016	13,754
ADB	Installation of a 5 MW Solar Photo Voltaic Grid Connected Power Plant in Kaptai	2012-2016	1,573
ADB	Installation of an Off Grid Wind Solar Hybrid System with HFO/Diesel Based Engine Steven Generator in Hatia Island	2012-2014	947
ADB	Upgradation of Khulna 150 MW Peaking Power Plant to 225 MW Combined Cycle Power Plant	2012-2016	7,866
ADB	132 KV Grid Network Development Project in Eastern Region	2013-2016	6,932
ADB	Solar Street Lighting Program in City Corporation	2012-2015	2,366
ADB	Construction & Expansion of Distribution network of North & South Zone under DPDC	2013-2016	3,431
ADB	Running Project: Construction of 132/33/11KV Grid S/S in DESCO Area	2013-2017	5,435
ADB	Augmentation & Rehabilitation of Distribution System in DESCO Area	2013-2017	11,064
ADB, IDB	Construction of Ashuganj 450 MW Combined Cycle Power Plant (North)	2011-2015	299,960
ADB, IDB	400/230/132 KV Grid Network Development	2014-2017	23,382
ADB, KfW,	Development of New 132/33 KV and 33/11 KV Sub-Station under DESA Project	2006-2015	3,710
AFD, ADB	Construction of new 132/33 KV & 33/11 KV S/S under DPDC	2013-2017	12,937
EA	Chapainawabganj 100MW HFO Based Power Plant	2013-2015	8,924
ECA	Shahjibazar 330MW Combined Cycle Power Plant	2013-2015	19,458
ECA	Construction of Bibiyana-3, 400MW CC Power plant	2013-2016	23,614
ECA	Extension of Barapukuria Coal Fire Thermal Power Station by 275MW (3rd Unit)	2013-2017	18,356
ECA	Construction of Ghorasal 365MW CC Power Plant	2013-2017	16,532
ECA	New Project: Ghorasal-3 Repairing Project	2015-2017	19,869
EIB	Conversion of Shahjibazar 2*35 MW Power Plant to 105 MW Combined Cycle Power Plant	2013-2016	3,071
EIB	Conversion of Baghabari 100 MW to 150 MW Combined Cycle Power Plant	2013-2015	4,342
IDA	Construction of Siddhirganj 335 MW Peaking Combined Cycle Power Plant	2009-2015	18,223
IDA	Upgradation of Rural Electricity Distribution System (Dhaka, Chittagong & Syslet Division)	2014-2018	37,050

Development Partners	Project Name	Duration	Amount (million BDT)
IDB	Bhola 225 MW Duel Fuel Combined Cycle Power Plant	2011-2015	14,058
IDB	Conversion of 150 MW Sylhet Gas Turbine Power Plant to 225 MW Combined Cycle Power Plant	2014-2017	6,570
IDB	Rural Electrification Expansion Barisal Division Programme-1	2010-2016	1,560
JICA	Bheramara Combined Cycle Plant Development (360 MW)	2010-2017	32,211
JICA	National Power Transmission Network Development Project	2013-2017	17,675
JICA	Bangladesh Central Zone Power Distribution Project	2009-2015	10,083
JICA	Rural Electrification Upgradation Project (Rajshahi, Rangpur, Khulna and Barisal Divisions)	2013-2016	10,543
JICA	Running Project: Matarbari 2*600MW Ultra Super Critical Coal Fired Power Project	2014-2023	289,390
KfW	Pre-Payment Metering for Distribution Comilla & Mymensingh	2013-2015	10,083
KfW	Pre-payment Metering Project for Six NOCS Division under DPDC	2013-2015	910
Kuwait Fund,	Greater Chittagong Power Distribution Project, Scada Rehabilitation	2009-2015	859
NDF, ADB, NORDIC,	Development of 10 Town Power Distribution	2003-2015	2,690
UDCF	Bibiyana-Kaliakoir 400 KV & Fenchuganj-Bibiyana 230KV Transmission Line	2010-2017	7,400
WB	Enhancement of Capacity of grid Substation & Transmission Line for Rural Electrification	2014-2017	9,123

ADB = Asian Development Bank, ECA= export credit agency , EDCF = Economic Development Cooperation Fund, EIB= European Investment Bank, IDA =International Development Association, IDB=Inter-American Development Bank, KfW = Kreditanstalt fur Wiederaufbau, JBIC = Japan Bank of International Cooperation, JICA = Japan International Cooperation Agency, NDF = Nordic Development Fund, NORAD = Norwegian Agency for Development Cooperation

Source: Planning Commission "ANNUAL DEVELOPMENT PROGRAMME FOR 2013-2014", "2014-2015", "2015-2016")

The World Bank has been involved in the development of the power sector in Bangladesh for a long time. Since 1989, the World Bank has provided about 1.1 billion USD to support project costs and totaling 4.4 billion USD for power sector development ("Project Performance Assessment Report", World Bank 2014). In particular, approximately 50 million USD of loan was provided from FY2000 to FY2013 to the power sectorprojects.

ADB, during 1993-2015, provided loan, grant, and technical support for 99 projects of total 4,170 million USD to enegy sector. This accounts for 22.9% of total provided loan, grant, and technical support from ADB to Bangladesh ("Asian Development Ban Member Fact Sheet (Data are as of 31 December 2015)", ADB 2016)

(2) Loan conditions

Notable donors which participate in the power sector of Bangladesh are WB, ADB and JICA. They provide businesses in the country's power sector loans with very different conditions as shown in Table 19-6.

Regarding JICA loan, as Bangladesh has become a lower-middle income category country, JICA can provide ODA loan to Bangladesh (inter-governmental loan) at annual interest rate and interest rate

during construction of 1.4%, repayment period of 30 years and grace period of 10 years.
Regarding WB loan, although the loan condition varies from project to project, it is assumed in this estimation that interest rate is 5% p.a., repayment period is 15-year with a 5-year grace period.
As for ADB loan, the project owner can borrow 100% of the project cost under a 2% p.a. interest rate, 25-year repayment period with a 5-year grace period.

Table 19-6 Loan Conditions of WB, ADB and JICA Loans

Loan condition	WB*)	ADB**)	JICA
Annual interest rate	0.75%	2%	0.7%
Interest rate during construction	0.75%	2%	0.7%
Repayment period	38 yrs	25 years	30 years
Grace period	6 yrs	5 years	10 years

*) Loan condition in the case of International Development Association
**) Loan condition in the case of Asian Development Fund
Source: Interviews and public documents ("Terms and Conditions of Japanese ODA Loans (Effective from October 1, 2014)" for JICA loan, " Asian Development Fund: FAQs (http://www.adb.org/site/adf/faqs)" for ADB loan and "IDA Terms (Effective as of July 27, 2016)" for WB loan)

Regarding the funding scheme, it should be noted that funding international donors are injected to project owners in a 2-step manner. As a results, there exists 2 levels of principal and interest payment, which is principal and interest payment by the government of Bangladesh to donors (step 1), and that of project owners to GOB.
The annual interest rates of loan provided by multi-lateral and bi-lateral financial entities at step 2 during the construction and the operation are assumed to be the same with that of GOB loan.

19.2.2 Financial support from the government of Bangladesh

The government of Bangladesh provides loan to support the capital expenditure of state-owned enterprises and according to "Lending and relending terms of local/Foreign currency loans" published by the Ministry of Finance, loan conditions are stipulated to each enterprise.
In the case of BPDB, BPDB is mandated to maintain its capital structure at "debt 40%: equity 60%". In the actual application, its mandate is modified to "debt 60%: equity 40%", considering the recent trend of BPDB's balance sheet (see Figure 19-14), in which government's financial support (subsidies) is injected to BPDB every year so that the ratio of the sum of capital reserve and government subsidies to the total asset is maintained around 40%.
Annual interest rate for the government loan to BPDB is basically 3%, but if financing from international donor agencies to principal capital exists, it could be 3-5% depending on a ratio of the financing. The loan currency is Bangladeshi Taka. Pay-back grace period is 5 years. A pay-back period is 15 years after the pay-back grace period. It is necessary to pay interests during the pay-back grace period.

Table 19-7 Loan Conditions of Government of Bangladesh (Case of loan to BPDB)

Debt : equity ratio	40%:60% *
Annual interest rate	3%
Interest rate during construction	3%
Repayment period	20 years
Grace period	5 years

Source: Ministry of Finance "Lending and relending terms of local/Foreign currency loans", Interviews with BPDB.
Note: in actual application, government subsidies are provided to BPDB so that its capital structure maintains "debt 60%: equity 40%" ratio.

19.2.3 Loan conditions of commercial banks to the power sector

Loan conditions of commercial banks to the power sector are as follows. Annual interest rate and interest rate during construction are both 13%. Repayment period is 15 years without grace period.

Table 19-8 Loan Conditions of Commercial Banks

Annual interest rate	13%
Interest rate during construction	13%
Repayment period	15 years

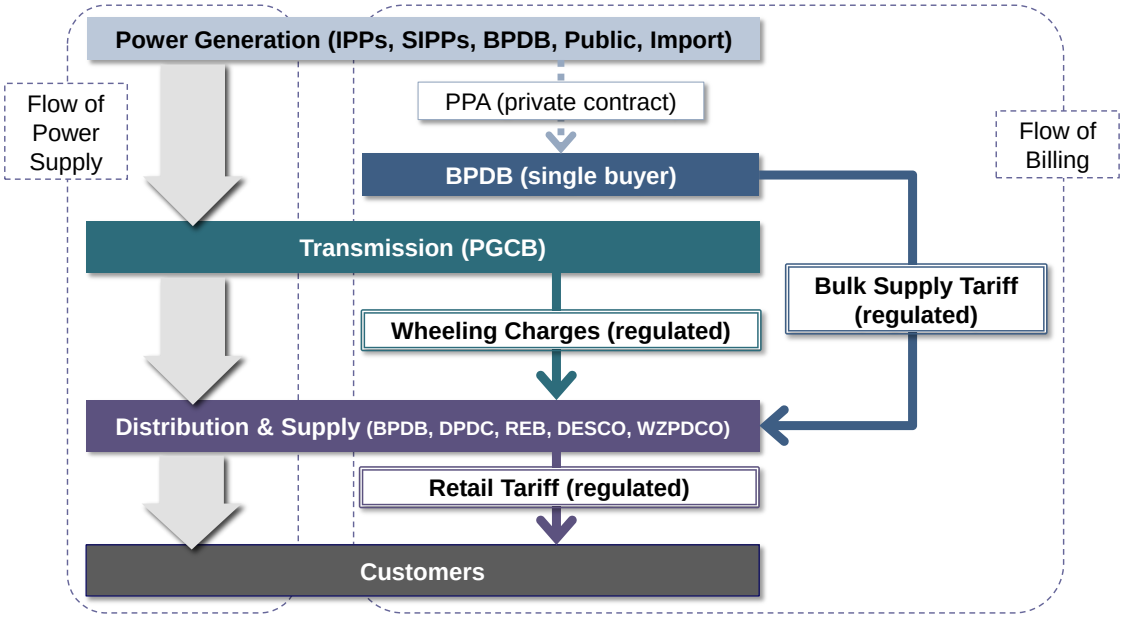
Source: Interviews with BPDB

19.3 Financial Performance of Main Players in the Power Sector

Different business entities exist in power generation, transmission, and distribution sectors in Bangladesh power sector; there is an interaction of electricity and billing between each sector. In order to grasp the overview as to what extent the current retail electricity tariff posed on end consumers can cover for the necessary cost for the operation of the power sector, the overall balances of the power sector and the financial situation of the each utility was analyzed.

19.3.1 Financial performance of the overall power sector

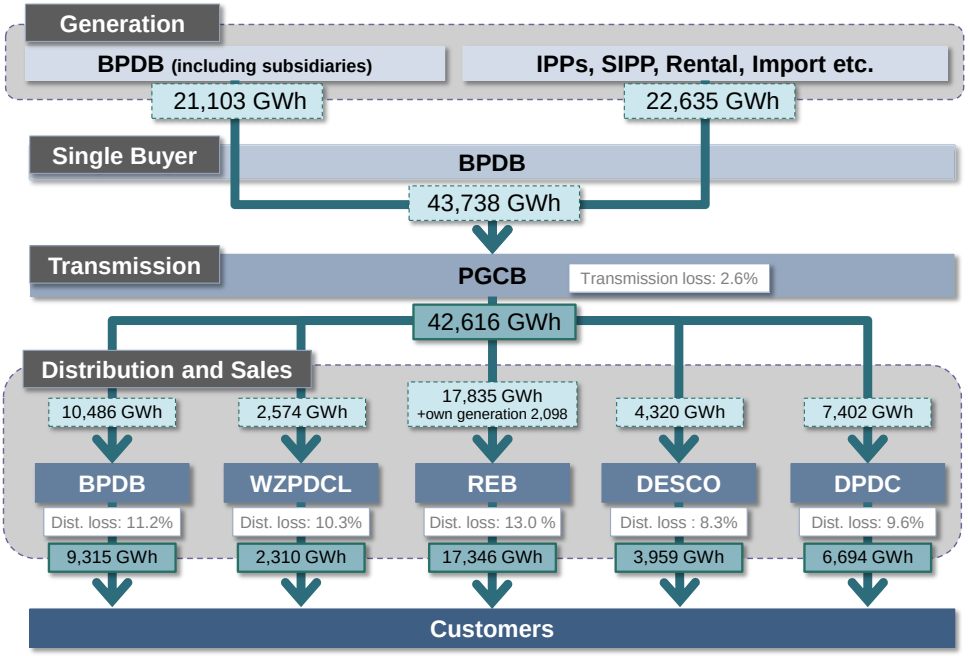
The flow of power supply and flow of billing in Bangladesh power sector are illustrated in Figure 19-4. The flow of power supply starts from each generation utility, which is then transmitted using the transmission grid of the transmission operator (PGCB) and the distribution grid of the distribution operator, finally reaching the customers.
On the other hand, the flow of billing is slightly different. Power generated in IPPs, SIPPs, BPDB plants, public plants, and imported power are all bought by BPDB, the single buyer in Bangladesh power sector, based on the PPA (power purchase agreement) with each generation entity and BPDB. The purchased power, which is purchased by distribution entities at the regulated bulk supply tariff, is transmitted by PGCB to the distribution entities. The distribution entities pay PGCB the wheeling charge for power transmission. Finally, power is supplied to the customers by distribution entities at a regulated retail tariff.



Source: JICA Survey Team

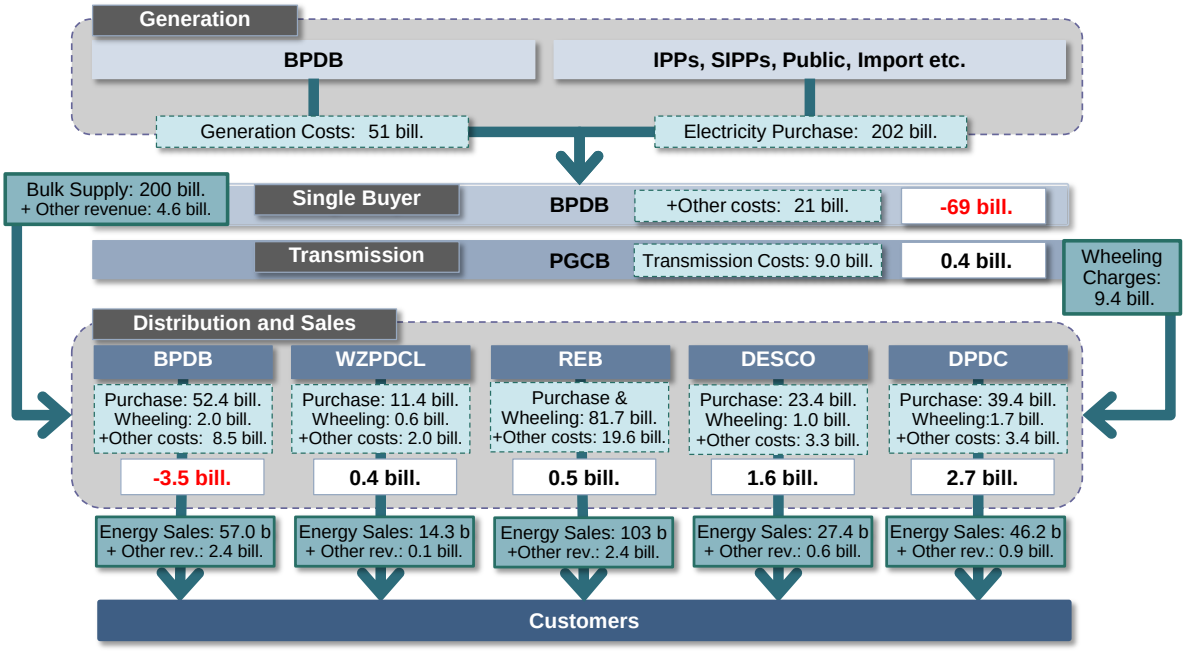
Figure 19-4 Flow of Power Supply and Flow of Billing

Figure 19-5 and Figure 19-6 describe the flow of power supply and billing between the main stakeholders of the Bangladesh power sector in 2015.



Source: JICA Survey Team

Figure 19-5 Overview of Power Supply Flow (2015 Snapshot)



Source: JICA Survey Team

Figure 19-6 Overview of Financial Situation (2015 Snapshot)

As stated above, there are various generation entities other than BPDB, including IPP, SIPP, and public plants. All of the generated electricity is purchased by the generation division of BPDB as the single buyer. The power is then wholesaled to distribution utilities such as WZPDCL, REB, DESCO and DPDC, as well as to its own distribution division.

In FY2014-2015, BPDB purchased total electricity worth 202 billion BDT from IPP, SIPP, public plants, rental plants, and India (power import); other than this electricity purchase cost, 51 billion BDT was incurred for generation at BPDB's own plants, and 21 billion BDT was incurred for other expenses including general administration cost. On the other hand, BPDB sells the purchased and generated electricity to the distribution entities for 200 billion BDT. Its revenue is far below its generation cost, resulting in a loss of approximately 70 billion BDT.

The transmission operator, PGCB, covers its transmission cost by collecting wheeling charges from the distribution entities. It had a slightly positive margin in FY2015, but its profitability is low.

Each distribution entity supplies electricity to the customers. In FY2014-2015, distribution entities sold approximately 248 billion BDT worth of electricity to the customers. Taking a look at the balance of the distribution sector after offsetting its payment of wholesale electricity and wheeling charges and its own cost of distribution, while all distribution entities but BPDB have a positive margin in FY2014-2015, BPDB's distribution division records a negative margin of approximately 3.5 billion BDT. In other words, both the generation and the distribution divisions of BPDB are in a financial deficit, resulting in a total of 72.8 billion BDT as entire BPDB.

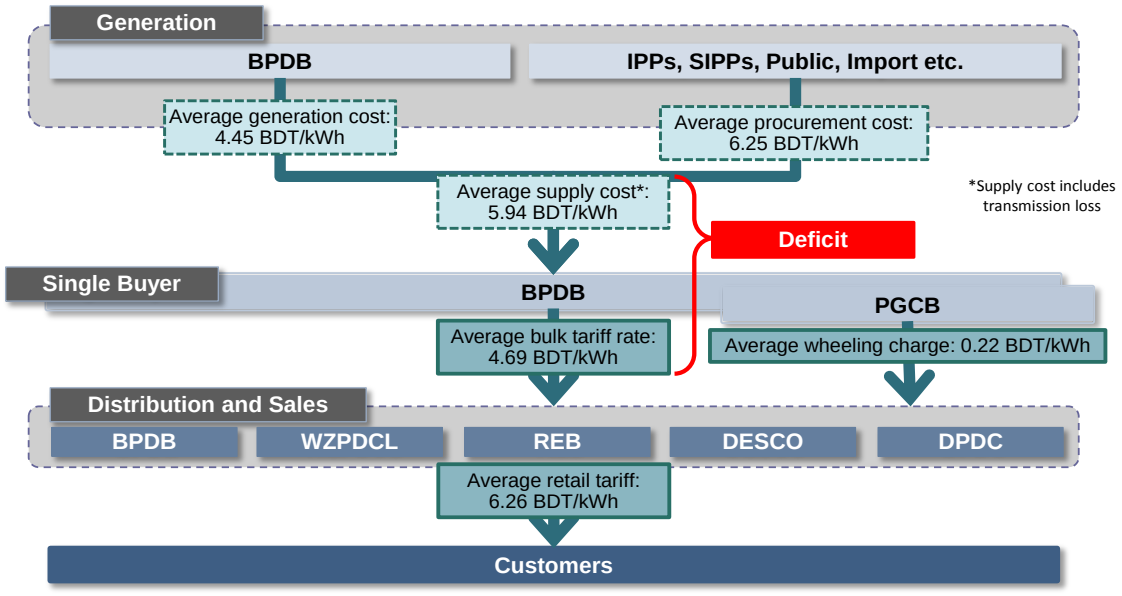
From the aforementioned analysis, it can be concluded that the financial deficit in the power sector can be accredited to the differences in cost of electricity procurement paid by BPDB to the generation entities and bulk supply tariff. Table 19-9 and Figure 19-7 compare the electricity purchase cost per electricity supply and wholesale electricity cost per electricity supply. In FY2014-2015, BPDB procures electricity from the generation entities and its own generation plants at an average price of 5.94 BDT/kWh (after applying general administration cost) and sells to the distribution entities at an average bulk supply tariff of 4.69 BDT/kWh.

Distribution entities sold electricity to the customers at an average of 6.26 BDT/kWh in FY2014-2015. Although there is no deficit between the retail electricity tariff and the bulk supply tariff, the final balance of distribution entities are either a small positive margin or a negative margin.

Table 19-9 Generation Cost, Supply Cost, and Bulk Supply Tariff

Particulars	Unit	FY2013-14	FY2014-15
a) Procurement cost (without general administration cost)	BDT/kWh	5.81	5.78
b) Procurement cost (including general administration cost)	BDT/kWh	5.96	5.94
c) Bulk supply tariff	BDT/kWh	4.71	4.69
c)-b) Difference between bulk supply tariff and procurement cost	BDT/kWh	-1.25	-1.25

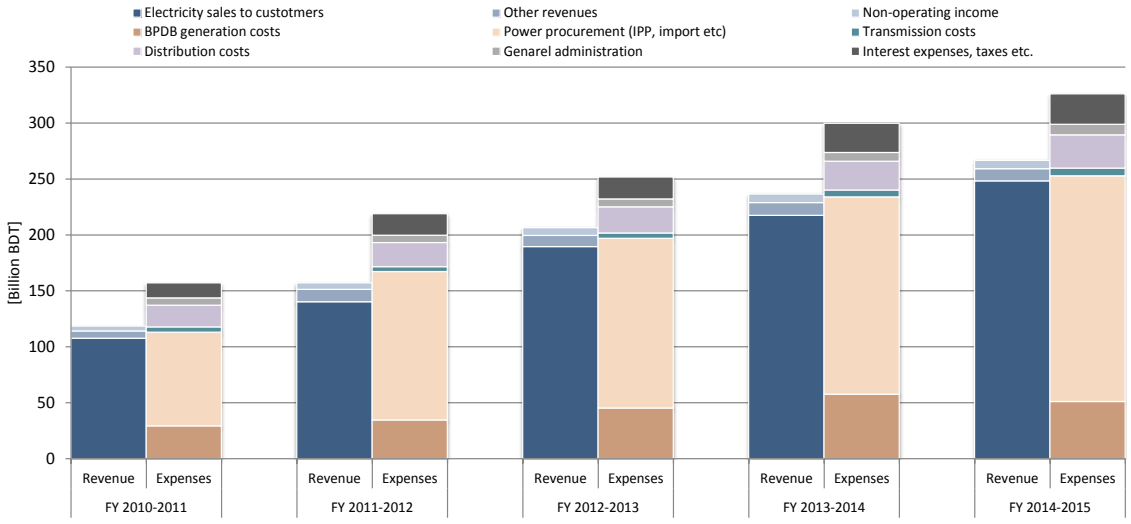
Source: BPDB, PGCB, WZPDCL, DESCO, and DPDC Annual Reports



Source: JICA Survey Team

Figure 19-7 Supply Cost, Bulk Supply Tariff, and Retail Tariff of Electricity (FY2014-2015)

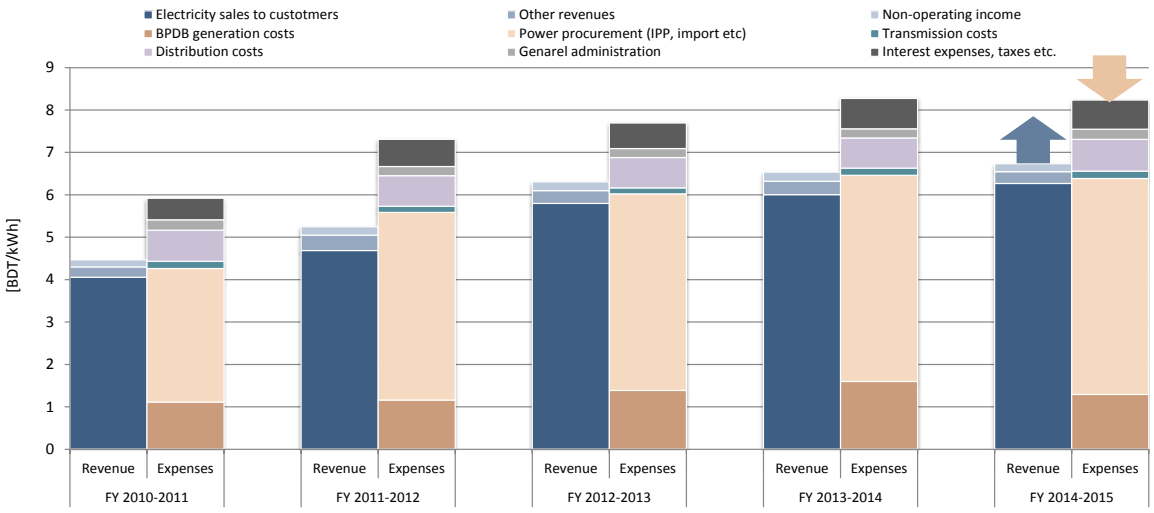
In order to determine to what extent the retail electricity tariff is able to cover for the electricity supply cost of the whole power sector, this study analyzed the financial situation of the virtual "vertically integrated utility," which is the consolidated balance of the BPDB, PGCB and distribution entities. In other words, the analysis of the "vertically integrated utility" integrates the P/L statement of these utilities, by offsetting the revenue and expenses incurred from transaction between each utility. The estimated result of the consolidated balances is summarized in Figure 19-8. The left bar of each year shows the revenue (mainly consisting of electricity retail revenue) and the right bar shows the expenses. The figure shows that the revenue of retail electricity from the customers does not cover the costs of generation (sum of costs from BPDB's own generation plants and electricity purchase cost).



Source: BPDB, PGCB, and distribution utilities annual report

Figure 19-8 Consolidated Balances of the Bangladesh Power Sector (billion BDT)

Figure 19-9 shows the consolidated revenue and expenses of each utility of the power sector per electricity sales to customers (BDT/kWh). While electricity tariff revenue rate has increased annually, cost per kWh has increased as well; therefore, the revenue has not been able to cover the costs. However, cost per kWh slightly decreased between FY2013-2014 and FY2014-2015 while the revenue per unit increased; hence there was a little improvement during the period though the balance is still a huge negative.



Source: BPDB, PGCB, and distribution utilities annual report

Figure 19-9 Consolidated Balances of the Bangladesh Power Sector per Electricity Sales (BDT/kWh)

As stated above, in order to maintain the financial soundness of the power sector, appropriate measures need to be taken, including the raise of electricity tariff and reduction of the supply cost, especially the cost of electricity purchase which accounts for more than half of the total supply cost. Such analysis on the supply cost is conducted in the next chapter.
In this chapter, the financial situation of each power utility is analyzed more in details.

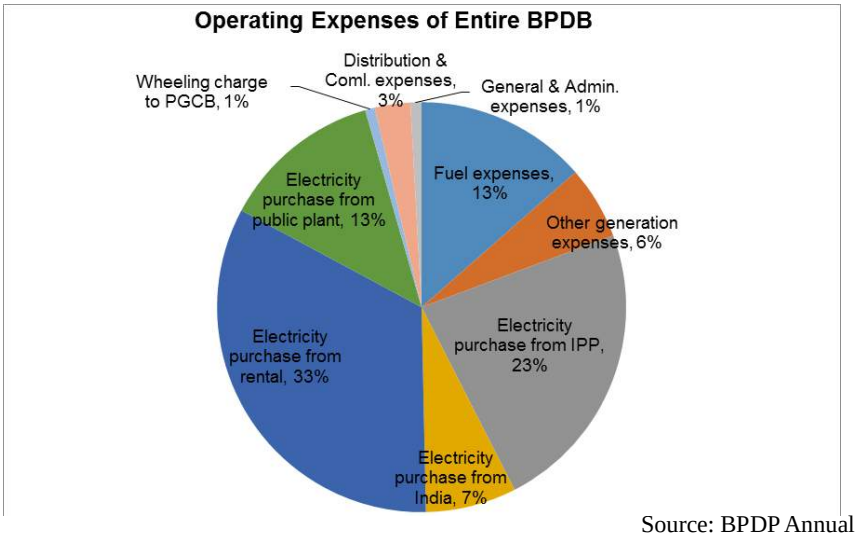
19.3.2 Financial performance of BPDB

Table 19-10 and Figure 19-10 show the entire balances of BPDB, including its generation division and distribution division. As already stated, both BPDB's generation and distribution divisions are in a financial deficit, especially in generation division which includes the cost of electricity purchase. Of the operating expenses incurred in FY2014-2015, electricity purchase accounts for approximately 75%; payment to rental plants, particularly holds approximately one third of the total electricity purchase cost.

Table 19-10 Balances of the Entire BPDB (million BDT)

Head of accounts	FY2013-14	FY2014-15
1. Operating Revenue	**194,288**	**211,876**
Energy Sales (Bulk)	186,371	204,921
Other operating income	7,917	6,955
2. Operating Expenses	**244,789**	**264,624**
Fuel expenses	41,927	35,869
Other generation expenses	15,824	15,248
Electricity purchase from IPP	44,634	61,313
Electricity purchase from India	11,457	19,003
Electricity purchase from rental	97,503	87,748
Electricity purchase from public plant	22,724	33,656
Wheeling charge to PGCB	1,849	2,018
Distribution & Coml. Expenses	6,970	7,451
General & Admin. Expenses	1,901	2,318
3. Operating profit/loss	**-50,501**	**-52,748**
4. Other expenses (including exchange fluctuations)	17,591	20,082
5. Net income/loss for the year	**-68,092**	**-72,830**

Source: BPDB Annual Report 2014-2015



Source: BPDP Annual Report 2014-2015

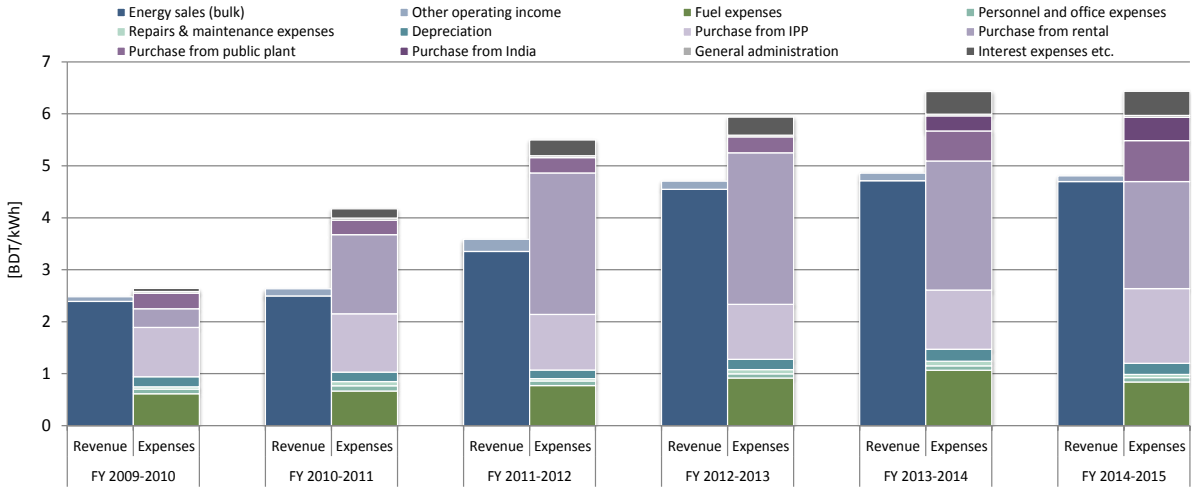
Figure 19-10 Operating Expenses of the Entire BPDB

The financial performance of BPDB's generation division and distribution division are each

investigated below.

(1) Balances of the Generation Division

Figure 9-11 illustrates the revenue and expenses of BPDB generation division per electricity supply. Balances of BPDB's generation division greatly worsened in FY2010-2011, and thereafter its revenue from bulk supply has been far less than its cost. When analyzing by each item, it can be seen that increase in its electricity purchase cost is far larger than the increase in its own generation cost. In other words, BPDB has expanded its portion of electricity purchase, instead of increasing its own generation plant, to meet the increased electricity demand. However, such measures have increased the overall cost of the generation division, leading to the enlarged gap between the bulk supply tariff revenue and its costs.



Source: JICA Survey Team

Figure 19-11 Revenues and Expenses of BPDB Generation Division per Electricity Sales (BDT/kWh)

(2) Power Distribution Division

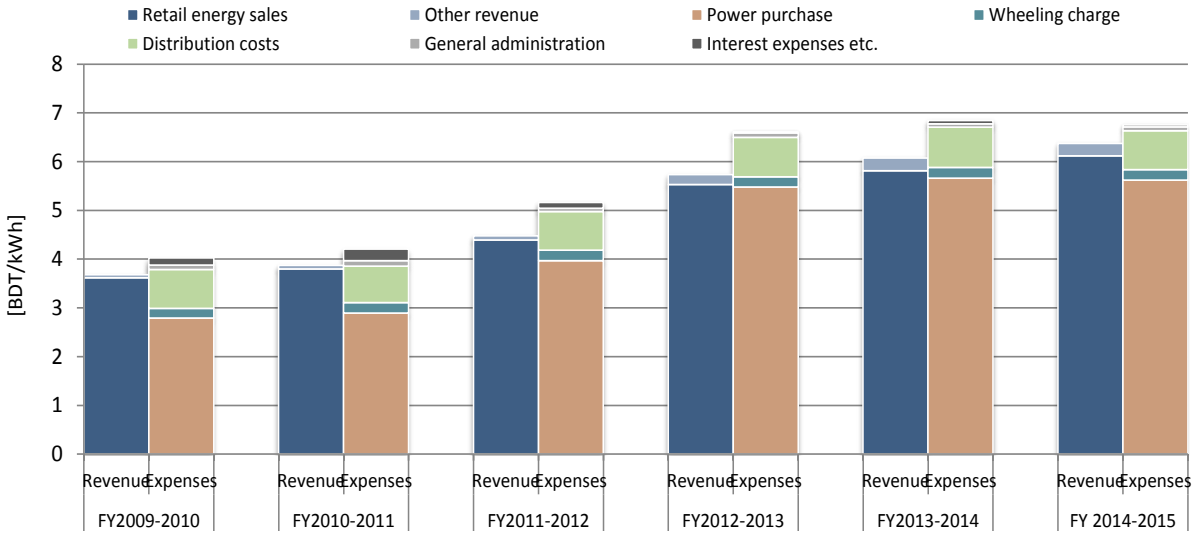
Figure 19-12 illustrates the revenue and expenses of BPDB's distribution division. As stated above, revenue from electricity retail sales is not sufficient to cover the full costs of supply, including its own distribution expenses and wheeling charge; therefore, as with the case of the generation division, BPDB's distribution division has continuously been in a financial deficit.

Considering that other distribution entities, which are analyzed later in the section, have mostly been balancing their revenue and expenses (although their balances do not have much leeway), and that bulk supply tariff is set differently among the distribution entities, BPDB could be setting a higher level of bulk supply tariff for itself (the distribution division) to mitigate the financial deficit of the generation division. The average power procurement cost, bulk supply tariff, and the average retail tariff of BPDB's distribution division are described in Table 19-11.

Table 19-11 Overall Balances of BPDB (Distribution)

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Wholesale electricity purchase cost	mil. BDT	42,161	47,896	52,365
Wholesale electricity purchase (before distribution loss)	GWh	8,737	9,597	10,486
Average bulk supply tariff	BDT/kWh	4.83	4.99	4.99
Retail electricity sales	mil. BDT	42,562	49,163	57,024
Retail electricity	GWh	7693	8456	9315
Average retail tariff	BDT/kWh	5.53	5.81	6.12

Source: BPDB Annual Report



Source: BPDB Annual Report

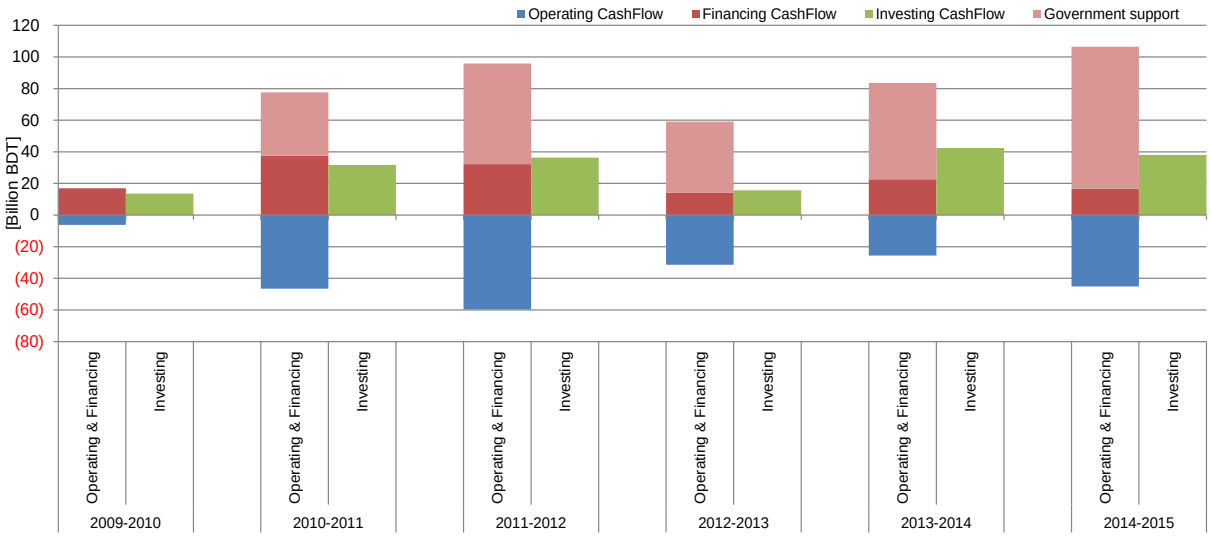
Figure 19-12 Revenue and Expenses of BPDB Power Distribution Division per Energy Sales (BDT/kWh)

(3) Cash Flow and Balance Sheet (Subsidization Issues)

Figure 19-13 shows the annual cash flow of the entire BPDB. The right bar (green) of each year shows the investing cash flow, or the amount of capital investment. The blue part of the left bar of each year shows the operating cash flow, and the dark red part of the left bar shows the financial cash flow. In other words, the figure describes how BPDB procures capital investment funding, from its own sources and external sources. Budgetary support from the government, or subsidy, was recorded separately from the financial cash flow in BPDB's cash flow sheet; therefore the amount is shown in light red.

In general, power utilities tend to show a positive operating cash flow. This is because the operating cash flow includes the profit after tax and other non-cash expenses such as depreciation, which often is a large positive in infrastructure businesses. Therefore, when conducting a cash flow analysis, it is usually the case to compare between the operating cash flow (depreciation, which is return from the past capital investment) and investing cash flow (future capital investment); if large amount of funding is necessary for capital renewal and extension, the shortfall is procured from external sources (positive financial cash flow), while if there is not a large amount of capital renewal and extension needed, necessary funding for reinvestment decreases, and funding from external sources is returned (negative financial cash flow).

However, special attention needs to be paid to the fact that operating cash flow has always been negative in BPDB's cash balance, especially since FY2010-2011. This is due to the fact that generation division of BPDB has recorded a large amount of financial deficit, therefore offsetting the positive operating cash flow from depreciation to a negative operating cash flow as a whole. This situation can be noted as very strange and unsound, considering the nature of power utilities' business model.



Source: BPDB Annual Report

Figure 19-13 Cash Flow of the Entire BPDB

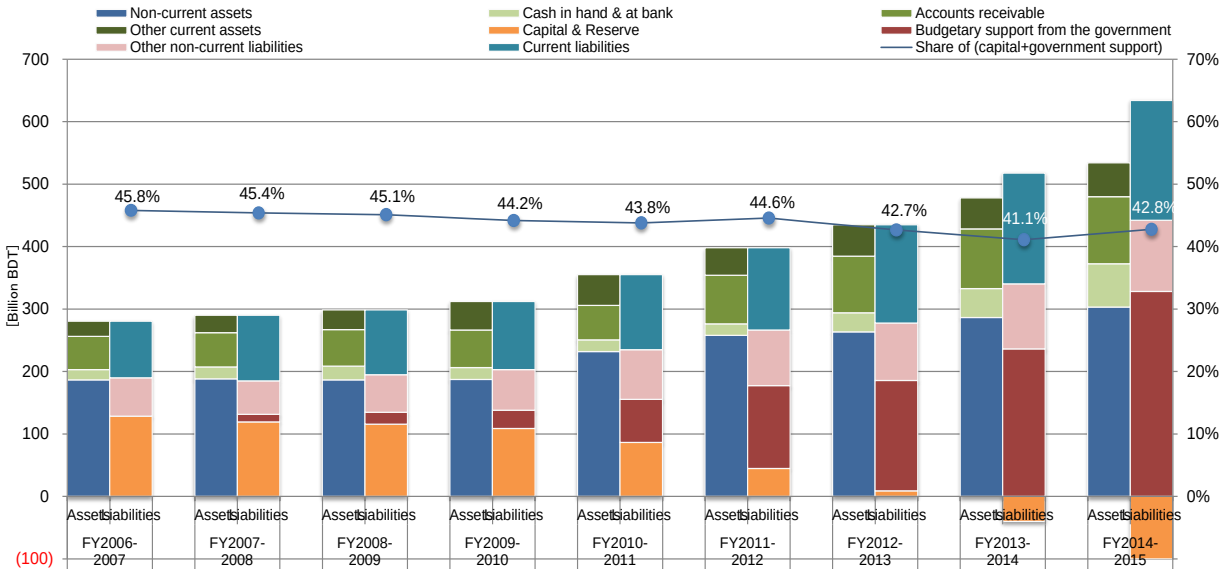
In addition to the cash outflow from the capital investment, operating cash flow, which is supposed to be positive, is recording a net outflow. Since the regular operations cannot maintain the funding of BPDB, the Government of Bangladesh has been providing "budgetary support from the government," which is provided separately from the normal loans. As there is a net increase of budgetary support each year, the accumulated balance of this budgetary support has been growing for the past three years, as shown in Table 19-12.

Table 19-12 Budgetary Support from the Government to BPDB (billion BDT)

Item	FY2010-2011	FY2011-2012	FY2012-2013	FY2013-2014	FY2014-15
Balance of budgetary support	69.005	132.572	176.634	236.363	328.215
Net increase of budgetary support	40.000	63.567	44.062	59.729	91.852

Source: BPDB Annual Report

Figure 19-14 illustrates the annual balance sheet of the entire BPDB. The left side of the bar graph shows the asset, while the right side of the bar shows the liabilities and capital reserve. Due to accumulated deficit, the capital reserve (shown in orange in the graph) has decreased each year, which as a result turned BPDB's capital reserve into capital deficit from FY2013-2014. Budgetary support from the government (shown in dark red in the graph) to BPDB has been increasing rapidly to make up for depleting capital reserve. The line graph shows the percentage of capital reserve and balance of subsidies to the whole asset; the percentage has maintained to be in 40's, which implies that while the subsidy is provided as a liability, its actual role is similar to equity injection. As discussed in 19.2.2 , BPDB is mandated by the government to maintain its capital structure to be "debt 40%: equity 60%" as the loan condition, but currently the government appears to provide subsidies to BPDB so that the share of capital reserve (including subsidies) constantly accounts for more than 40%, though not 60%.



Source: BPDB Annual Report

Figure 19-14 Balance Sheet of the Entire BPDB

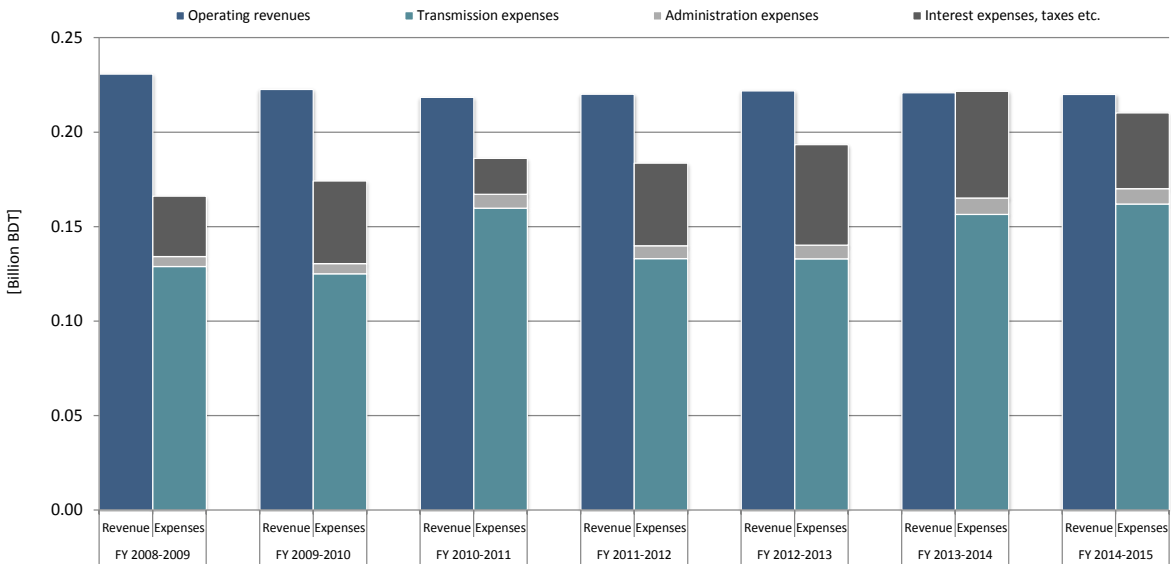
In fact, such issues are already recognized among the government of Bangladesh. According to the article of Financial Express on 29th Aug, 2015, a government official commented that the government is considering converting BPDB's large debt into equity. Requisite debt-equity ratio that is mandated by the government is 40:60; they must improve their debt-equity ratio promptly. If loan of "Budgetary Support from Government against Subsidy (Difference of Buying & Selling Rate)" is converted into equity, capital and reserve of BPDB as of FY2014-2015 increases to 228.4 billion BDT, and the ratio of capital reserve against total asset improves to around 40%.
However, while this measure may tentatively contribute to improving the financial situation, unless BPDB's situation of back spread is resolved, it is clear that the financial situation would worsen again. In order to resolve the situation, raising the bulk supply tariff and retail tariff would be necessary; such measures will be further considered in the following chapters.

19.3.3 Financial performance of PGCB and distribution entities

The study also analyzed the financial situation of power utilities other than BPDB, including PGCB and each distribution entity.

(1) Financial Performance of PGCB

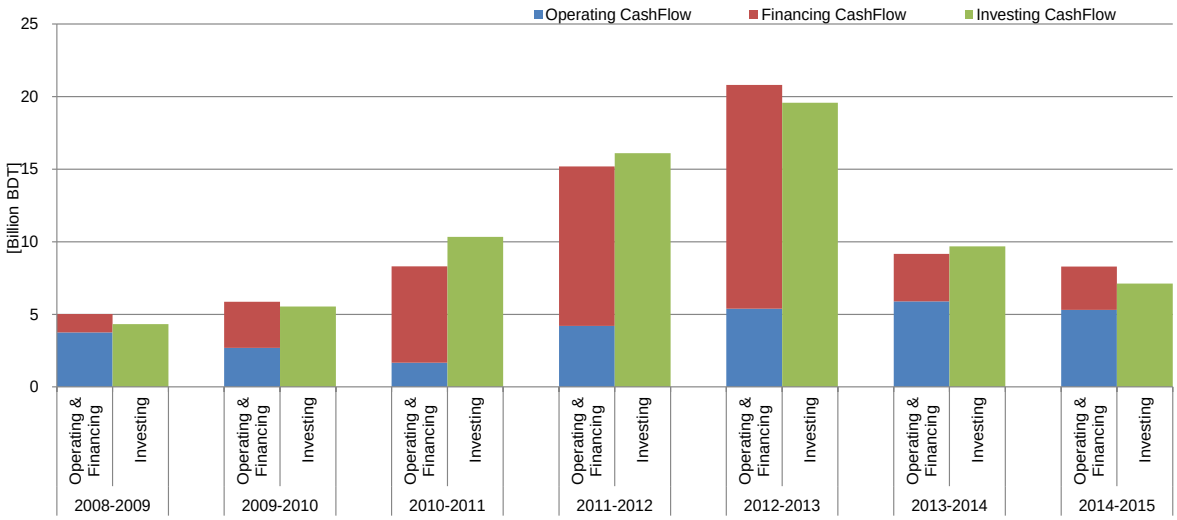
PGCB is the only system operator which possesses all transmission facilities/equipment and the license to conduct power transmission operations in Bangladesh. Each distribution entity pays wheeling charge at a rate approved by BERC.
The historical trend of PGCB's revenue and cost balances per electricity supply, based on its financial statement data, is shown in Figure 19-15. The wheeling charge rate has continued to be set at a fixed rate for a long period (0.2291 BDT/kWh), thus its revenue per kWh has been almost constant. On the other hand, cost per kWh has gradually increased, which is reducing the profit margin of PGCB. If its financial balances continue to worsen, it could have negative impacts on PGCB's transmission investment plan.



Source: PGCB Annual Reports

Figure 19-15 PGCB's Revenue and Cost Balances per Energy Supply (BDT/kWh)

PGCB's cash flow is shown in Figure 19-16. Its operating cash flow has been positive, which is a sound situation for a power utility company (compared to BPDB). Investing cash flow of PGCB was constantly increasing from FY2008-2009 to FY2012-2013, implying that there was a large need for capital investment for new construction and/or renewal. Because the capital investment far exceeded the operating cash flow, PGCB's debt financing greatly increased each year during that period. After 2013, the fund needs for capital investment became moderate and the additional loan decreased.



Source: JICA Survey Team

Figure 19-16 PGCB Cash Flow

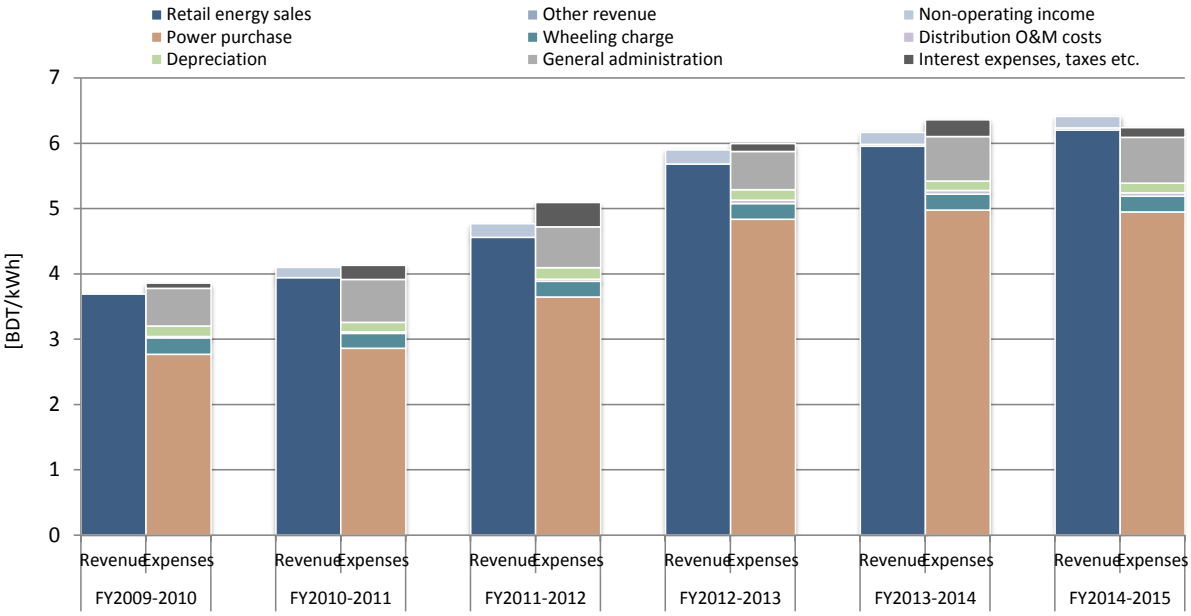
(2) Financial Performance of WZPDCL

WZPCL's revenue and expenses, and its balances per electricity sales are illustrated in Table 19-13 and Figure 19-17. WZPDCL had been in a slight deficit in the past several years, as its revenue was slightly smaller than its expenses. However, in FY2014-2015, it had a slight profit margin.

Table 19-13 Overview: Balances of WZPDCL

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Wholesale electricity purchase cost	mil. BDT	9,379	10,606	13,430
Wholesale electricity purchased (before distribution loss)	GWh	2,187	2,394	2,574
Average bulk supply tariff	BDT/kWh	4.29	4.43	5.22
Retail electricity sales	mil. BDT	11,019	12,693	14,402
Retail electricity	GWh	1,939	2,132	2,310
Average revenue per unit	BDT/kWh	5.68	5.95	6.23

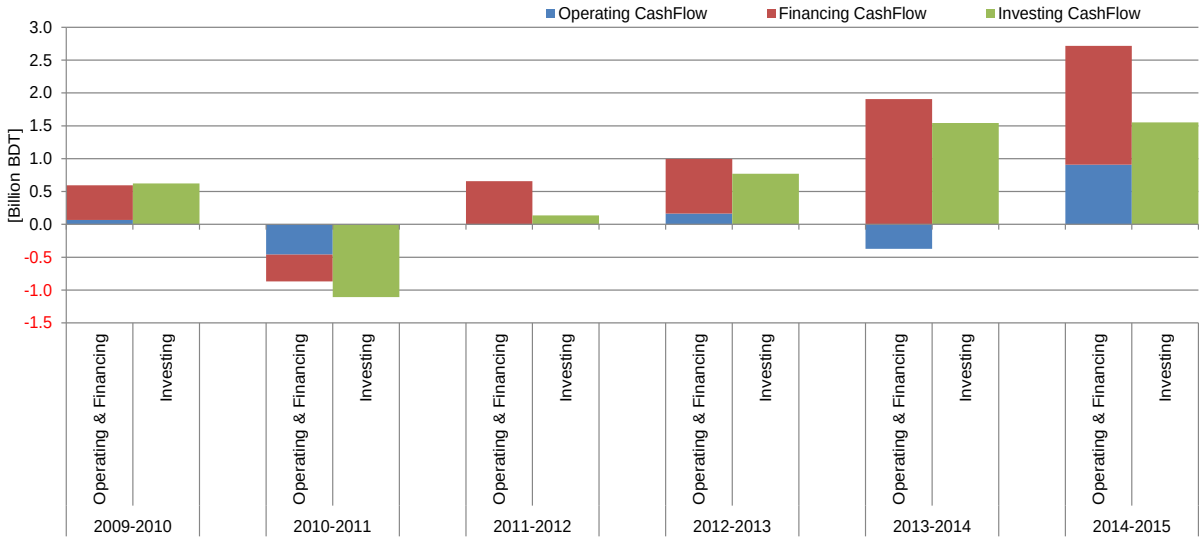
Source: WZPDCL Annual Report



*per kWh of retail sales
Source: WZPDCL Annual Reports

Figure 19-17 WZPDCL Balances per Energy Sales

The cash flow of WZPDCL is shown below in Figure 19-18. WZPDCL's operating cash flow was negative from FY2009-2010 to FY2011-2012, like the case of BPDB, though the amount is much smaller. It was positive in FY2012-2013, then turned negative in FY2013-2014, and became positive again in FY2014-2015. Investing cash flow of WZPDCL has been increasing since FY2011-2012, which drives WZPDCL to rely more on debt financing.



Source: WZPDCL Annual Report

Figure 19-18 WZPDCL Cash Flow

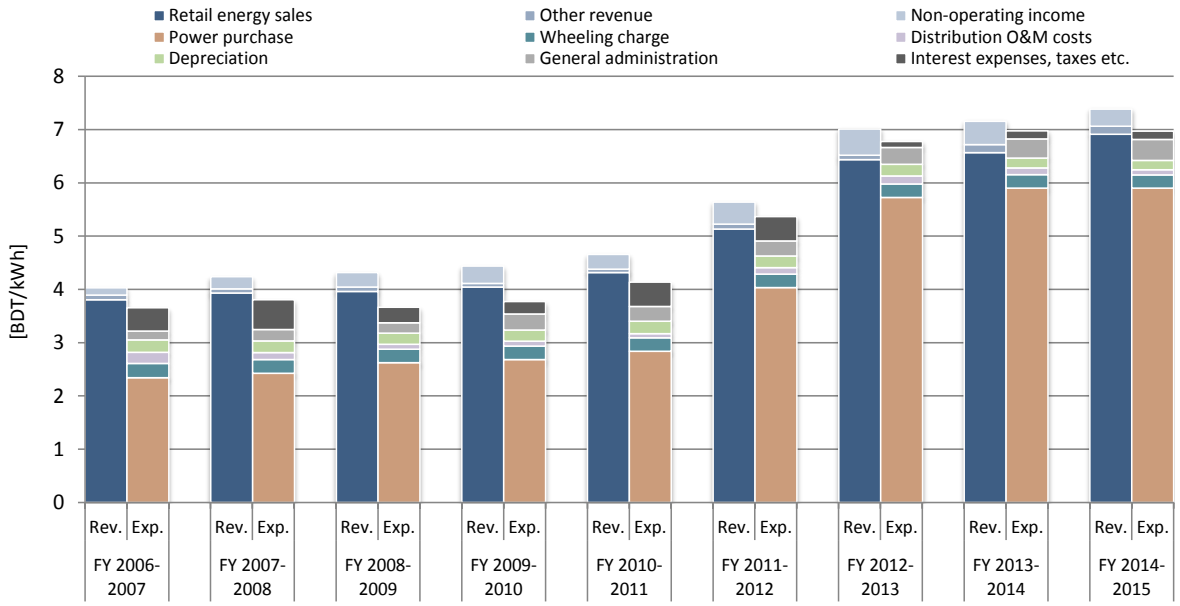
(3) Financial Performance of DESCO

DESCO has maintained a positive final margin, but since FY2012-2013, the margin has been small, after including the contribution from non-operating revenues (i.e. revenues other than electricity sales); that is, it has not been able to cover its expenses with its revenue from electricity sales. Table 19-14 and Figure 19-19 illustrate such situation.

Table 19-14 Overview: Balances of DESCO

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Wholesale electricity purchase cost	**mil. BDT**	**20,393**	**22,898**	**24,344**
Wholesale electricity purchased (without distribution loss)	GWh	3,726	4,067	4,320
Average bulk supply tariff	BDT/kWh	5.47	5.63	4.58
Retail electricity sales	mil. BDT	21,951	24,431	27,358
Retail electricity	GWh	3,412	3,722	3,959
Average revenue per unit	BDT/kWh	6.43	6.56	6.91

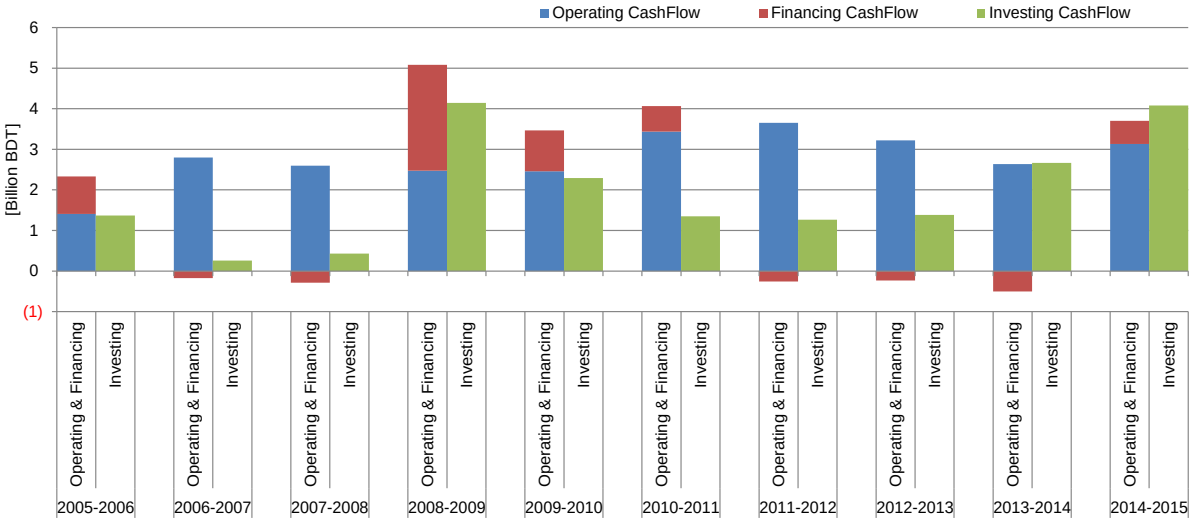
Source: DESCO Annual Report



*per kWh of retail sales
Source: DESCO Annual Reports

Figure 19-19 DESCO Balances per Energy Sales (BDT/kWh)

DESCO's cash flow situation, illustrated in Figure 19-20, is far better than that of BPDB and WZPDCL. Its operating cash flow is mostly covering its investing cash flow. In other words, it implies that the return from past capital investment is large enough for funding the reinvestment, and there is little reliance on additional debt financing to make up for this. However, capital investment has been increasing in the past few years; if such trend continues, it may press DESCO to rely more on debt financing in the future.



Source: JICA Survey Team

Figure 19-20 DESCO Cash Flow

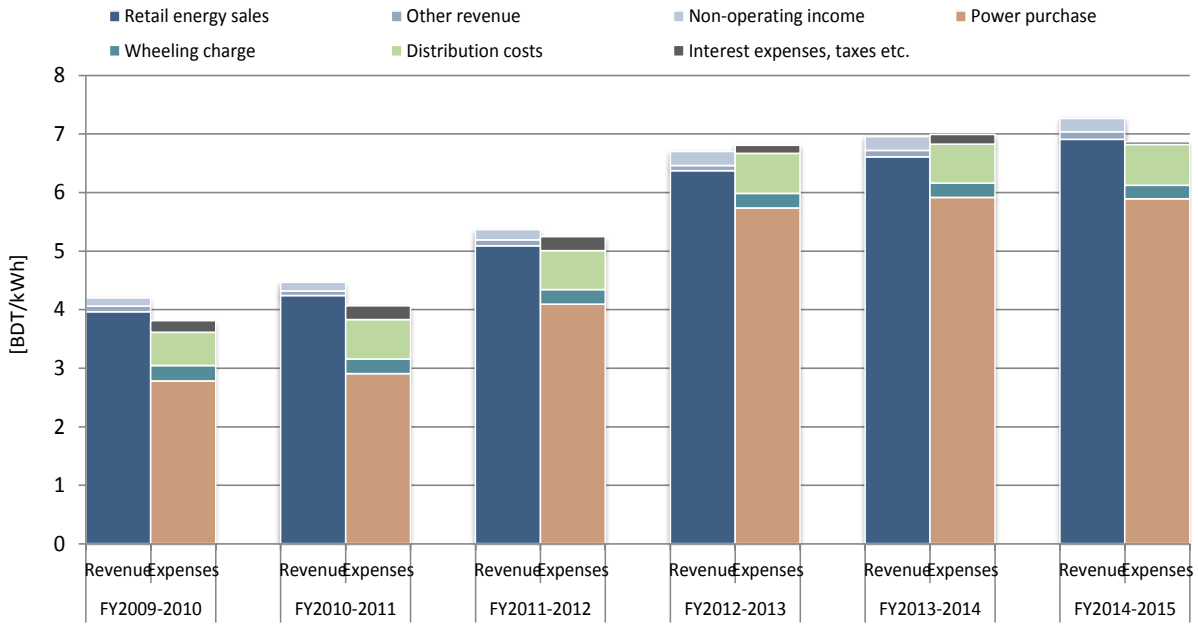
(4) Financial Performance of DPDC

Up until FY2011-2012, DPDC had a positive margin, but as increase in retail electricity tariff could not catch up with the increase in bulk supply tariff, it turned into financial deficit for FY2012-2013. Table 19-15 and Figure 19-21 illustrate such situation.

Table 19-15 Overview: Balances of DPDC

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Wholesale electricity purchase cost	mil. BDT	34,076	37,498	39,424
Wholesale electricity purchased (without distribution loss)	GWh	6,593	7,038	7,402
Average bulk supply tariff	BDT/kWh	5.17	5.33	5.33
Retail electricity sales	mil. BDT	37,851	41,882	46,218
Retail electricity	GWh	5,943	6,341	6,694
Average revenue per unit	BDT/kWh	6.37	6.60	6.90

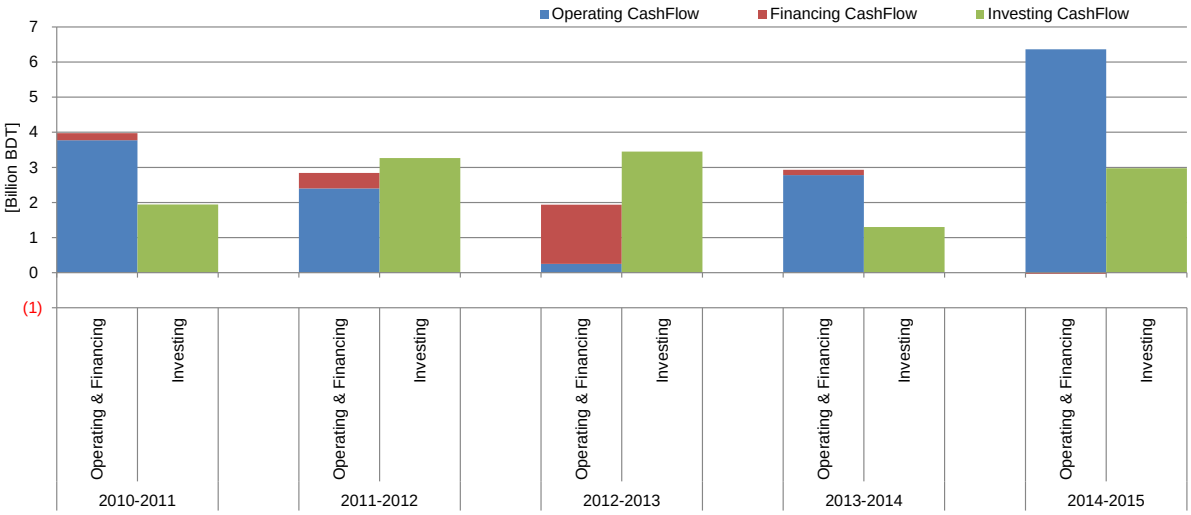
Source: DPDC Annual Report



*per kWh of retail sales
Source: DPDC Annual Reports

Figure 19-21 Balances of DPDC per Energy Sales (BDT/kWh)

Annual changes in DPDC's cash balance are shown in Figure 19-22. As with the case of DESCO, its operating cash flow mostly covers its capital investment and its reliance on additional debt financing is small; it has maintained a relatively sound financial situation.



Source: JICA Survey Team

Figure 19-22 DPDC Cash Flow

(5) Financial Performance of REB

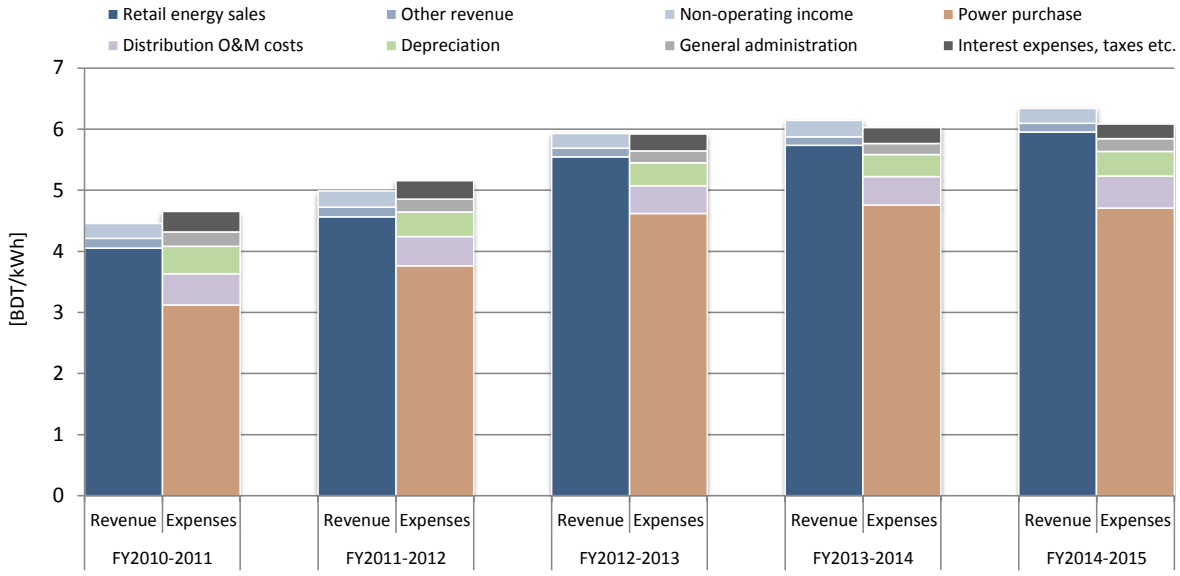
REB, unlike the other distribution entities, does not publish its financial statements on its website; therefore, its financial data was acquired directly from REB in this survey. Since the format of the financial data was different from a standard P/L statement, the survey reorganized the items so that the data would be comparable with the other entities; however, it needs to be noted that even after reorganizing, the data format may not be exactly the same for comparison.

REB's margins turned from negative to positive after FY2012-2013, and its operating margins have been gradually improving. Its average bulk supply tariff from BPDB has not increased as much compared with the other distribution utilities. This may be due to the fact that BPDB's bulk supply tariff to REB is set at a lower level than the other distribution entities, one type of internal subsidization. Such situation is shown in Table 19-16 and Figure 19-23.

Table 19-16 Overview: Balances of REB

Particulars	Unit	FY2012-13	FY2013-14	FY2014-15
Wholesale electricity purchase cost	mil. BDT	63,580	74,180	81,712
Wholesale electricity purchased (without distribution loss)	GWh	14,222	16,161	17,835
Average bulk supply tariff	BDT/kWh	4.47	4.59	4.58
Retail electricity sales	mil. BDT	76,316	89,362	103,309
Retail electricity	GWh	13,754	15,582	17,346
Average revenue per unit	BDT/kWh	5.55	5.73	5.96

Source: Documents provided by REB



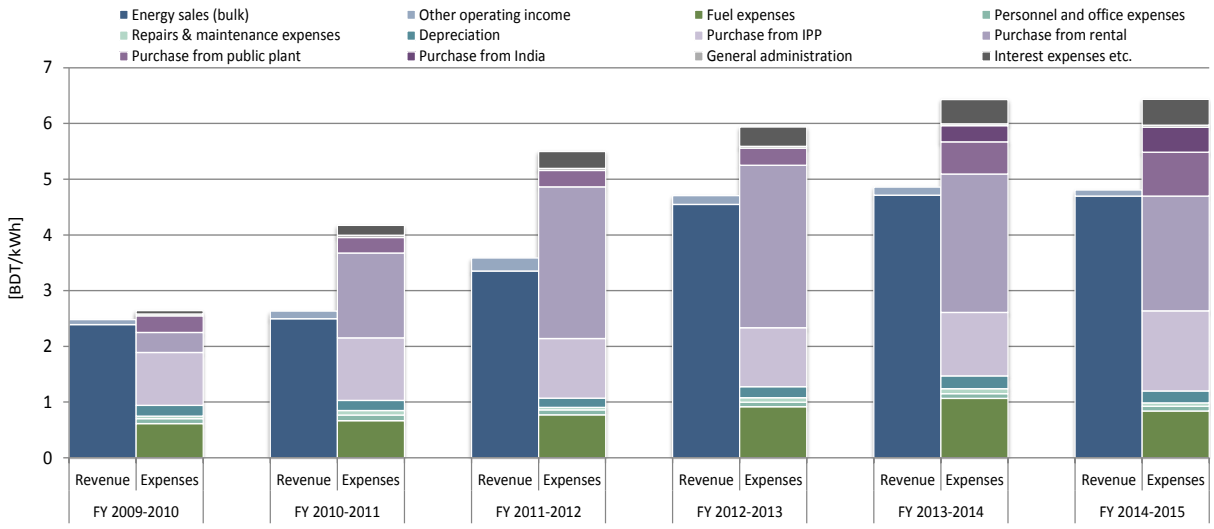
*per kWh of retail sales
Source: Documents provided by REB

Figure 19-23 Balances of REB per Energy Sales (BDT/kWh)

19.3.4 Cost structure of power generation

(1) Historical Trend of Generation Cost (Electricity Procurement Cost) of Bangladesh

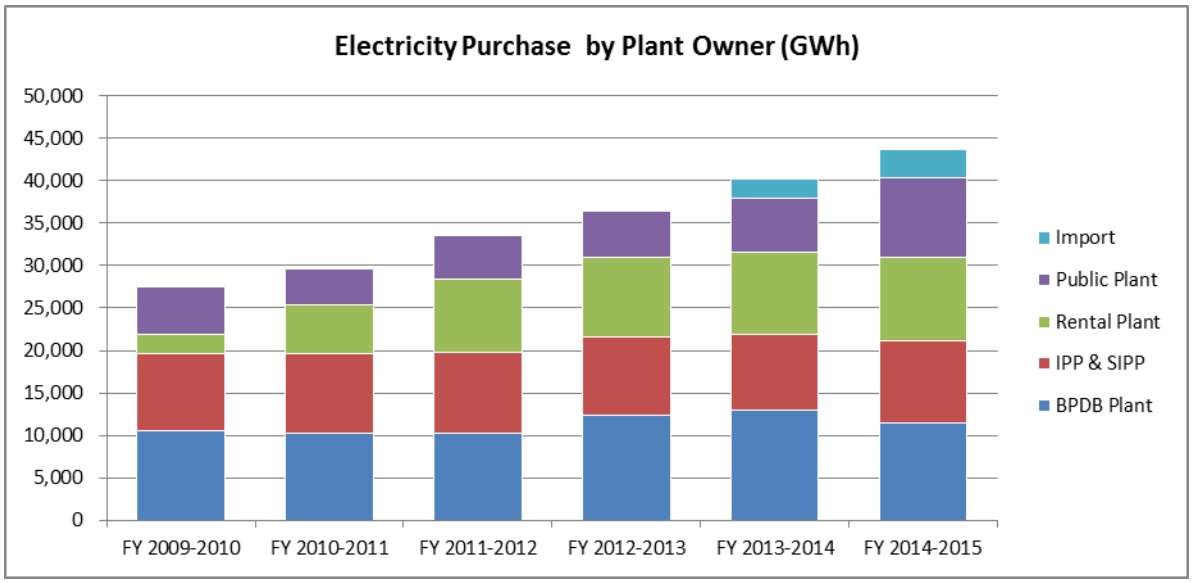
As already stated in the previous sections, the current electricity tariff rates are not sufficient to cover its actual cost of electricity supply. As shown in Figure 19-24, the cost of BPDB generation division, especially its electricity procurement cost, has been increasing rapidly recently, and the raise in electricity tariff has not been able to catch up with such increase.



Source: BPDB Annual Reports

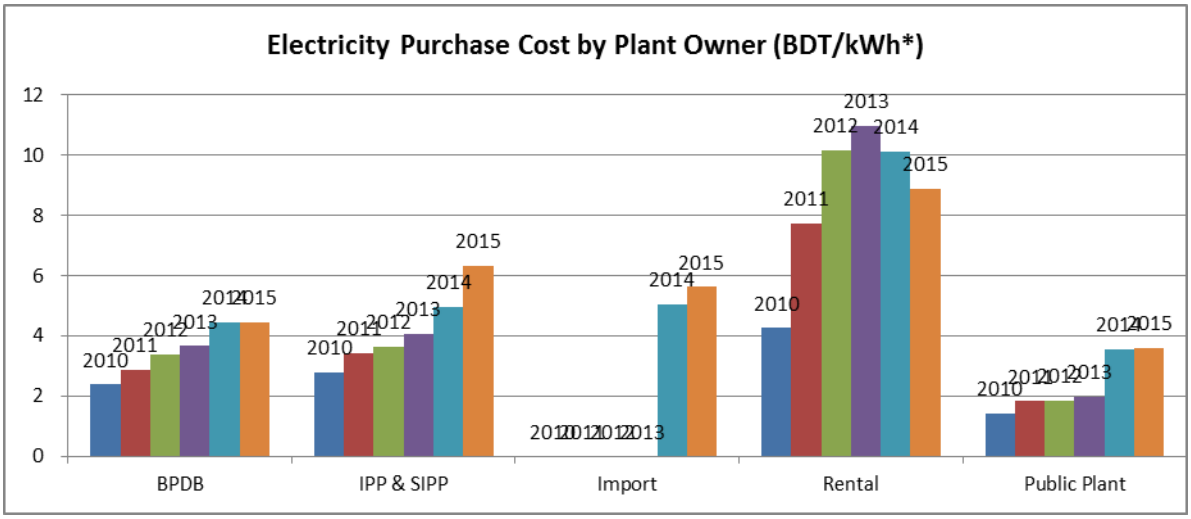
Figure 19-24 Balances of BPDB (Generation Division) per Electricity Sales (BDT/kWh)

Electricity procurement of BPDB by supplier is shown in Figure 19-25. The figure shows that its electricity purchase, especially from rental plants, has been increasing along with recent increase in electricity demand. Although the average electricity purchase cost of rental plants, as shown in Figure 19-26, has been in a decreasing trend since FY2013-2014, it is still very expensive compared with other suppliers. The average electricity purchase cost from rental plants was 8.90 BDT/kWh in FY2014-2015, whereas the average for IPP/SIPP and public plants in the same year was 6.33 BDT/kWh and 3.61 BDT/kWh, respectively. Thus, one of the main reasons of increasing electricity cost can be largely due to the increase in electricity purchase from rental plants that are much more costly than other plants.



Source: BPDB Annual Reports

Figure 19-25 BPDB Electricity Procurement (Breakdown by Plant Owner)

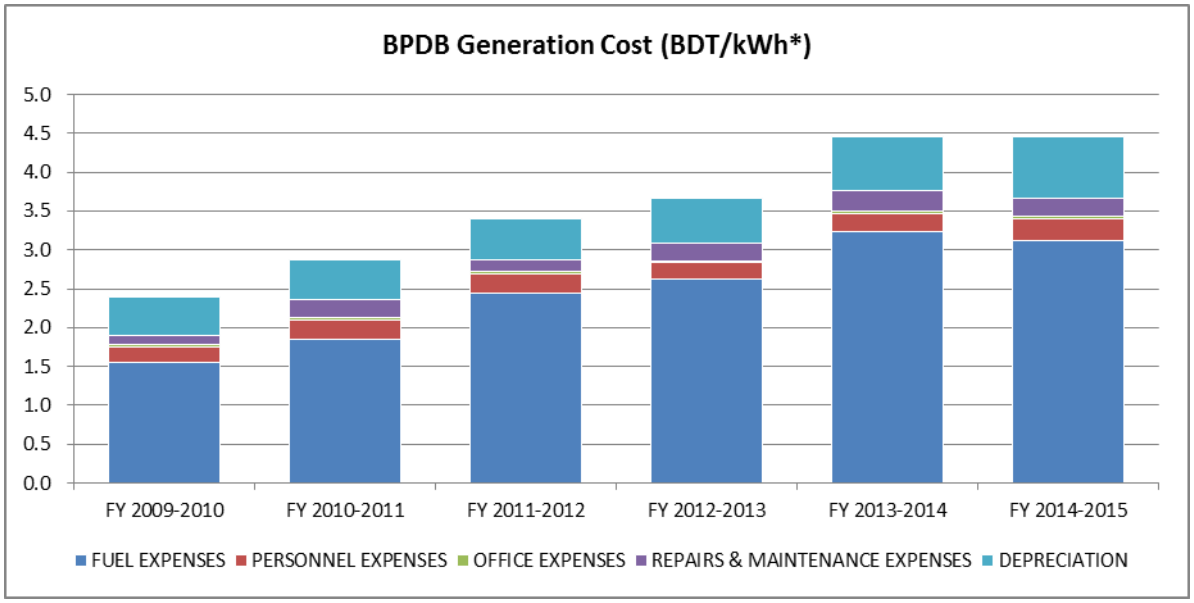


*per kWh of electricity purchase (net generation for BPDB)
Source: BPDB Annual Reports

Figure 19-26 BPDB Electricity Purchase Cost (by Plant Owner)

(2) Generation Cost of BPDB

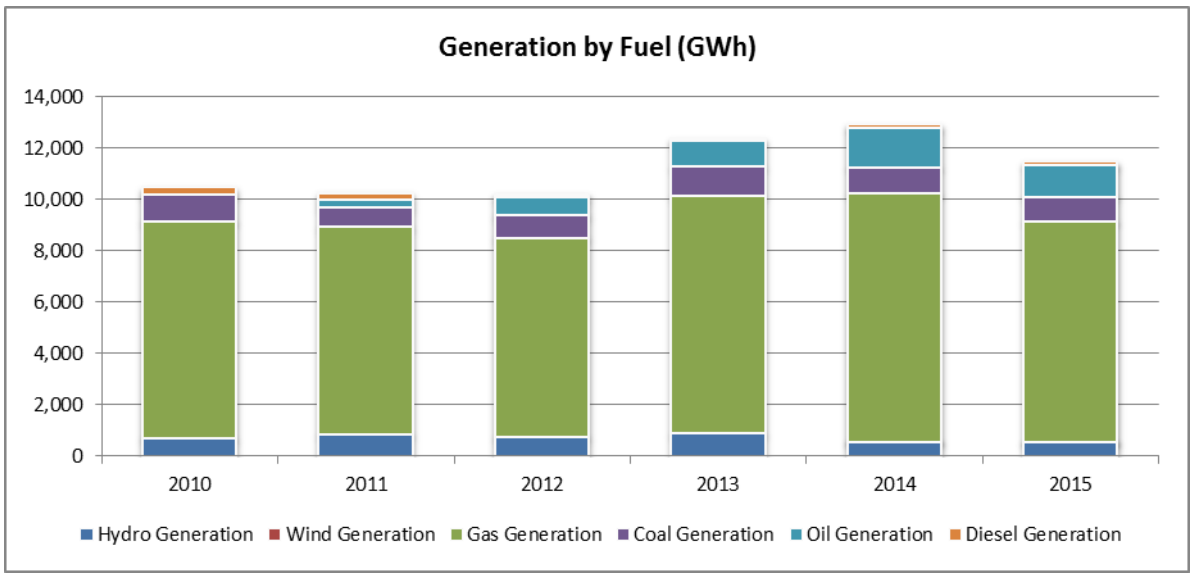
As it can be seen from the figures above, there has been an increase in not only the electricity purchase cost from external generation entities, but also the generation costs of BPDB's own plants as well, mainly due to the increase in fuel cost, as shown in Figure 19-27.



*per kWh of net generation
Source: BPDB Annual Reports

Figure 19-27 Generation Cost of BPDB's Own Plants

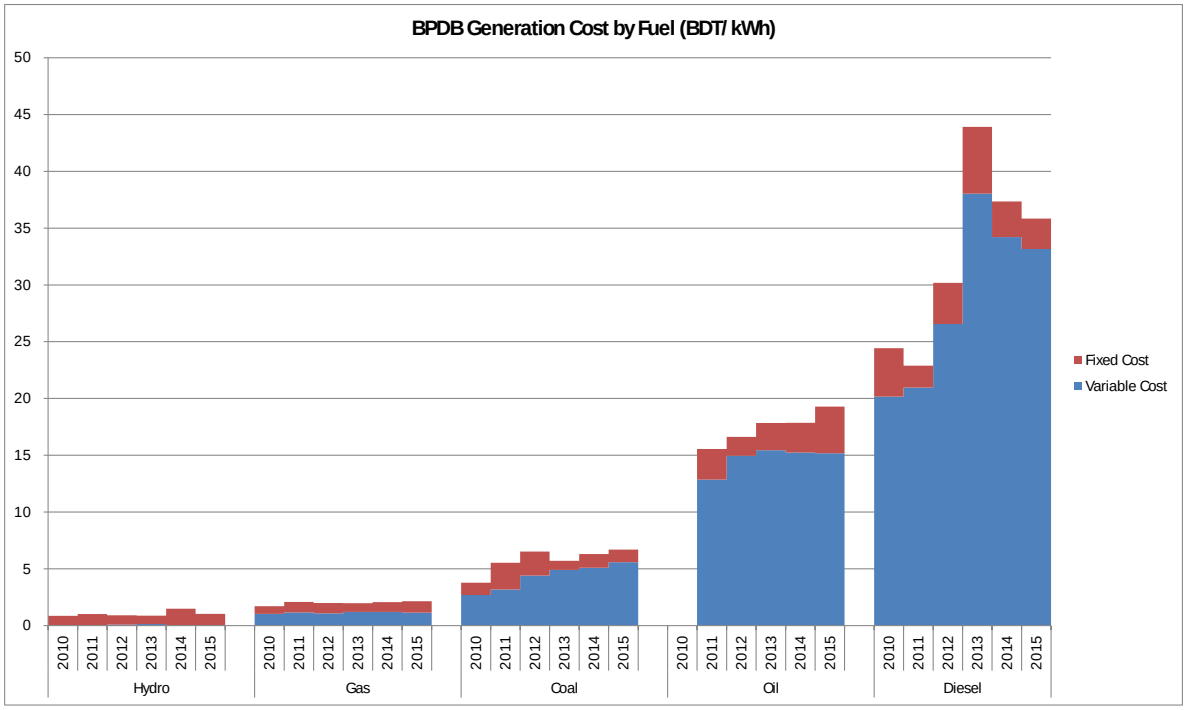
Figure 19-28 illustrates the breakdown of generated electricity in BPDB plants by fuel type. Gas fuel holds a major share of the total generated electricity; however, the increasing portion of oil fuel, which is more costly than gas, can be considered as one of the factors for the increased cost.



Source: BPDB Annual Reports

Figure 19-28 Breakdown of Electricity Generation by Fuel in BPDB Owned Plants

Generation cost by fuel in BPDB owned plants is shown in Figure 19-29. In BPDB owned plants, generation cost of oil and diesel are significantly higher than other sources.
It may seem strange that the generation cost of coal plants is higher than gas plants, which is different from the general trend. This is because while the fuel supply of gas for electricity has relied on domestic procurement and a low fuel price has been maintained compared to the international prices, the fuel price for coal plants does not differ significantly from the international prices, even if the fuel is domestically procured. Therefore, if the supply cost of gas is raised to the international level in the future, it will have a significant effect on the overall generation cost. In order to mitigate such predicted rise in fuel prices, achieving higher thermal efficiency in power plants (current average of 33.29% in the public sector, according to 2015 BPDB AR) will be required promptly.



*per kWh of net generation
Source: BPDB Annual Reports

Figure 19-29 Generation Cost of BPDB's Own Plants (by Fuel)

Regarding the subsidy for electricity tariff in Bangladesh, in addition to the budgetary support from the government to BPDB for its financial deficit as already explained in the previous chapter, the current situation of gas fuel price for electricity being kept lower than the international level can be considered as a kind of subsidy for fuel cost. While the former type of subsidy for electricity is clearly stated on the financial statement as an item "subsidy from the government," the latter type can be considered to be a "hidden subsidy" as it is not clearly seen on financial statements.

19.3.5 Summary of the financial performance of the power sector and implications for the way forward

(1) Financial Performance of the Power Sector in Bangladesh

Analyzing the balances of the each power utility (BPDB, PGCB, WZPDCL, DESCO, DPDC and REB), while both the generation and distribution division of BPDB were in a financial deficit, the transmission operator PGCB and other distribution entities have maintained a small amount of profit margin or sometimes a slight financial deficit. However, by analyzing the power sector as a vertically integrated utility (the consolidated P/L statement of the six utilities), it can be seen that the power

sector of Bangladesh as a whole has continuously been in a financial deficit.
A large part of the deficit in the power sector comes from the deficit incurred in BPDB, especially its power generation division. In other words, one can perceive such situation as follows: although the retail electricity tariff has gradually been raised, it is still set at a low level, and as a result, in order to maintain the business of distribution entities, the standard of bulk supply tariff is much lower than the actual the costs of generation and procurement.
As a result, BPDB has had a large amount of financial deficit each year, and its operating cash flow, which is generally positive for a power utility, has been negative in the past few years. In order to avoid its own capital reserves from depleting and becoming short of operation funding, BPDB has been maintaining its operation by acquiring budgetary support from the government, of which accumulated balance has been rapidly increasing in the past years.
PGCB, the sole operator of power transmission system, has maintained to perform relatively well and maintained a certain margin of profit. However, while the wheeling charge rate has been fixed for a long period of time, its cost has been gradually increasing; therefore, but its profitability has been worsening in recent years.
As for the distribution utilities, the situation in most entities is better than BPDB's distribution division, and some of them have maintained a margin of profit. However, their profitability does not appear to be high enough to maintain financial soundness. It also needs to be noted that, because the cost of power purchase from BPDB accounts for a large share in the costs of supply of distribution utilities, if bulk supply tariff is raised for improving the financial conditions of BPDB, it is essential to raise the retail electricity tariff at the same time.

(2) Implications for the Way Forward

In order to turn the power sector's financial performance ino sound conditions, it is strongly recommended that achieving the revenue-cost balance so that the power sector does not need to rely on government subsidies. In order to do that, not only tariff increase to meet the costs of supply but also cost reduction, especially reduction of power procurement cost, needs to be taken.

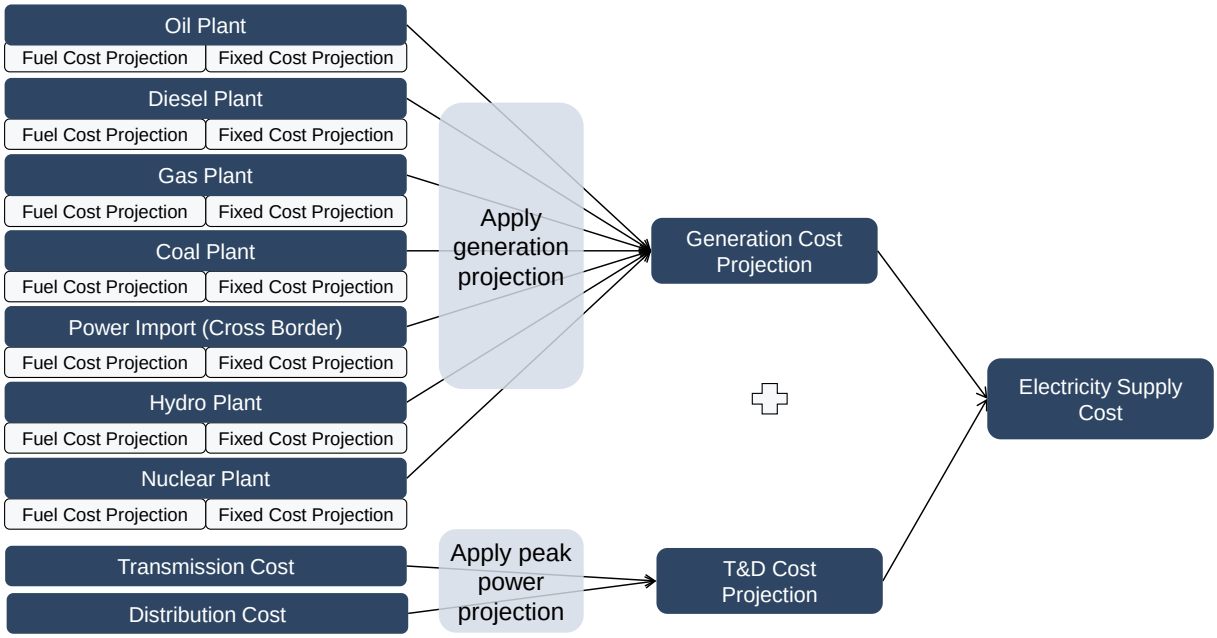
Tariff Increase
Considering that BPDB's financial condition is in a critically serious situation and the financial support from the government has been increasing, raising bulk supply tariff for BPDB to cover the costs of power generation is indispensable. This will also lead to the increase of retail tariff, otherwise the distribution companies will also be faced with financial difficulties.

Cost Reduction
In the meantime, reducing the costs of power supply, especially power procurement, should also be addressed for mitigating the negative effect of tariff increase on households and national economy. Above all, power procurement from small rental power plants, which is much more costly than other types of power generation and recently has been increasing both in volume and price, needs to be dealt with. Because the efficiency of these small power generators is not higher than large-scale power plants, they should be driven away gradually. In order to so that, developing large-scale power plants in a timely manner to meet the increasing power demand is important.

Necessity of Roadmap and Action Plan
However, both of the aforementioned can be made only gradually, because the former needs to conside the negative effect of drastic tariff increase and the latter cannot evade from the obligation of power purchase agreement (PPA). Hence it is supposed to take certain time to achieve the revenue-cost balance and totally remove the deficit. If government support still needs to be employed for some period, the government should provide a mid- and long-term roadmap as well as a short-term action plan to show how and when the dependence on subsidies will be removed.

19.4 Estimation of the Future Costs of Electricity Supply

To serve for the analysis on the effect of raising electricity tariff on Bangladesh national economy (to be discussed in Chapter 21), future projection of electricity supply cost was estimated. In this estimation, the cost of electricity supply was segregated into power generation cost and transmission & distribution costs, and then the power generation cost was estimated for each of gas-fired, oil-fired, coal-fired, diesel, hydro, and nuclear plants, as well as power import, segregated into fuel cost (variable cost) and other costs (fixed cost). As for the future projection of energy mix as the condition of power generation cost, Scenario 3 of the Power Development Plan as discussed in Chapter 11 was referred to.



Source: JICA Survey Team

Figure 19-30 Projection Method of Electricity Supply

The projection methods of fuel cost and other costs are described hereafter.

19.4.1 Projection of generation cost

The projection of the variable cost (US cent/kWh) in generation cost referred to the parameters of Scenario 3 of the Power Development Plan in Chapter 11, where the total fuel cost (million USD) for each plant type (i.e. oil, diesel, gas, coal, power import, hydro and nuclear) was estimated based on the fuel price projection of IEA's "World Energy Outlook".
In the same manner, the projection of the fixed cost (US cent/kWh) in generation referred to the parameters of Scenario 3 of the Power Development Plan, where the total fixed cost (million USD) for each plant type (i.e. oil, diesel, gas, coal, power import, hydro and nuclear) was estimated considering the inflation rate in the future.

19.4.2 Projection of transission and distribution costs

For the projection of transmission and distribution costs, a simplified methodology was employed based on the assumption that these costs, mostly fixed cost, increase in accordance with the peak generation demand (MW). Referring to the data provided in the financial statements of PGCB and distribution entities, the unit costs per peak generation demand for the past years was calculated, and then the unit costs in the future were estimated taking into consideration these historical data and the inflation rate. The result was multiplied by the peak power projection provided by the Power Development Plan, to derive the projection of transmission and distribution costs.

19.4.3 Results of the cost estimation

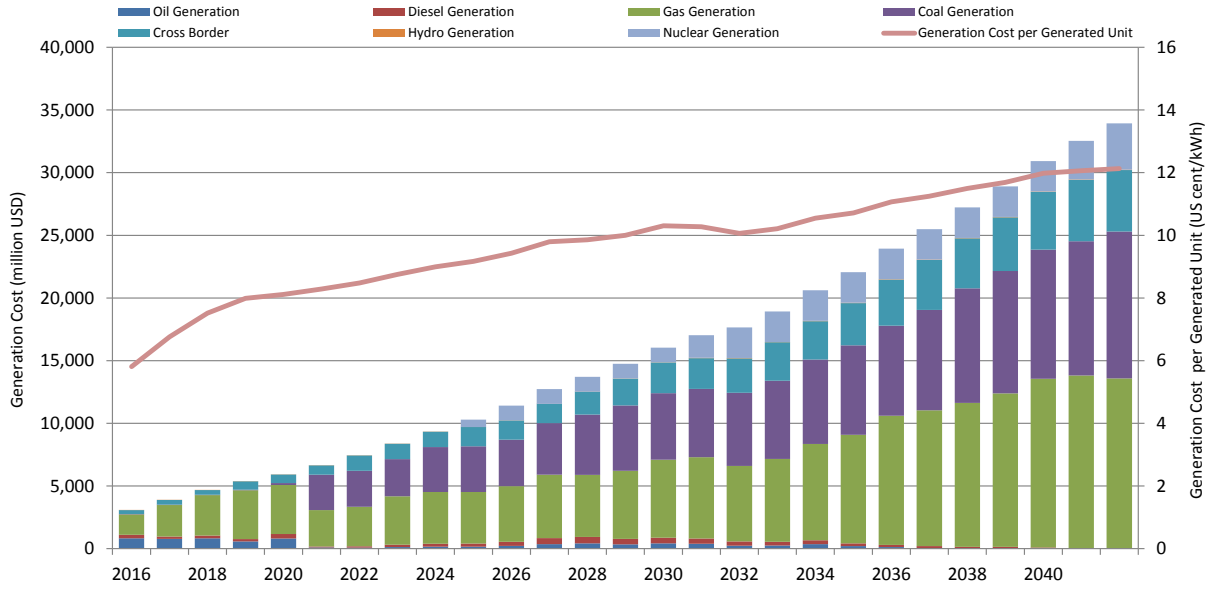
Figure 19-31 and Figure 19-32 are the projection of generation cost in USD and in BDT respectively. The bar chart in these figures is the total generation cost broken down by the plant type (gas, coal, oi, hydro, nuclear etc.), whereas the line chart in these figures is the average cost of generation per generated unit (in US cent/kWh and BDT/kWh).

The total generation cost increases from approximately 3.9 billion USD in 2016 to 33.9 billion USD in 2041, which is about 9.1% increase per annum. In terms of BDT, the total electricity supply cost increases from 0.31 trillon BDT in 2016 to 3.40 trillion BDT, which is about 10.1% increase per annum. In this study, the exchange rate of BDT against USD is expected to depreciate (from 79 BDT/USD in 2016 to 100 BDT/USD in 2041) because of the higher inflation rate in Bangladesh than that of international price, hence the growth rate of nominal prices in BDT becomes higher than that in nominal USD.

The average cost of generation per generated unit in US cent/kWh nearly doubles from 6.76 US cent/kWh in 2016 to 12.13 US cent/kWh in 2041, which is about 2.4% growth per annum. In terms of BDT/kWh, it increases from 5.34 BDT/kWh to 12.14 BDT/kWh in 2041, about 3.3% growth per annum.

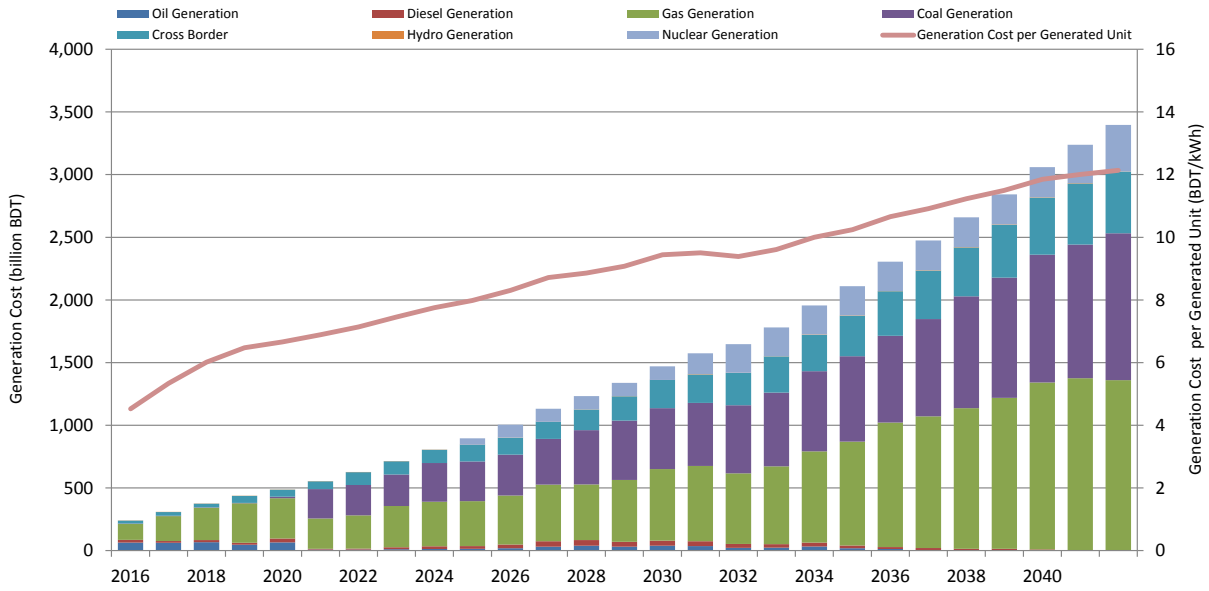
It can be observed from these figures that the increase of average generation cost becomes dull in a year when the share of gas-fired power generation becomes low. Because this cost projection uses international fuel prices, not the current domestic prices in Bangladesh, the generation cost of gas-fired power plant becomes higher than that of coal-fired, hydo, and nuclear power plants, though it’s still lower than that of oil-fired and diesel power plants.

The increased share of coal-fired and nuclear power plants, as well as that of power import that is mainly hydro, contributes to mitigating the overall increase in the generation cost. Generation of oil plants, whose fuel cost is extremely expensive, is nearly driven away by 2041.



Source: JICA Survey Team

Figure 19-31 Projection of Generation Cost by Fuel (USD)



Source: JICA Survey Team

Figure 19-32 Projection of Generation Cost by Fuel (BDT)

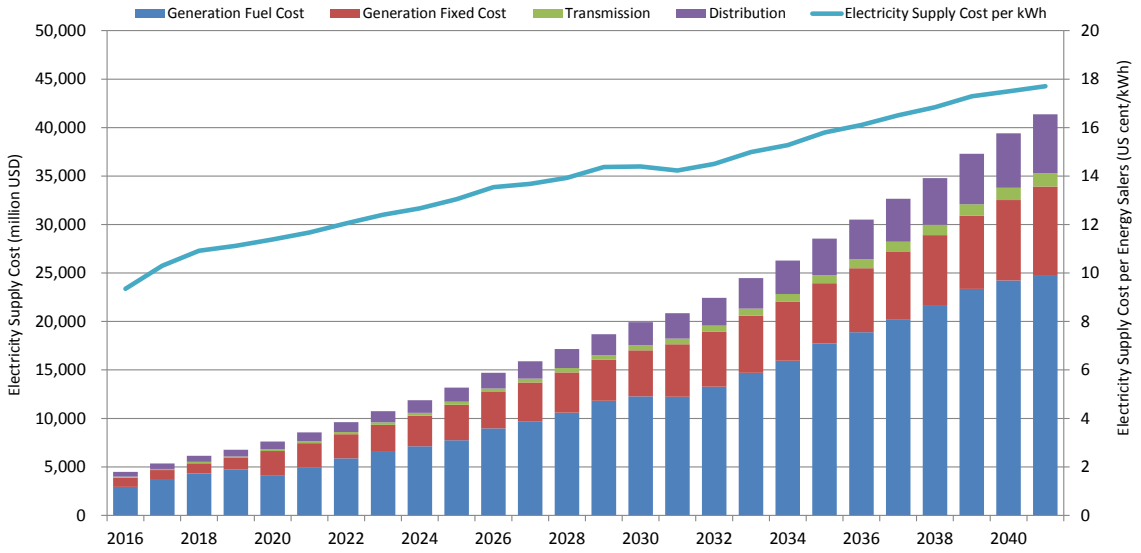
The projected cost of electricity supply, which includes not only generation cost but alos transmission and distribution costs, are shown in Figure 19-33 (in USD) and Figure 19-34 (in BDT). In the same manner, the bar chart in these figures is the total cost of supply consisting of generation fuel cost, generation fixed cost, transmission cost, and distribution cost, whereas the line chart is the average cost of supply per energy sales (in US cent/kWh and BDT/cent). It needs to be noted that Figure 19-31 and Figure 19-32 used "kWh of power generation" while Figure 19-33 and Figure 19-34 used "kWh of energy sales to end-consumers" after transmission and distribution losses, thus the denominator to calculate the unit cost is different.

The total electricity supply cost increases to approximately 4.5 billion USD (0.35 trillion BDT) to 41.4 billion USD (4.14 trillion BDT) in 2041, which is 9.3% (10.3%) increase per annum.

The average cost of electricity supply per kWh of energy sales is expected to increase from 9.34 US cent/kWh (7.38 BDT/kWh) in 2016 to 17.70 US cent/kWh (17.72 BDT/kWh) in 2041. During this period, the average cost of supply increases by 2.6% per annum (3.6% per annum in BDT). This growth rate is expressed in nominal prices. In terms of real price that excludes the effect of inflation, the cost of electricity supply is expected to increase by about 1.1% per annum.

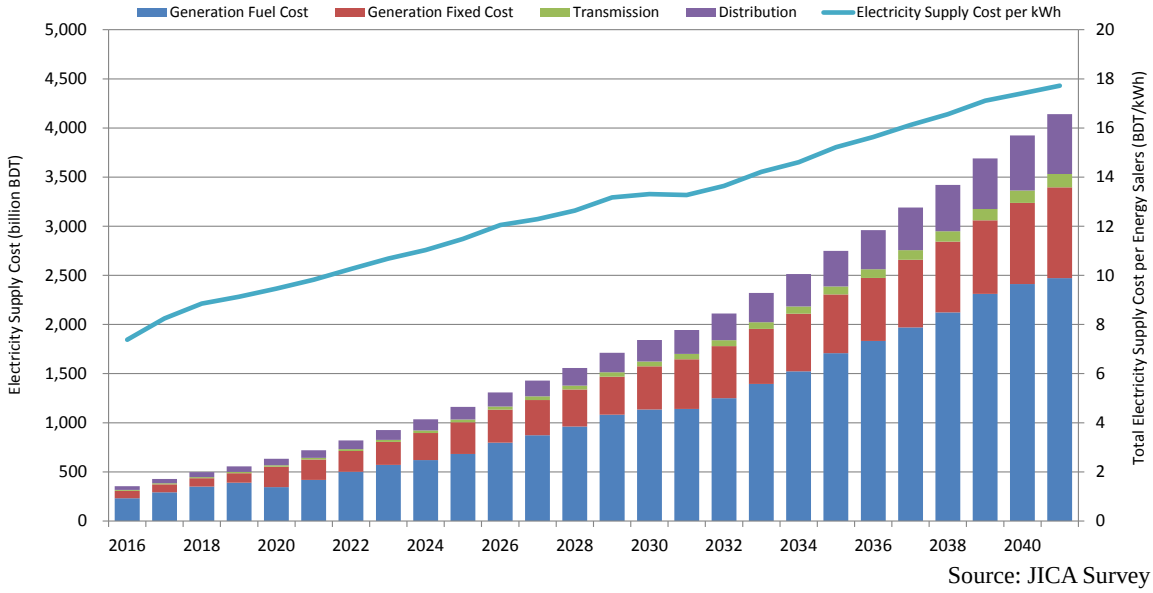
In the anaylysis of overall electricity supply cost of a virtual "vertically integrated utility" in Section 19.3.1 , the average costs of power supply for FY2014-2015 were approximately 8.23 BDT/kWh. The gap between this and the estimated electricity supply cost for 2016 (7.38 BDT/kWh) can be accredited not only to the recent declining trend of international prices of oil and gas but also to the difference of methodology in calculating the generation costs; while the cost analysis of the virtual "vertically integrated utility" is based on the actual accounitng data, projection up to 2041 is the simulation using the international fuel prices outlook as provided by IEA and the fixed cost of a model power plant.

Therefore, though this cost projection may not be perfectly consistent with the historical trend in the past, its result is sufficient to obtain an implication that the cost of electricity supply (real price) in Bangladesh is expected to increase by around 1%-1.5% per annum as a long-term prospect.



Source: JICA Survey Team

Figure 19-33 Projection of Electricity Supply Cost (USD)



Source: JICA Survey Team

Figure 19-34 Projection of Electricity Supply Cost (BDT)

Chapter 20 Financial Performance of the Gas and Oil Sector

20.1 Natural Gas Tariff

20.1.1 Overview of natural gas tariff in Bangladesh

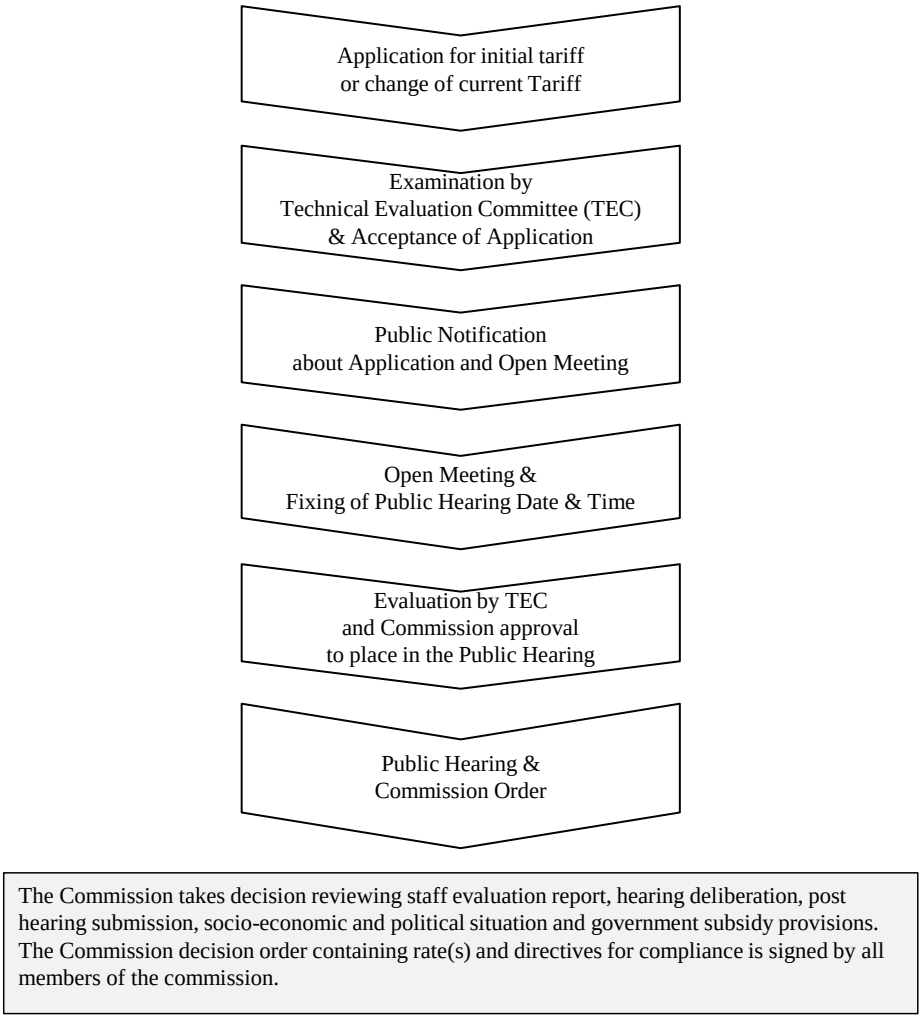
Like the case of electricity tariff, BERC (Bangladesh Energy Regulatory Commission Act) is authorized to regulate the tatiff of natural gas and petroleum products.

Table 20-1 BERC's Missions

· Enforcement of fiscal discipline of the energy sector
· Introduction of performance targets and incentive-based regulation
· Introduction of uniform operational standards and quality of supply
· Transparency in tariff determination and economic efficiency
· Increased opportunities for development of competitive markets
· Increased opportunities for efficiency and economic growth
· Public involvement into the energy sector

Source: BERC website

BERC has prepared two regulations regarding the gas sector, i.e. Gas Transmission Tariff Regulation (2010) and Gas Distribution Tariff Regulation (2010). These regulations are formulated in consideration for the new entrant of private entities and stipulate the procedures to approve the tariff of gas transmission and distribution, such as the procedure of submitting the application for gas tariff by a licensee, BERC's procedure of reviewing the application for gas tariff, and the procedure of issuing the approval for applied gas tariff.
Both regulations specify in detail the standard methodology to calcurate the costs of supply as the basis of tariff calculations. Figure 20-1 shows the outline of the process to determine natural gas tariff.



Source: "Data Collection Survey on Bangladesh Natural Gas Sector - Final report" (JICA, 2012)

Figure 20-1 Process of Determining Natural Gas Tariff in Bangladesh

Natural gas tariff is classified by the following customer categories. For commercial customers the tariff rate is set in proportion to the mcf (1000 cubic feet) of metered gas consumption, whereas for residential customers two types of tariff rates are provided, i.e. rate per metered consumption and monthly fixed rate in accordance with the appliances in use. Table 20-2 shows the historical trend of natural gas tariff rates.

- Power generation
- Fertilizer raw material
- Industrial
- Commercial
- Tea estate
- Captive power generation
- CNG station
- Seasonal industry (brick field etc.)
- Domestic (metered)
- Domestic (monthly fixed rate in accordance with the appliances in use)

Table 20-2 Natural Gas Tariff Rates Since1969

(Unit: BDT/mcf)

Effective from	Power	Fertilizer	Industry	Commercial	Tea estate	Captive Power	CNG Statioon	Brick field (seasonal)	Domestic		
									Metered	Single Burner	Double burner
28.06.1969	1.60	1.60	2.92	6.40	-	-	-	-	6.40	6.30	10.50
19.06.1974	3.72	3.72	7.20	12.00	-	-	-	-	12.00	15.00	28.00
01.12.1977	5.00	5.00	9.00	13.00	-	-	-	-	13.00	16.00	30.00
02.06.1979	6.25	6.25	16.00	17.00	-	-	-	-	16.00	20.00	36.00
07.06.1980	7.75	7.75	18.00	19.00	-	-	-	-	18.00	22.00	40.00
07.06.1981	9.30	9.30	27.75	28.00	-	-	-	-	20.00	25.00	45.00
01.07.1982	10.50	10.50	31.00	31.00	-	-	-	-	27.00	35.00	65.00
30.06.1983	11.50	11.50	36.00	36.00	-	-	-	-	34.00	45.00	80.00
27.06.1984	13.05	13.05	36.00	45.20	-	-	-	51.00	34.00	45.00	80.00
30.06.1985	15.66	15.66	43.20	54.24	-	-	-	61.20	40.80	60.00	100.00
28.06.1986	19.09	19.09	52.14	65.39	-	-	-	78.30	44.88	66.00	110.00
18.06.1987	24.82	24.82	52.14	85.00	72.30	-	-	78.30	56.10	80.00	130.00
01.07.1988	28.54	28.54	59.96	97.75	83.15	-	-	90.05	56.10	92.00	150.00
01.07.1989	33.00	28.54	70.00	110.00	83.15	-	-	-	65.00	100.00	170.00
01.07.1990	37.95	32.82	80.42	126.50	95.62	-	-	-	74.75	115.00	195.00
01.07.1991	39.08	33.98	85.23	134.22	100.62	-	-	106.19	74.75	115.00	195.00
01.05.1992	43.05	37.39	93.74	134.22	110.16	-	43.05	116.67	82.12	126.00	215.00
01.03.1994	47.57	41.34	103.07	147.53	113.26	-	-	128.28	82.12	160.00	250.00
01.12.1998	54.65	47.57	118.93	169.90	130.26	86.37	-	147.25	94.86	185.00	290.00
01.09.2000	62.86	54.65	136.77	195.39	149.80	99.11	-	169.33	109.02	210.00	330.00
01.01.2002	65.98	57.48	143.57	205.30	157.16	104.21	-	177.83	114.40	275.00	350.00
01.09.2002	70.00	60.00	140.00	220.00	140.00	100.00	-	220.00	120.00	325.00	375.00
15.02.2003	-	-	-	-	-	-	70.00	-	-	-	-
01.07.2004	72.45	62.15	145.20	228.50	145.20	-	-	228.50	126.10	340.00	390.00
01.09.2004	-	-	-	-	-	103.50	-	-	-	-	-
01.01.2005	73.91	63.41	148.13	233.12	148.13	105.59	-	233.00	130.00	350.00	400.00
25.04.2008							282.30	-	-	-	-
01.08.2009	79.82	72.92	165.91	268.09	165.91	118.26	-	-	146.25	400.00	450.00
12.05.2009							509.70		-	-	-
19.09.2011							651.29		-	-	-
01.09.2015			190.86	321.68	182.64	236.73	764.55		198.22	600.00	650.00

Source: PetroBangla Annual Report 2014, No. BERC/Tariff/Gas-12/Transmission & Distribution/3056

According to the gas sales regulations, gas retail tariff can be revised once a year. However, despite such stipulation, there have been cases where the regulations are revised irregulary on short notice due to the strong requests from the government.

The latest revision of natural gas tariff became effective since 1st September, 2015. BERC declared the price hike in a press briefing at BERC office on 27th August, 2015. According to No. BERC/Tariff/Gas-12/Transmission & Distribution/3056, the revised tariff rate was 600 BDT/month and 650 BDT/month for single and double burners respectively, that were up from 400 BDT/month and 450 BDT/month.

20.1.2 Comparison of natural gas tariff in Bangladesh with other countries

Table 20-3 compares the natural gas retail tariff in Bangladesh as of 2011 with other countries in Asia. The table illustrates that Bangladesh's retail gas tariff rates are significantly lower than other countries For example, gas tariff for power generation in Bangladesh is about two fifths of that in Pakistan and less than 10% of that in Singapore. In comparison with Pakistan where the economic conditions are relatively similar, tariff rates for CNG stand and residenrial costomers are slightly higher in Bangladesh, but in comparison with India, tariff rate for CNG stand is about half and the residential tariff is about one sixth in Bangladesh .

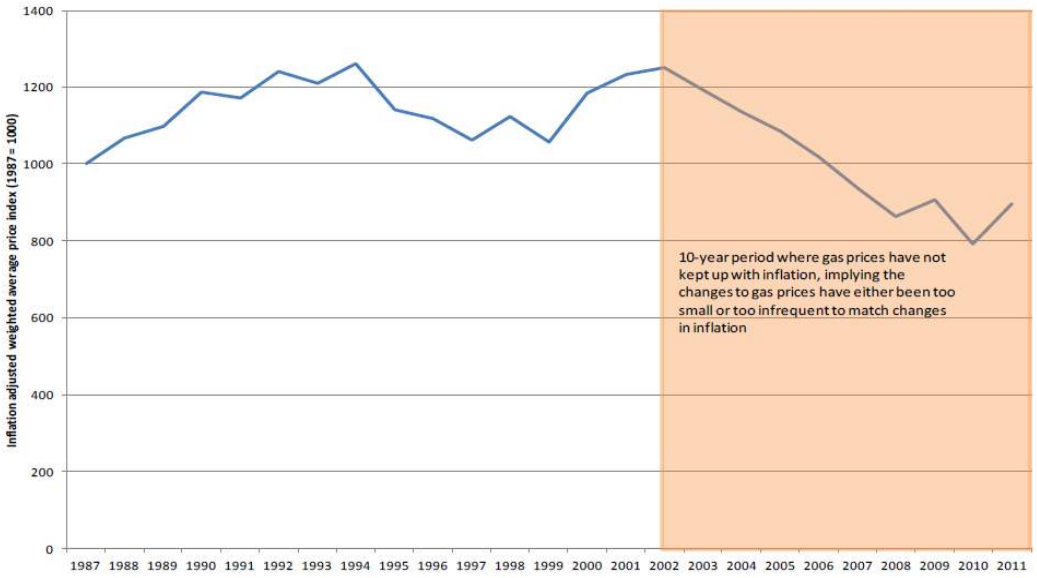
Table 20-3 Comparison of Gas Tariff Rates in Bangladesh with other Asian countries

(Unit: USD/mcf)

Country Effective Date of Tariff	Bangladesh 19/09/2011	Pakistan 7/08/2011	India 1/12/2011	Malaysia 1/06/2011	Thailand 1/06/2011	Indonesia 1/06/2011	Singapore 1/06/2011
Consumer Category							
Power	1.05	5.14	5.06	4.36	5.81	6.7	13.79
IPP	1.05	4.34					
Fertilizer							
Feed Stock	0.96	1.17	5.06				
Power	1.56	4.99					
Industry	2.19	4.99	18.19	5.12	6.2	5.97	35.21
Cement		7					
Ice Factory		6.05					
Captive Power	1.56	4.99					
CNG	8.6	6.57	16.17				
Large Commercial	3.54	6.05	18.19	5.12			
Small Commercial	3.54	6.05	23.51	5.12			
Domestic	1.93	1.24	12.27				
Tea Estate	2.19						

Source: ADB "Bangladesh: Tariff Reform and Inter-sectoral Allocation of Natural Gas" (2013)

Figure 20-2 shows the historical trend of average natural gas price in Bangladsh since 1997 indexized on real-price basis and with 1997 price as base year. If this curve is on a upward trend, the natural gas price increased higher than the general price level and if this curve is on a downward trend, the increase of natural gas price was lower than that of general price level. As this figure shows since 2002 the gas price increase has not come up with the inflation, i.e. gas price on real-price basis has been declining.



Source: "Bangladesh: Tariff Reform and Inter-sectoral Allocation of Natural Gas" (ADB, 2013)

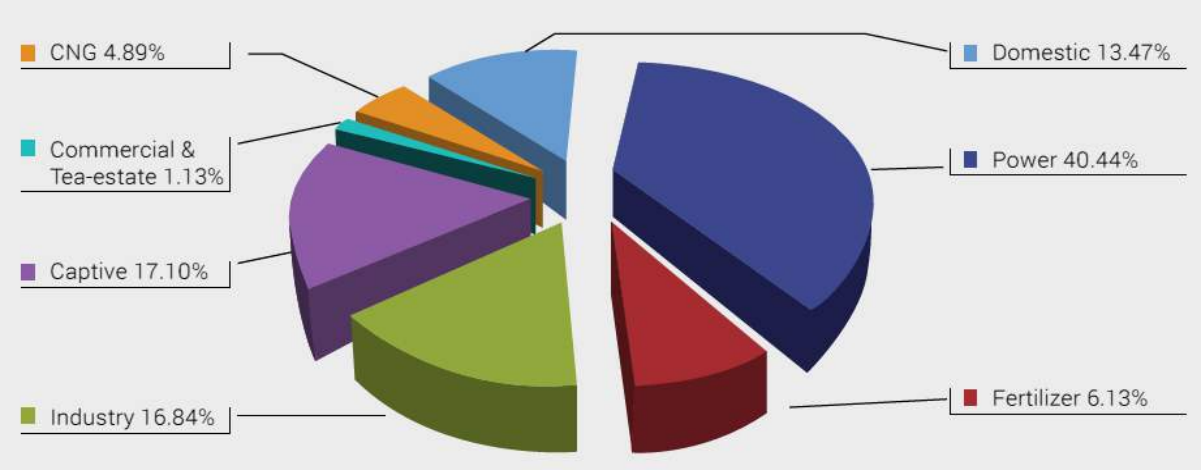
Figure 20-2 Trend of Average Gas Price Indexized with 1997 Price Level

20.2 Financial Performance of Petrobangla and BPC

In Bangladesh, natural gas supply is exclusively operated by the state-owned Bangladesh Oil, Gas & Mineral Corporation (Petrobangla). Petrobangla also has a subsidiarie companiess in coal suppylOi supply is handled by another state-owned company, Bangladesh Petroleum Corporation (BPC).

20.2.1 Petrobangla

Petrobangla is a state-owned company in charge of exploring fossil fuel resources natural gas business in Bangladesh. Petrobangla, along with its subsidiary companies, explores and develops natural gas, as well as operating the production, transmission, distribution, and retail of natural gas., It also conducts gas exploration with international oil companies (IOCs) under production sharing agreements (PSAs). Total natural gas sales as of FY2014-2015 were 877.3 billion cubic feet (BCF), and the power sector consumed about 40% of total gas sales (see Figure 20-3).



Source: Petrobangla's annual report 2013

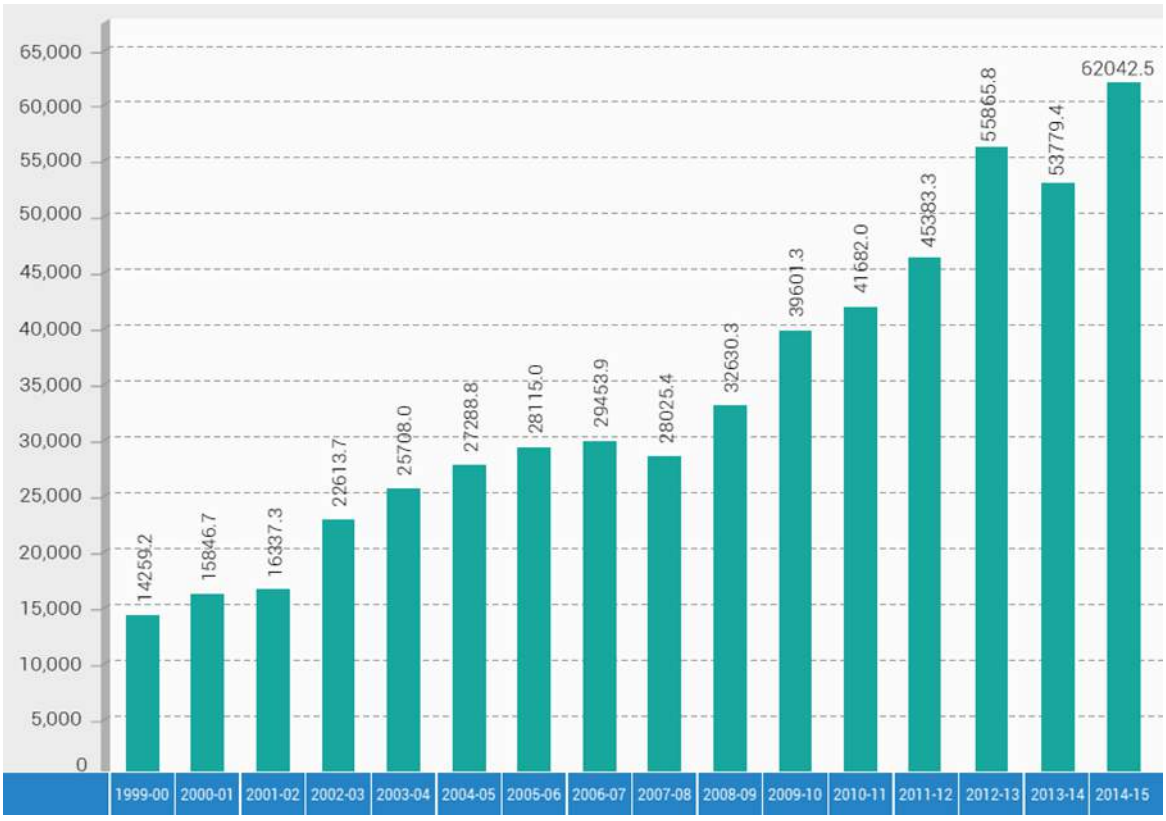
Figure 20-3 Sectorial Breakdown of Natural Gas Consumption in FY2014-2015

Gas tariff rates are determined upon the approvl of BERC. As shown in Table 20-2, gas prices for power generation and fertilizer raw material are set lower while gas prices for industrial and commercial sectors are set relatively higher.

According to Petrobangla's annual report of 2015, the consolidated revenue of Petrobangla group was 280,759 millionBDT, while the total expnses including the consts of sales, interest SD (supplementary duty), VAT (value-added tax), etc. reached 246,966 million BDT. The net profit after deducting income tax, dividend paid to the government etc. was 431,825 million BDT.

That is, Petrobangla has been making profit on its income statement andpaying taxes and duties to the government. The taxes and duties paid by Petrobangla to the government consist of various items such as SD (supplementary duty), VAT (value-added tax), DSL (debt-service liability) and CD (custom duty) and the total amount paid to the national budget in FY2014-2015 was 62,043 million BDT.

The profitability of Petrobangla, despite the very low tariff rates of natural gas compared to other countries, is due to the low costs of domestic gas production and the revenues from PSC (production sharing contract) that Petrobangla concluded with exploration companies such as IOCs. However, as the domestic gas production is supposed to decline and the country's dependence on imported LNG that is much costly increases, Petrobangla will be faced with difficualty in making profit under the current natural gas tariff rates. In other words, unless the natural gas prices are raised to match the international price level, Petrobangla's contribution to natural budget will deceline and in the future Petrobangla's financial conditions may become unsustainable without subsidies, as BPDB has already been in the situation.



Source: Petrobangla's annual report 2015

Figure 20-4 Taxes and Suties Paid by Petrobangla to the Government of Bangladesh

Table 20-4 Breakdown of Taxes and Duties Paid by Petrobangla to the Government of Bangladesh

Year	SD+VAT	DSL	Income Tax	Dividend	CD/VAT	Royalty	Total
1997-98	8431.1	2745.7	862.8	1000.1	404.1	-	13443.8
1998-99	9116.9	2984.9	1030.6	1500.0	168.0	-	14800.4
1999-00	8618.9	3253.3	1105.1	1150.0	131.9	-	14259.2
2000-01	11049.2	2503.8	1142.1	1058.6	93.0	-	15846.7
2001-02	10541.3	3327.3	917.2	1428.9	122.6	-	16337.3
2002-03	15576.4	3395.9	1456.8	1499.8	684.7	-	22613.7
2003-04	18235.2	3708.9	1620.4	1750.0	393.5	-	25708.0
2004-05	18481.0	3681.1	2530.6	2000.0	596.2	-	27288.8
2005-06	18526.7	3440.0	3597.8	2154.8	383.2	12.5	28115.0
2006-07	18801.5	4145.5	3665.1	2500.0	329.2	12.6	29453.9
2007-08	17900.6	3223.4	6490.5	-	350.1	60.9	28025.4
2008-09	19313.5	3533.0	7507.6	1715.3	554.7	6.3	32630.3
2009-10	20064.7	3331.2	10057.5	3281.6	2211.1	655.3	39601.3
2010-11	21625.5	3209.0	11050.9	4198.4	884.2	714.0	41682.0
2011-12	26668.1	2989.3	9378.9	3875.8	1470.6	1000.6	45383.3
2012-13	23861.6	3350.1	14257.2	8395.8	4596.4	1404.7	55865.8
2013-14	31616.0	2856.3	11854.2	4460.8	1443.0	1549.1	53779.4
2014-15	37498.6	2392.3	9471.7	11009.0	1425.4	245.5	62042.5

Source: Petrobangla's annual report 2015

20.2.2 Bangladesh Petroleum Corporation (BPC)

Bangladesh Petroleum Corporation (BPC), through its subsidiary companies as follows, conducts the import, refinery, storage and sale of crude oil and petroleum products.

- Refinery: ERL
- Lubricant blending: ELBL and SAOCL
- LPG bottling: LPGL
- Sales of petroleum products: POCL, MPL and JOCL.

The domestic prices of petroleum products are basically set to follow the international price level, because, unlike the natural gas that is produced domestically, oil is mostly imported. However due to the government control on prices, oil prices in domestic market are much less volatile than international prices. Therefore, when the rising trend of international oil prices continues, a negative gap between high import cost and low sales price can affect the financia conditions of BPC. Like the case of BPDB, government loan to suppot the finances of BPC when its financial conditions becomes seriously worse.

A study report published by IISD (International Institute for Sustainable Development) "Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform" (August 2013) estimates the government subsidies to petroleum product in Bangladesh by calculating the difference between the price of imported petroleum products and the domestic price regulated by the government. According to this analysis (see Table 20-5) subsidies to diesel oil increased significantly from 1.22 BDT/litre in FY2009-2010 to 16.43 BDT/litre in FY2011-2012. Though the domestic price was raised from 44

BDT/litre to 61 BDT/litre during the same time, the rapider increase of import cost widened the negative gap.

Table 20-5 Subsidies for Imported Diesel Oil and Furnace Oil

	Sales (million litres)	Per-unit supply cost (BDT/litre)	Selling price (BDT/liter)	Per-unit subsidy (BDT/litre)	Total subsidies (million BDT)
2009-2010					
Diesel	3045.894688	45.22	44	1.22	3715.992
Furnace oil	210.08653	38.00	30	8.002583	1681.235
2010-2011					
Diesel	3841.784894	62	46	16	61468.56
Furnace oil	589.275594	58.33	42	16.33	9622.87
2011-2012					
Diesel	3843.053914	77.45	61	16.45	63218.24
Furnace oil	956.20127	65.13	55	10.13	9686.319

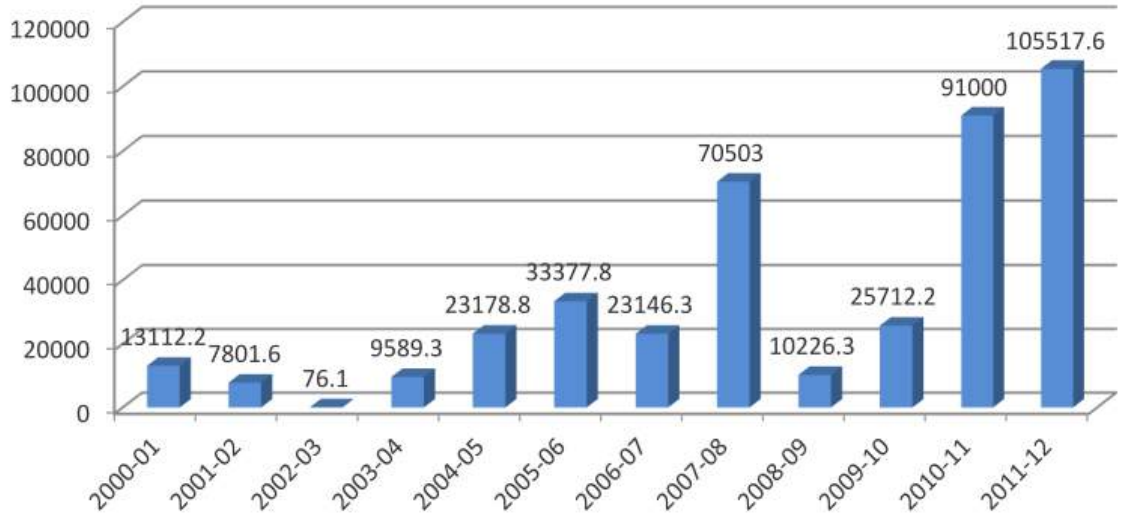
Source: IISD "Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform" (2013)

Because BPC has not disclosed its financial statements since FY2010-2011, details of its current financial situation are not clear, but as of FY2010-2011 the costs of sales were 312,347 million BDT, which far exceeded the annual sales 230,086 million BDT. The gross loss was 82,261 million BDT and after deducting interest payment and so on, the final net loss was 97,900 million BDT. In the previous year FY2009-2010, the costs of sales were 193,466 million BDT whereas the sales were 173,497 million BDT, the gross loss was 19,972 million BDT and the final net loss was 25,712 million BDT. The financial balance was worsened significantly in a year because of the price spike of crude oil at that time.

According to the aforementioned IISD report, BPC had been in net loss for more than 10 years and the situation especially got worse since late-2000s (see Figure 20-5).

BPC's balance sheet as of FY2010-2011 tells that the company's cumulative loss far exceeded its share capital and reserves and that the company is in a capital deficit of -320,280 million BDT. Even in the previous year it had a capital deficit of -222,281 million BDT but the situation was further worsened.

The recent trend of lowered crude oil prices is expected to mitigate the worsened trend of BPC's financial conditions, and it is recommended that appropriate price policies are implemented for diminishing BPC's cumulative loss taking advantage of this situation, and that, as the next step to follow, price policies are reviewed so that the price control are gradually removed and the domestic prices are more linked to international prices (market prices).



Source: IISD "Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform" (2013)

Figure 20-5 Historical Trend of BPC's Annual Loss (Unit: million BDT)

Chapter 21 Tariff Policy

21.1 Methodologies of the Analysis

In order to analyze the impacts on macro economy caused by increase of electricity tariff and natural gas price, this study utilized a macroeconomic analysis model called GTAP (*Global* Trade Analysis Project).
The GTAP model is a computable general equilibrium model (CGE model) developed based on the general equilibrium theory of microeconomics. This model, which was developed by Professor Hertel at Purdue University in 1992, aimed at making an impact analysis on tariff reduction or elimination, and this model covers the whole world.
The data set concerning the GTAP model is updated every few years. The latest version at present is the GTAP DATA BASE 8 on the basis of the global economic data in 2007, which categorizes the whole world into 134 regions and 57 industries. This version which was released in 2012 contains detailed categories of Asian and African countries, and data contained in the database is indicated in American dollars.
Since the GTAP model has spread internationally and is considered reliable, it is being used by international organizations such as the World Bank and OECD and research institutes of many countries.
By using the GTAP model, future forecasts become possible based on exogenous conditions. The primary exogenous variables of the GTAP are population (total population/labor population), tax ratio (such as a ratio of tariff), productivity, capital, and so on. Endogenous variables include various items such as GDP, the amount of trade (by industries/countries), output (by industries), private consumption (by products), and so on. Therefore, it is possible to forecast economies by selecting population (total population/labor population) and productivity as well as GDP of countries and regions other than the Indian Ocean Rim Association (such as Japan, China, America, and the EU) as exogenous conditions. Besides, it is also possible to forecast multiple scenarios by changing exogenous conditions.

In this study, the following parameters were used for the GTAP analysis.

- Category of area: Bangladesh, Asian countries, other countries in the other region;
- Category of sectors: Agriculture, coal*, oil*, gas*, electricity, industry, service;

Note) Items with asterisk (*) are used only for analysis of gas price increase

21.2 Analysis on Electricity Tariff

21.2.1 Single-year analysis

(1) Scenario setting

As the first step to analyze the economic impacts of electricity tariff increase on the national economy of Bangladesh, impact of the price increase on the economy was analyzed by using the parameters as of 2014, which is the latest available data for GTAP. In this study, this is called "single-year analysis"

The following three scenarios were envisaged as for the increase of electricity tariff.

- Scenario (a): average electricity tariff (consumer price) increase by 10%
- Scenario (b): average electricity tariff (consumer price) increase by 20%
- Scenario (c): average electricity tariff (consumer price) increase by 30%

Aforementioned increase rates are indicated in real price in USD. Considering the inflation rate in Bangladesh and depreciation of BDT against USD, the rate of tariff increase in nominal BDT becomes 19% in scenario (a), 29% in scenario (b), and 40% in scenario (c).

In Bangladesh, electricity tariff for final consumers is different depending on customer categories. However, due to the methodological limitation of the GTAP analysis, a single price increase ratio was applied to each scenario in the analysis (for example, one "average" 10% electricity tariff increase was used uniformly for scenario (a) regardless of different customer categories.

(2) Result of analysis: Impact on Bangladesh economy

The results of the GTAP analysis on electricity tariff increase are summarized in Table 21-1. 10% increase of electricity tariff, which is the scenario (a) in the table, pushes real GDP downward by 0.72% (USD 810.7 million). Similarly, 20% increase, which is the scenario (b), results in the downturn of real GDP by 1.45% and in the case of 30% increase, which is the scenario (c), real GDP is declined by 2.17%. The results show that the impact on nation economy is considerably huge especially in the scenario (c). Compared to the impact on national economy as a whole (GDP), the impact on real export and real import seem to be relatively small.
The results of sectoral analysis are shown in Table 21-2 and Table 21-3. If the electricity tariff is increased by 10% it will lead to the decrease of products in all sectors by between 0.2% and 0.4%. Electricity tariff increase by 10% also results in the decline in consumption in all sectors by between 0.6% and 1%.
In Table 21-3, which shows the effect on import and export, the impact on electricity sector is significantly high. However, the international trade of electricity itself is still trivial in Bangladesh, and the impact of tariff increase on the import and export of industrial products is relatively limited.

Table 21-1 Impacts of Electricity Tariff Increase on Bangladesh National Economy (single year analysis)

	(a) 10% Increase		(b) 20% Increase		(c) 30% Increase	
	Change ratio (%) in real USD	Monetary value (million USD)	Change ratio (%) in real USD	Monetary value (million USD)	Change ratio (%) in real USD	Monetary value (million USD)
Impact on real GDP	-0.72	-810.7	-1.45	-1618.6	-2.17	-2424.0
Impact on real export	-0.28	-79.3	-0.56	-157.7	-0.83	-235.1
Impact on real import	-0.27	-94.7	-0.55	-189.5	-0.82	-284.2

Source: JICA Survey Team

Table 21-2 Impacts of Electricity Tariff Increase on Each Sector (single-year analysis): production and consumption

	Production			Private sector's consumption		
	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase
Agricultural sector	-0.21	-0.43	-0.65	-0.59	-1.18	-1.76
Electricity sector	-0.42	-0.77	-1.08	-2.56	-4.92	-7.1
Industrial sector	-0.27	-0.54	-0.81	-0.69	-1.37	-2.05
Service sector	-0.36	-0.72	-1.07	-0.98	-1.95	-2.91

Source: JICA Survey Team

Table 21-3 Impacts of Electricity Tariff Increase on Each Sector (single-year analysis): export and import

	Real export			Real import		
	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase
Agricultural sector	2.51	5.08	7.71	-1.67	-3.31	-4.93
Electricity sector	-41.33	-63.78	-76.71	33.21	73.37	121.24
Industrial sector	-0.5	-1.00	-1.5	-0.05	-0.10	-0.16
Service sector	1.41	2.85	4.32	-1.3	-2.59	-3.87

Source: JICA Survey Team

21.2.2 Time-line analysis

(1) Scenario setting

As the next step to follow the aforementioned single-year analysis, a time-line analysis was conducted to analyze the impact of electricity tariff increase on the national economy in a future timeline from 2014 to 2041. The Case 1 assumes that the cost of electricity supply increases by 1.5% in real price per annum, such as increase from usin imported LNG etc., which refers to the analysis result in Chapter 19, and several scenarios were envisaged, as shown in Table 21-4, for analyzing the impact on macro economy of Bangladesh. The increased electricity tariff will come up with the cost of electricity supply by 2021 in Scenario 1, by 2031 in Scenario 2, and by 2041 in Scenario 3.

For simplicity, the Case 2, i.e. scenario analysis without assuming the increase of supply cost was also conducted as shown in Table 21-5.

Table 21-4 Scenarios of Electricity Tariff Increase: Case 1 (cost increase)

Scenario	Annual Increase in real USD
Increase of supply cost	1.5%/year in real price (9.5%/year in nominal BDT)
Base scenario	1.5%/year in real price (9.5%/year in nominal BDT)
Scenario 1	4.2%/year in real price (12.4%/year in nominal BDT) until 2021 1.5%/year in real price (9.5%/year in nominal BDT) from 2022
Scenario 2	2.6%/year in real price (10.7% in nominal BDT) until 2031 1.5%/year in real price (9.5%/year in nominal BDT) from 2032
Scenario 3	2.2%/year in real price (10.3%/year in nominal BDT) until 2041

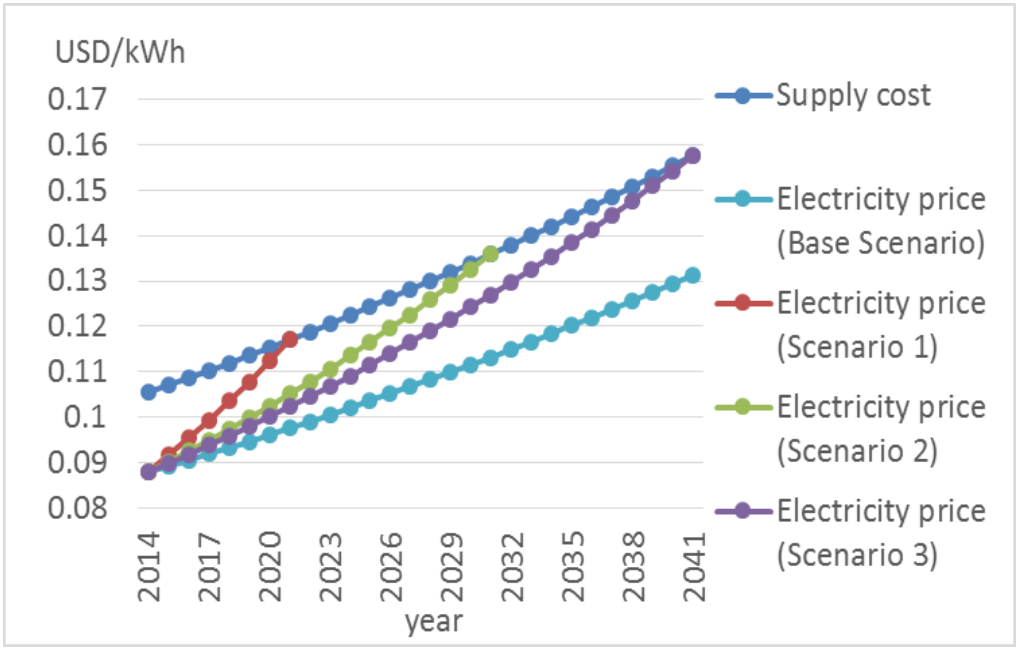
Source: JICA Survey Team

Table 21-5 Scenarios of Electricity Tariff Increase: Case 2 (no cost increase)

Scenario	Annual Increase in real USD
Increase of supply cost	0%/year
Base scenario	0%/year
Scenario 1	2.6%/year in real price (10.7%/year in nominal BDT) until 2021 0%/year from 2022
Scenario 2	1.1%/year in real price (9.1%/year in nominal BDT) until 2031 0%/year from 2032
Scenario 3	0.7%/year in real price (8.7%/year in nominal BDT) until 2041

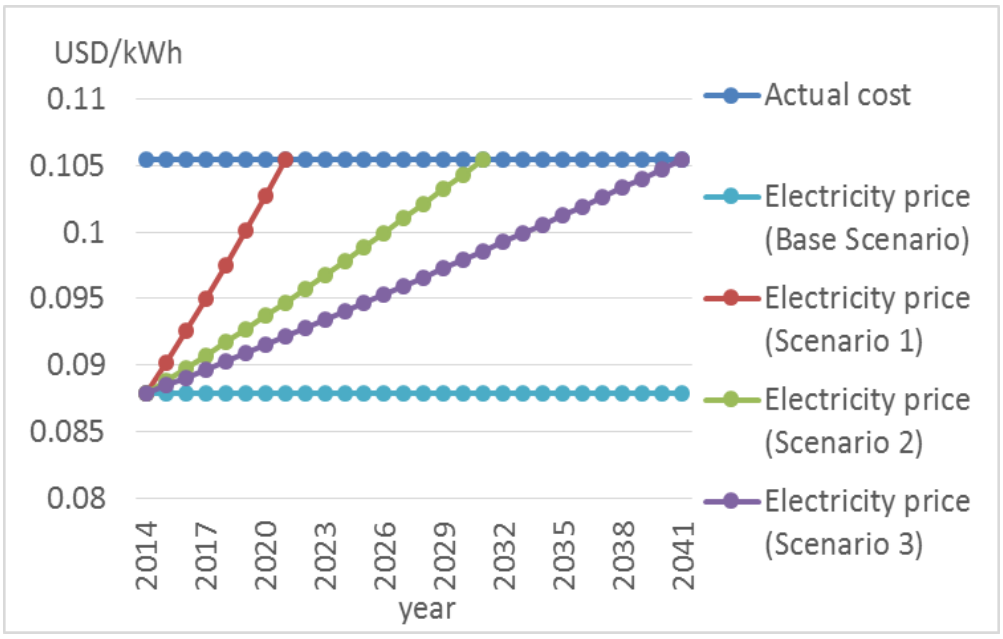
Source: JICA Survey Team

Figure 21-1 and Figure 21-2 summarize these scenarios of tariff increase.



Source: JICA Survey Team

Figure 21-1 Scenario of Increase of Electricity Tariff (Case 1)



Source: JICA Survey Team

Figure 21-2 Scenario of Increase of Electricity Tariff (Case 2)

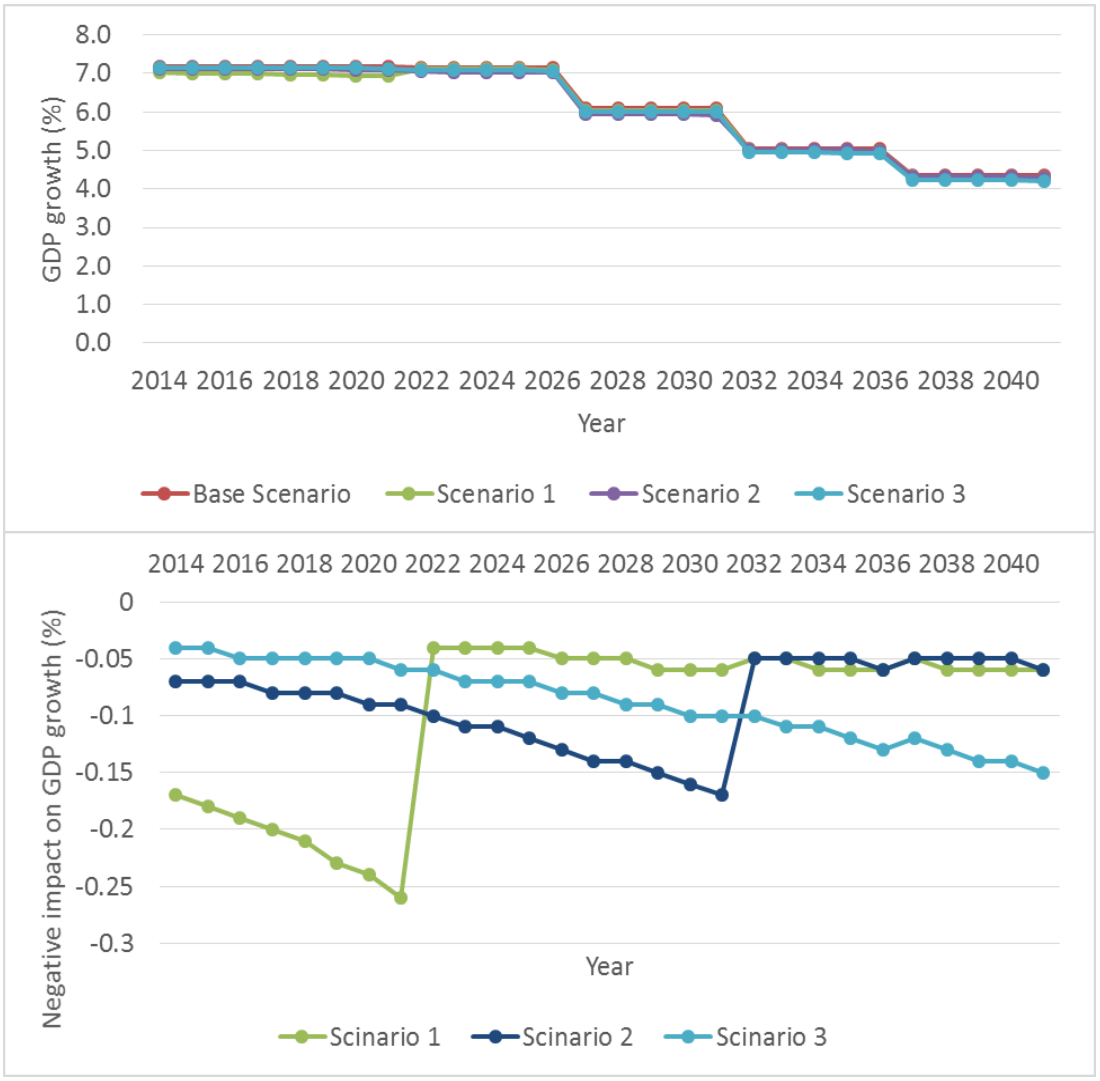
(2) Result of analysis: Impact on Bangladesh Economy

The result of GTAP analysis for Case 1 is summarized in Table 21-6 and Figure 21-3. Electricity tariff increase pushes down GDP growth by 0.26% in 2021 in Scenario 1, by 0.17% in 2031 in Scenario 2, and by 0.15% in 2041 in Scenario 3. Because the time-line analysis takes into account the economic growth in the future and the tariff increase is made along with the economic development, the negative impact on GDP is mitigated compared with the single-year analysis that assumes that the tariff increase occurs in a single year 2014.

Table 21-6 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 1)

	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.06	-0.06
Scenario 2	-0.07	-0.09	-0.17	-0.06
Scenario 3	-0.04	-0.06	-0.1	-0.15

Source: JICA Survey Team



Source: JICA Survey Team

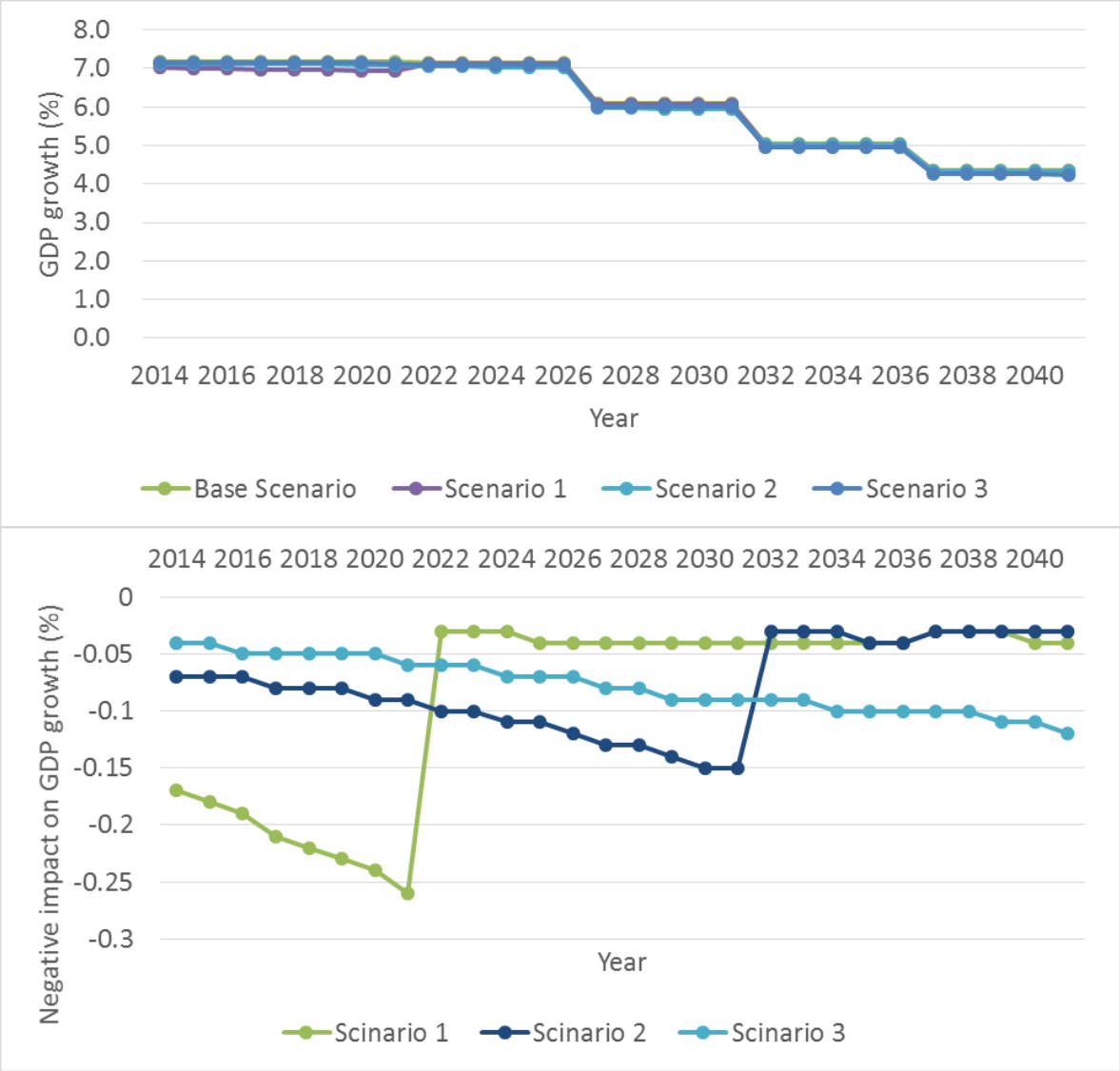
Figure 21-3 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 1)

The result of the GTAP analysis for the Case 2 is summarized in Table 21-7 and Figure 21-4. The result is almost similar to that of the Case 1. Electricity tariff increase pushes down the GDP growth by 0.26% in 2021 in Scenario 1, by 0.15% in 2031 in Scenario 2, and by 0.12% in 2041 in Scenario 3.

Table 21-7 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 2)

	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.04	-0.04
Scenario 2	-0.07	-0.09	-0.15	-0.03
Scenario 3	-0.04	-0.06	-0.09	-0.12

Source: JICA Survey Team



Source: JICA Survey Team

Figure 21-4 Impacts of Electricity Tariff Increase on Bangladesh National Economy (Case 2)

21.3 Analysis on Gas Price

In the same way, the analysis on the impact of gas price increase on national economy was conducted.

21.3.1 Single-year analysis

(1) Scenario setting

As the first step to analyze the economic impacts of gas price increase on the national economy of Bangladesh, impact of the price increase on the economy was analyzed by using the parameters as of 2014, which is the latest available data for GTAP. In this study, this is called "single-year analysis"

The following two scenarios were envisaged as for the increase of gas price.

- Scenario (a): average gas price increase by 50%
- Scenario (b): average gas price increase by 100%

Aforementioned increase rates are indicate in real price in USD. Considering the inflation rate in Bangladesh and depreciation of BDT against USD, the rate of price increase in nominal BDT become 62% in scenario (a), and 116% in scenario (b).

(2) Result of analysis: Impact on Bangladesh economy

The results of the GTAP analysis for increase of gas price are summarized in Table 21-8. 50% increase of gas price, which is the scenario (a) in the table, pushes real GDP downward by 1.26% (USD 1,407.9 million). 100% increase, which is the scenario (b), results in the decline of real GDP by 2.47%. The results show that the impact on nation economy is considerably huge especially in the scenario (b).
The results of sectoral analysis are shown in Table 21-9 and Table 21-10. If the gas price is increased by 50%, it will lead to the decrease of products in all sectors by between 0.5% and 2.9% except oil sector. Gas price increase by 50% also results in the decline in the consumption in all sectors by between 0.8% and 8.6%.
In Table 21-10, which shows the effect on import and export, the impact on gas sector is significantly high, if the international trade of natural gas is introduced without barriers in Bangladesh.

Table 21-8 Impacts of Gas Price Increase on Bangladesh National Economy (single year analysis)

	(a) 50% Increase		(b) 100% Increase	
	Change ratio (%) in real USD	Monetary value (million USD)	Change ratio (%) in real USD	Monetary value (million USD)
Impact on real GDP	-1.26	-1407.9	-2.47	-2759.1
Impact on real export	-0.72	-204.7	-1.35	-382.8
Impact on real import	-1.36	-472.6	-2.70	-937.7

Source: JICA Survey Team

Table 21-9 Impacts of Gas Price Increase on Each Sector

	Production		Private sector's consumption	
	(a) 50% Increase	(b) 100% Increase	(a) 50% Increase	(b) 100% Increase
Agricultural sector	-0.53	-1.04	-0.81	-1.59
Coal sector	-0.48	-1.03	-1.13	-2.22
Oil sector	0.25	0.49	-1.42	-2.78
Gas sector	-2.92	-5.40	-8.56	-14.47
Electricity sector	-2.28	-4.33	-4.08	-7.60
Industrial sector	-1.49	-2.93	-1.12	-2.19
Service sector	-1.15	-2.26	-1.41	-2.73

Source: JICA Survey Team

Table 21-10 Impacts of Gas Price Increase on Each Sector

	Real export		Real import	
	(a) 50% Increase	(b) 100% Increase	(a) 50% Increase	(b) 100% Increase
Agricultural sector	8.18	16.90	-5.28	-10.22
Coal sector	5.25	10.13	-2.45	-4.71
Oil sector	3.42	6.88	-1.5	-2.94
Gas sector	0	0.00	39,184	606,589
Electricity sector	-57.23	-79.29	49.18	110.79
Industrial sector	-1.46	-2.86	-0.74	-1.53
Service sector	5.1	10.67	-3.49	-6.93

Source: JICA Survey Team

21.3.2 Time-line analysis

(1) Scenario setting

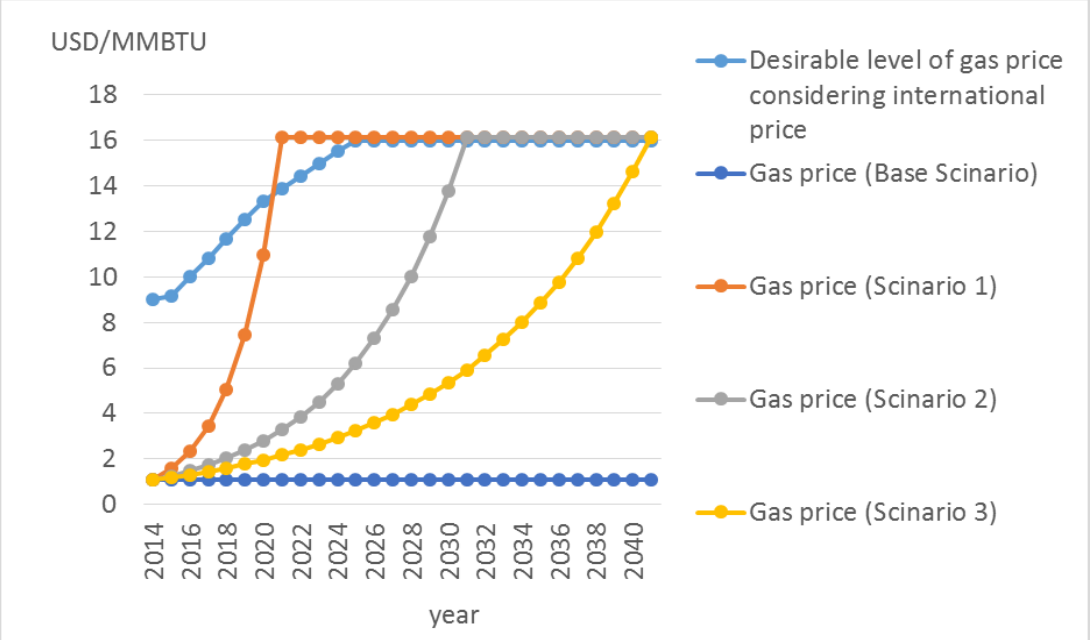
As the next step to follow the aforementioned single-year analysis, a time-line analysis was conducted to analyze the impact of domestic gas price increase on the national economy on a future timeline from 2014 to 2041. The Scenario 1 assumes that the increase of domestic gas price will come up with the progressively increasing international gas price by 2021, by 2031 in Scenario 2, and by 2041 in Scenario 3. As discussed in Chapter 8, CIF (cost, insurance and freight) price of LNG in Asia is expected to decline in the future but more conservative prospect is applied in this analysis so that the international gas price will become constant in the future.

Table 21-11 Scenarios of Gas Price Increase

Scenario	Annual Increase of Gas Price in real USD
Base Scenario	0%/year
Scenario 1	47.2%/year in real price (58.8% in nominal BDT) until 2021 0%/year from 2022
Scenario 2	17.3%/year (26.6%/year in nominal BDT) until 2031 0%/year from 2032
Scenario 3	10.6%/year (19.3%/year in nominal BDT) until 2041

Source: JICA Survey Team

Figure 21-5 summarizes these scenarios of tariff increase.



Source: JICA Survey Team

Figure 21-5 Scenario of Increase of Gas Price

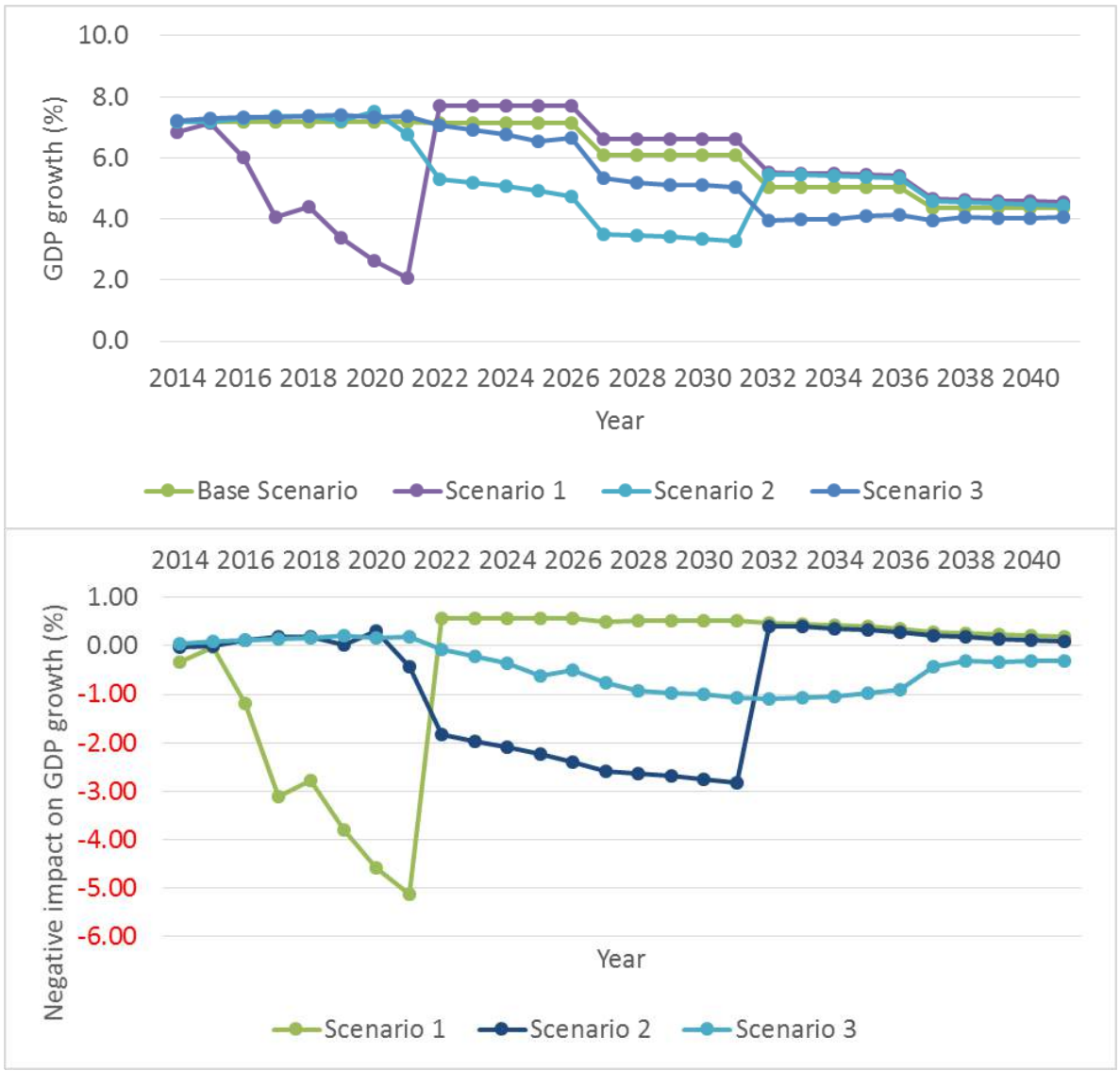
(2) Result of analysis: Impact on Bangladesh economy

The result of GTAP analysis is summarized in Table 21-12 and Figure 21-6. Gas price is dropped by 5.13% in 2021 in Scenario 1, and by 2.82% in 2031 in Scenario 2. The negative impact of gas price on the national economy is relatively large in Scenarios 1 and 2, in which the domestic gas price is raised rapidly to come up with the international price. The negative impact on the national economy is smaller in Scenario 3, which is the scenario of less-accelerated increase of gas price.

Table 21-12 Impacts of Gas Price Increase on Bangladesh National Economy

	2014	2021	2031	2041
Scenario 1	-0.33	-5.13	0.52	0.18
Scenario 2	-0.02	-0.43	-2.82	0.09
Scenario 3	0.04	0.19	-1.08	-0.32

Source: JICA Survey Team



Source: JICA Survey Team

Figure 21-6 Impacts of Gas Price Increase on Bangladesh National Economy

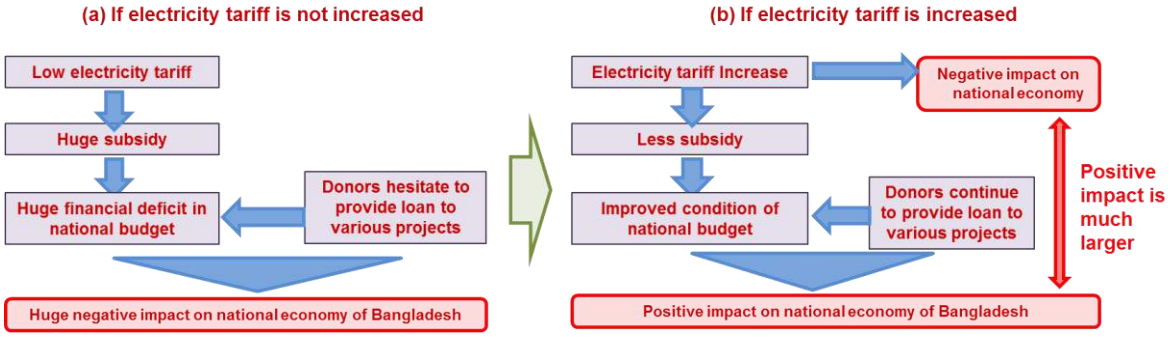
21.4 Policy Recommendations on Increase of Electricity Tariff

21.4.1 Electricity tariff reform

The analyses in Chapter 19 and Chapter 20 revealed that BPDB is facing a serious budgetary situation. Hence, raise electricity tariff in a planned way to ensure the budget to recover the cost of electricity supply needs to be formulated urgently. Both bulk supply tariff and retail tariff need to be increased appropriately so that the whole supply cost can be recovered without subsidies.

Unless appropriate measures to increase electricity tariff are not in place, more subsidies will need to be provided to BPDB which will lead to the growth of financial burden for the national budget of Bangladesh. In fact, international donor agencies have been more reluctant in providing loans to infrastructure projects in Bangladesh. As a result, development of infrastructure in Bangladesh might be delayed and the economic growth might be decelerated (see (a) in the following figures).

Raising electricity tariff may give negative impact on the growth of national economy, but improving the national budget will motivate international donor agencies to provide financial support to infrastructure development. In total, more positive effects on the national economy can be expected in the long term so that Bangladesh will be able to come closer to achieving the national target of economic growth.

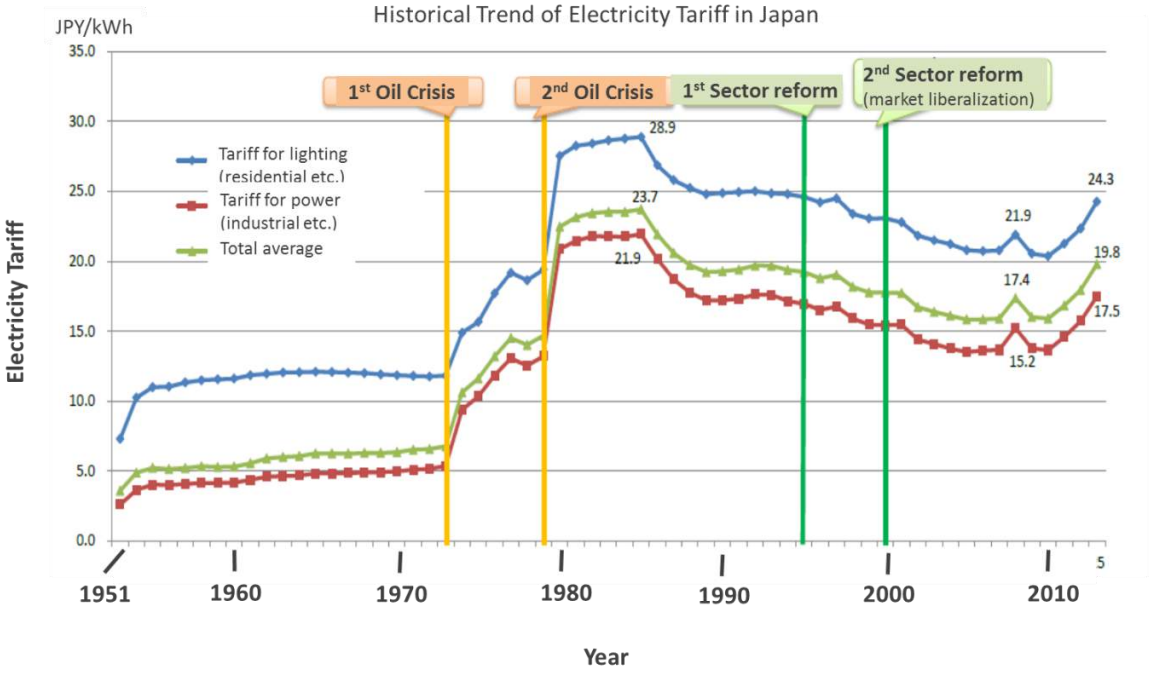


Source: JICA Survey Team

Figure 21-7 Positive Impact of Electricity Tariff Increase on National Economy of Bangladesh

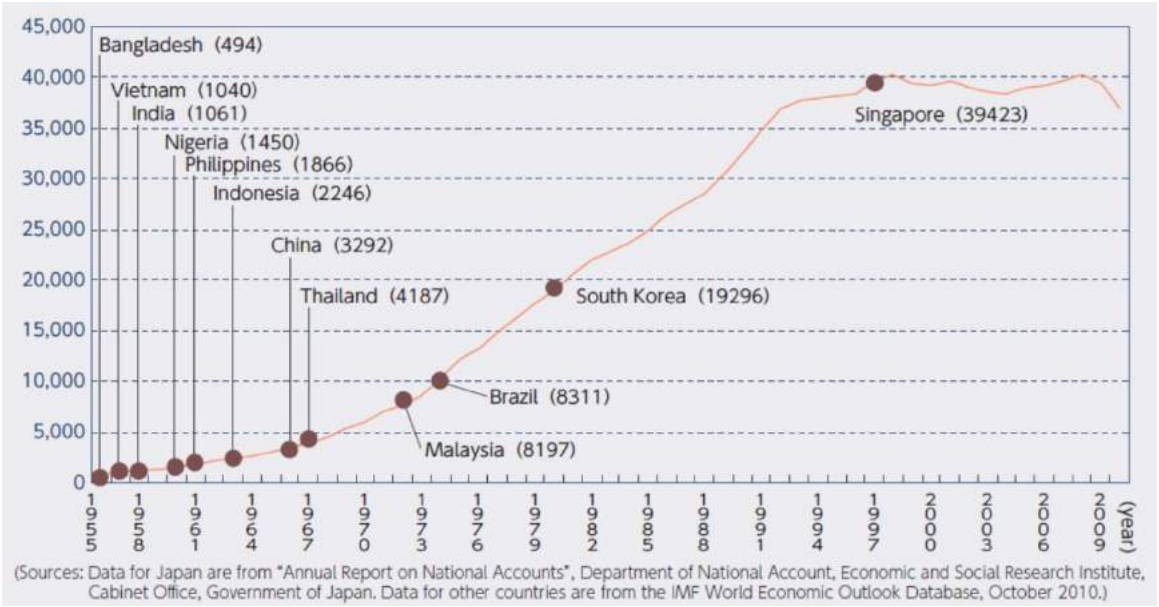
However, the result of GTAP analysis, especially conspicuous in the single-year analysis, revealed that a rapid increase of electricity tariff may trigger a serious negative effect on the national economy in Bangladesh. Therefore, a meticulous approach needs to be taken so that the electricity tariff is raised progressively.

Japan's experience in the past, i.e. during the period of rapid economic development, tells the importance of balancing between the energy price and the national economy. During the period of economic development in 1950's and 1960's, the electricity tariff was relatively stable, which is supposed to contribute greatly to the accelerated economic growth in Japan.



Source: Agency for Natural Resources and Energy, Japan

Figure 21-8 Historical Trend of Electricity Tariff in Japan

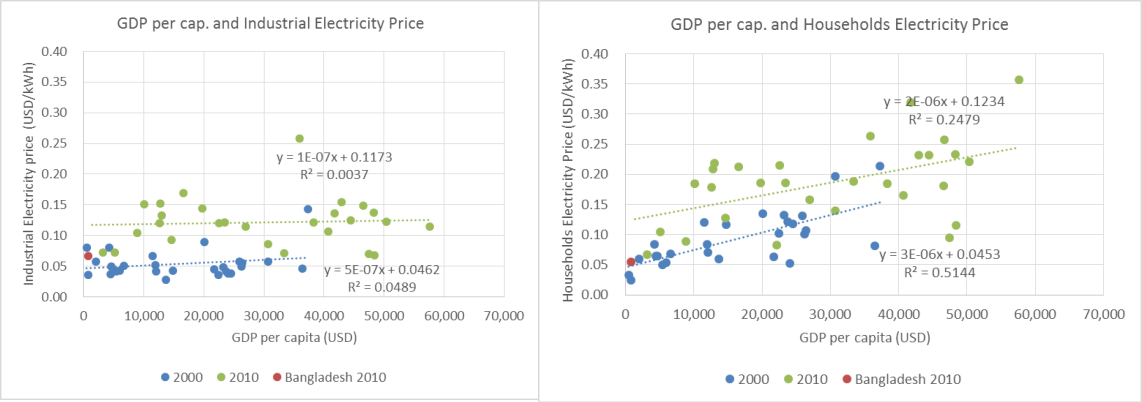


Source: Ministry of the Environment, Japan, "White Paper, Annual Report 2011"

Figure 21-9 Historical Trend of GDP per Capita in Japan

Also, it should be noted that current electricity tariff in Bangladesh is relatively low in comparison with that of other developing countries, though the disparity is not large.
Figure 21-10 shows the relation between GDP per capita and electricity tariff in selected OECD countries and major Asian countries such as China, India, Indonesia, Singapore, Thailand, and Bangladesh.

There seems to be no relation between GDP per capita and the electricity tariff for industrial sector. However, there seems to be some positive correlation between GDP per capita and electricity tariff for residential sector, at least looking at the data of the year 2000 (correlation coefficient is 0.72, p=0.000). This implies that electricity tariff for residential sector is apt to be low in developing countries but is gradually increased in accordance with the level of economic development to cover full supply cost. As indicated in Table 21-13, the current household electricity tariff in Bangladesh is still half that of Thailand.



*GDP per capita is nominal amount using OECD exchange rate.
Source: IEA Energy prices and taxes 2008 and 2012, and BERC

Figure 21-10 GDP per Capita and Electricity Tariff

Table 21-13 GDP per Capita and Electricity Tariff

Unit: USD/kWh

	Industry				Household			
	2000		2010		2000		2010	
	GDP per cap (2000)	Industry Electricity Tariff (2000)	GDP per cap (2010)	Industry Electricity Tariff (2010)	GDP per cap (2000)	Households Electricity Tariff (2000)	GDP per cap (2010)	Households Electricity Tariff (2010)
Australia	21,665	0.045	51,846		21,665	0.063	51,846	
Austria	24,517	0.038	46,660		24,517	0.118	46,660	0.258
Belgium	23,207	0.048	44,383	0.125	23,207	0.132	44,383	0.232
Canada	24,032	0.038	47,464	0.070	24,032	0.053	47,464	0.095
Chile	5,229		12,785	0.152	5,229		12,785	0.209
Czech Rep.	5,995	0.043	19,764	0.144	5,995	0.054	19,764	0.186
Denmark	30,744	0.058	57,648	0.114	30,744	0.197	57,648	0.356
Estonia			14,641	0.093			14,641	0.127
France	22,466	0.036	40,706	0.107	22,466	0.102	40,706	0.165
Germany	23,719	0.041	41,788	0.136	23,719	0.121	41,788	0.319
Greece	12,076	0.042	26,919	0.114	12,076	0.071	26,919	0.158
Hungary	4,620	0.049	13,009	0.133	4,620	0.065	13,009	0.219
Ireland	26,236	0.049	48,261	0.137	26,236	0.101	48,261	0.233
Israel			30,736	0.086			30,736	0.140
Italy	20,059	0.089	35,878	0.258	20,059	0.135	35,878	0.263
Japan	37,300	0.143	42,909	0.154	37,300	0.214	42,909	0.232
Korea	11,948	0.052	22,151		11,948	0.084	22,151	0.083
Mexico	6,650	0.051	8,851	0.104	6,650	0.068	8,851	0.089
Netherlands	25,921	0.057	50,341	0.123	25,921	0.131	50,341	0.221
New Zealand	13,641	0.028	33,394	0.071	13,641	0.060	33,394	0.188
Poland	4,493	0.037	12,598	0.120	4,493	0.065	12,598	0.179
Portugal	11,502	0.067	22,540	0.120	11,502	0.120	22,540	0.215
Slovak Rep.	5,403	0.042	16,555	0.169	5,403	0.050	16,555	0.213
Slovenia			23,439	0.121			23,439	0.186
Spain	14,788	0.043			14,788	0.117		
Turkey	4,215	0.080	10,112	0.151	4,215	0.084	10,112	0.184
UK	26,401	0.055	38,293	0.121	26,401	0.107	38,293	0.184
US	36,450	0.046	48,374	0.068	36,450	0.082	48,374	0.116
China	955		4,515		955		4,515	
India	452	0.080	1,388		452	0.033	1,388	
Indonesia	780	0.036	3,125	0.072	780	0.025	3,125	0.067
Singapore	23,793		46,570	0.148	23,793		46,570	0.181
Thailand	2,016	0.057	5,112	0.072	2,016	0.060	5,112	0.105
Bangladesh	407		760	0.067	407		760	0.054

Source: IEA Statistics, Energy Prices and Taxes, 2008, 2012

It is inevitably needed for Bangladesh to raise tariff to cover the cost of supply and to mitigate the subsidization to BDBP and raising the electricity tariff for residential sector rapidly also cannot be evaded.

In the meanwhile, the analyses in this chapter also revealed that a rapid increase of electricity tariff will cause huge negative impacts on the national economy in Bangladesh. An important lesson from these analyses is that the negative impacts on the Bangladesh economy can be mitigated if the electricity tariff is raised progressively.

Currently the decision on raising tariffs is made through the consultation among stakeholders such as

BERC and relevant ministries (i.e. Ministry of Power, Energy and Mineral Resources, Ministry of Planning etc.). Considering that the increase of prices of basic commodities such as electricity may cause serious effect on the living standard of the nation, especially that of lower-income people, it is recommended to consider a moderate increase in tariff rates for those in the residential sector who only consume the minimum volume of electricity to sustain their life, such as keeping the same rate of increase as that of general consumer price increase, i.e. 1.5% increase in real USD (9.5% increase in nominal BDT).

For other customer categories, it is recommended to increase tariffs to follow the proposed scenario in this study, i.e. 2.6% increase in real USD (10.7%/year increase in nominal BDT), until 2031 and then 1.5%/year in real USD (9.5%/year increase in nominal BDT) after 2032. However, this proposal is the minimum requirement of tariff increase. From the viewpoint that improving the financial situation as early as possible is desired, it is strongly recommended to increase the tariff as rapidly as possible if the negative effect on the national economy is accepted.

Table 21-14 Proposed Scenario of Electricity Tariff Increase

Customer Category	Range (KWH)	BDT/Kw SEPT	Scenario of price increase
Domestic-A	1-50	3.33	Keep minimum increase (e.g. 1.5%/year increase in real USD / 9.5%/year increase in nominal BDT*)
	1–75	3.53	
	76–100	5.01	Increase according to the scenario. (e.g. 2.6%/year increase in real USD / 10.7% increase in nominal BDT* until 2031, 1.5%/year increase in real USD / 9.5%/year increase in nominal BDT* after 2032) ＋the amount cover the price cost gap of lower categories
	101–200		
	201–300	5.19	
	301–400	5.42	
	401–600	8.51	
	Above 600	9.93	
Agricultural pumping-B	Flat	2.51	Keep minimum increase (e.g. 1.5%/year increase in real USD / 9.5%/year increase in nominal BDT*) or according to the scenario.
Small industry category-C	Flat	7.42	Increase according to the scenario. (e.g. 2.6%/year increase in real USD / 10.7%/year increase in nominal BDT* until 2031, 1.5%/year increase in real USD / 9.5%/year increase in nominal BDT* after 2032)
	Peak	6.64	
	Off peak	9.00	
Non-residential category-D		4.98	
Commercial category-E	Flat	9.58	
	Off peak	8.16	
	Peak	11.55	
Medium Voltage 11 KV General Category-F	Flat	7.32	
	Off peak	6.62	
	Peak	9.33	
Extra High Voltage Category (132KV)-G	Flat	6.96	
	Off peak	6.35	
	Peak	9.19	
High Voltage 33 KV General Category-H	Flat	7.20	
	Off peak	6.55	
	Peak	9.28	
Street Lights & Pump Category-J		6.93	

*If current inflation rate in nominal BDT is considered

Source: Developed based on document of BERC

In parallel with the retail electricity tariff for end-consumers, bulk supply tariff needs to be increased to cover the gap between supply cost and revenue. Bulk supply tariff is expected to be increased in accordance with the scenario similar to that of retail electricity tariff for end-consumers.

21.4.2 Capacity building of human resource for financial review

For gaining public acceptance on the drastic increase of electricity tariff, the electric power sector needs to show the efforts to reduce the cost of electricity supply. Therefore the power sector needs to take on a strong initiative to reduce the cost of supply, especially the cost of power generation, while proposing the increase of tariff.

Involvement of third parties in the process of cost reduction is a cogent approach. If this approach is not easy in terms of confidentiality because the most critical part in the cost of supply that needs to be reviewed is the procurement of wholesale generation and most of the PPA is a private contract, BPDB instead should take a strong initiative to launch a special task team for rationalizing the cost of supply. Then, if it is difficult to change the condition of the singed contracts, it should establish an external body to check the cost efficiency whenever BPDB sings a new contract. Support from international donor agencies for capacity development should be considered.

21.4.3 Gas price reform

As discussed in Chapter 8, it is expected that the supply of natural gas will fall much short of domestic demand in Bangladesh, and Bangladesh needs to expand gas supply through LNG import. If Bangladesh continues to fill the gap between domestic gas price and international gas price with subsidies, financial deficit of the Bangladesh government will be accumulated.

Like the case of electricity tariff, international donor agencies would be reluctant to provide loans to infrastructure projects in Bangladesh. As a result, development of infrastructure in Bangladesh would be delayed and economic growth will be decelerated. Raising gas price might have negative impact on the national economy, but it will motivate international donor agencies to continue providing loans for the development of infrastructure, an in total, a positive impact on the national economy can be expected in the long term so that Bangladesh will be closer to achieving the target of economic growth.

The Bangladesh Energy Regulatory Commission Act 2003 (BERC Act 2003), in its Chapter 6, article 34, paragraph 2(b), stipulates that it is necessary "to harmonize the tariff with the cost of production, transmission, marketing, distribution, supply and storage of energy". This text does not seem to take into consideration the cost increase driven by LNG import. Hence, it is important to consider increasing the natural gas price progressively to meet the international market price of natural gas so that the further increase of financial deficit in the national budget is avoided. When Bangladesh revises the BERC Act 2003, the harmonization with international market price should also be considered.

According to the result of GTAP analysis, it is indispensable for Bangladesh to increase domestic natural gas price but it is recommended to achieve this gradually, since the rapid increase of gas price gives a huge negative impact on the Bangladesh national economy. Considering the prospects of LNG import and international gas price, continuous annual increase by 10%/year to 20%/year in real USD (19%/year to 29%/year in nominal BDT) would be appropriate.

PART VI TECHNICAL SUPPORT

Chapter 22 Recommendations on the Implementation & Monitoring of the Master Plan

The issues required to be addressed with a scope wider than the scopes of subject-specific development plans and those of individual sectors in the implementation of this master plan in future and the monitoring of its progress, including some recommendations made in the preceding chapters, are described in this chapter. The issues that were not considered to be the preconditions for the formulation of this master plan, but which have to be considered in the monitoring of its implementation and its revision in future are also described in this chapter.

22.1 Capacity building for master plan revision

22.1.1 Collaboration and Cooperation between Organizations involved in the Formulation of MP

In Bangladesh, the Power Division under the Ministry of Power, Energy and Mineral Resources (MoPEMR) is responsible for developing power development plan, and the practical works are done by the Bangladesh Power Development Board (BPDB). In the meanwhile, the Energy and Mineral Resource Division under MoPEMR is responsible for the energy supply plan other than electricity and the practical works are done by Petrobangla, Bangladesh Petroleum Corporation (BPC) and so on.
This study observed that, because of the separated administration between electricity and other energy sources, there is no organizational structure that supervises the overall energy supply and demand in Bangladesh comprehensively. As the domestic production of natural gas in Bangladesh is expected to deplete whereas the energy demand will continue to increase rapidly, the country will need to depend more on imported energy sources.
Considering this situation, the importance of developing an energy supply plan from a comprehensive viewpoint is expected to gain importance for determining how to appropriate the limited domestic energy production among various sectors and which energy sources to import for supplying to which sector and how much.
In developing the aforementioned power development plan and energy supply plan, a systematic relation among stakeholders is needed so that the responsibility of various data necessary for making future projection such as the actual operational data and facility development plan is identified and that these data are administrated in unity. Current status is that, as observed by the JICA Study Team, relations among the organizations responsible for administrating these data are not sufficiently established.
These power development plan and energy supply plan need to be updated regularly by reflecting the conditional changes. Therefore establishing an institutional framework is necessary to develop and implement both plans comprehensively by involving all the relevant stakeholders for these plans to share information.

22.1.2 Periodical Rolling Revision of the Milestone Plan

Although a PSMP has been formulated every five years as a milestone plan, its periodical revision based on a rolling plan has not been conducted appropriately. In principle, a power supply plan in a power development plan is formulated on the basis of demand projection and appropriate standards for ensuring the reliability of supply. However, as the proportions of the projects mentioned in power development plans that have reached the operation stage have been small, a list of prospective projects for investment tends to be included in a power development plan as it is. In principle, a power development plan has to be revised in accordance with power demand and the supply reliability standards as the planning and preparation for projects progress. It is also necessary to revise the power development plan and the energy supply plan formulated in this survey periodically, at least once a year, with changes in the situation including the state of the economy, supply/demand balance of energy sources including domestically-produced natural gas and power supply/demand balance taken into consideration.

22.1.3 Strengthening of integrated statistical processing functions

BPDB has a record of electricity sales to its customers and those wholesaling to other distributing companies. The total sum of them is the total volume of electricity sold by BPDB, but is not identical with the total volume of electricity that is sold by distribution companies including BPDB and used by end consumers. For analyzing the trend of electricity consumption in Bangladesh more specifically, grasping the electricity sales of all distribution companies to end-consumers with sectorial breakdown, such as residential, commercial, industrial etc., is more important. Power Division and/or BPDB is suggested to take an initiative to develop a database of nationwide electricity consumption uniformly as a routine.

The JICA Study Team also observed that there is no government agency responsible for grasping how each sector (residential, commercial, industrial, transport etc.) utilizes energy as the combination of various sources of energy supply such as electricity, natural gas, LPG, oil products, non-commercial fuel (bio fuel) etc. When the JICA Study Team interviewed with various organizations, there were some opinions that, in order to mitigate the increase of natural gas demand, new supply of natural gas to residential sector and transport sector should be restricted and these sectors should be induced to use LPG instead. However, if this idea is actually implemented without long-term perspective of energy supply and demand, it may result in the rapid increase of LPG procurement that is apt to be costlier than LNG, and the burden of nationwide energy cost may become heavier. In order to realize the long-term optimization of nationwide energy balances, GoB needs to strengthen the function to consider and coordinate the national energy policy comprehensively.

Although it should be the Government of Bangladesh that decides which organization is to be responsible for performing these integrated statistic processing functions, the Survey Team recommends the establishment of Integrated Statistics Bureau in MoPEMR for the centralized management of all the data from the organizations under the jurisdiction of the Power Division and the Energy Division with the need to revise the power and energy master plan periodically taken into consideration.

22.1.4 Introduction of Key Performance Indicators

Furthermore, GoB is suggested to set appropriate KPIs (key performance indicators) in the process of planning and to set quantitative target based on this, in order to indicate clearly the directions of energy policy of Bangladesh. Above all, as the country's energy demand is expected to increase rapidly, target setting for rationalizing energy supply and demand (energy efficiency) is indispensable. In addition, strengthening the capacity to analyze the effect of conditional changes on these KPIs and, if necessary, to adjust the targets and plans flexibly to reflect the changes is also required.

Examples of KPIs that serve for target-setting for the power and energy sectors are as follows.

- Energy efficiency: energy intensity per GDP (toe/million BDT), GDP elasticity of energy consumption etc.;
- Economy: cost per unit of energy supply (BDT/kWh) etc.;
- Environmental consideration: emission factor of greenhouse gas etc.;
- Stable supply of energy: energy security index (dependence on energy import, diversification of energy sources), average frequency and duration of power interruption (SAIFI, SAIDI) etc.;
- Optimized supply of energy: balance of aforementioned 3E (integrated indicator), composition of energy source mix etc.;

Currently the main stakeholder agencies in Bangladesh do not have sufficient organizational and staff capacity to deal with these new challenges and international support for improving the capacity of planning, policy implementation and monitoring/evaluation is also needed. Japan has also provided various kinds of assistance such as the dispatch of policy advisors, training programmes and capacity development support programmes. These kinds of assistance will still be needed for Bangladesh.

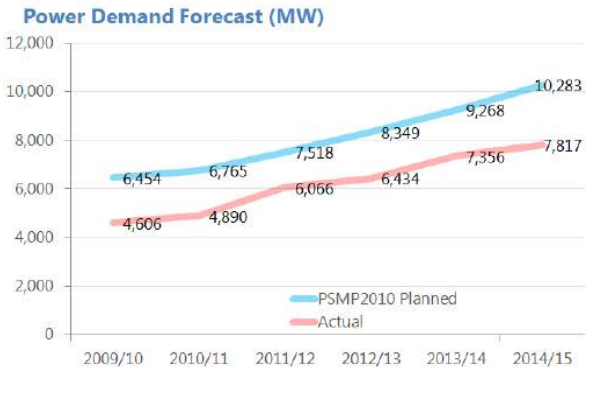
22.2 Measures to Facilitate Improvement of Investment Climate

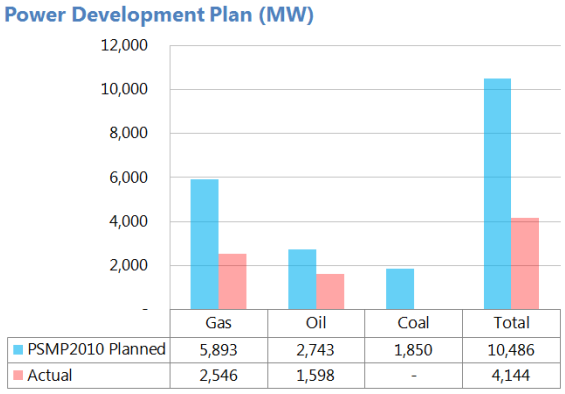
22.2.1 Outline

As a rapid economic growth is expected in Bangladesh, a power development plan has been formulated to reinforce power generation facilities to meet the increasing power demand. However, as the construction of power generation facilities has not been progressing as planned in reality, as mentioned in detail in the chapter of the power development plan, the demand has been suppressed due to the limited supply and, therefore, the difference between the actual demand and the demand projection including potential demand has been large. This fact may have undeniably had negative impact on the economic growth in Bangladesh.

It is obvious that the milestones in a power development plan, however theoretically the plan may have been formulated, will be just empty theories in the current state in which various factors impede the construction of power source facilities.

Therefore, a discussion conducted on the way to create a climate that makes investment in power development attractive with opinions of investors taken into account is described in the following.





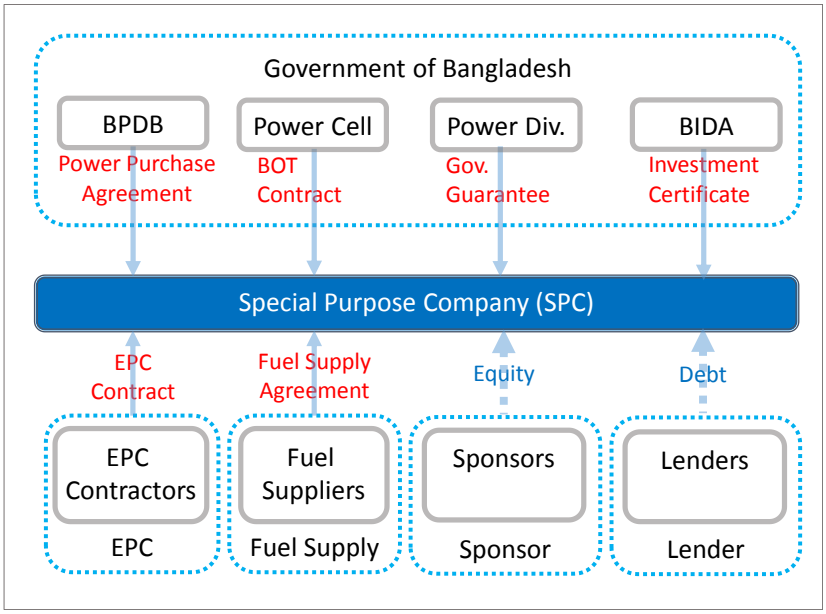
	Gas	Oil	Coal	Total
PSMP2010 Planned	5,893	2,743	1,850	10,486
Actual	2,546	1,598	-	4,144

Source: JICA Survey Team

Figure 22-1 PSMP2010 Review (Power Development Plan)

22.2.2 Project Implementation Structure

In addition to conventional loan projects implemented with public financing from international organizations, projects with PPP investment that utilize the technological capacity and capital of the private sector more than the loan projects are considered a promising means of power development in Bangladesh. The figure below shows a possible project implementation structure assumed for the implementation of IPP projects in Bangladesh.



Source: JICA Survey Team

Figure 22-2 Organaization of IPP

The sponsor of a project consisting of a contractor and an investor usually minimizes the project risk by establishing a special purpose company (SPC) and concluding contracts with various organizations to be involved in it through the SPC. The major project risks are summarized in the following.

- ■ Risks directly concerned with the Government
- ✓ Risks associated with power sales agreements and payment of electricity charges
- ✓ Foreign exchange and remittance risks
- ✓ Country and political risks
- ■ Risks to be controlled mainly by contractors
- ✓ Risks of delay and cost overrun
- ✓ Risks in fuel procurement
- ✓ O&M risks (including risks in the construction of power transmission, transforming and distribution facilities)

22.2.3 Risks directly concerned with the Government

In Bangladesh, an SPC and BPDP conclude a power purchase agreement (PPA) and the SPC becomes the only off-taker of the power under the PPA. Because this agreement provides long-term security, in principle, investors consider it an important agreement that promises profitability of their investment in the project life. Investors prefer a large proportion of the payment for electric power to be made in foreign currencies, while the investee prefers a large proportion of it to be made in the local currency, as they collect electricity charges from users in the local currency. This proportion of the payment in foreign currency has significant influence on investors' decision on investment. If there is a restriction on foreign exchange applicable to a case in which a SPC exchanges the profit from a project after deducting the local costs that it has saved in the local currency in a foreign currency and remits it to the country of the investor, such a restriction will also be an obstacle to the investment.

Power Division applies for the licenses and permits for the establishment of SPCs and construction of facilities with a consent of Power Cell and applies for a government guarantee with a consent of the Ministry of Finance. All the permission and licensing for investment in foreign currencies used to be controlled by the Board of Investment, Bangladesh, (BOI). However, it is currently controlled by Bangladesh Investment Development Authority, which was established recently as a one-stop center for foreign investors. The government's efforts in reorganizing itself in accordance with the needs of investors such as the case mentioned above should be highly appreciated. A contractor for the implementation of a project with foreign investment is required to be established as a joint venture (JV) of a foreign investor and a local partner, and a foreign investor is not allowed to participate in

such a project as its sole investor in many countries, including Bangladesh, in order to facilitate the development of domestic and local industries.
Successful project implementation naturally requires strict compliance with agreed rules and provisions of the agreement, which requires minimization of the country and political risks as the major precondition. These are the risk factors in the agreement directly concerned with the Government.

22.2.4 Risks to be controlled mainly by contractors

The risk of delay and cost overrun is a risk to be hedged by contractors. The conclusion of an EPC agreement between a SPC and an EPC contractor is a means to hedge such risk. The risk in fuel procurement, which may emerge in different forms in different projects, is considered a risk to be controlled by contractors. The O&M risk is also considered a risk to be controlled by contractors.
There is a risk that power may not be transmitted as planned when the power source facilities have been constructed and put in use as planned, if a project for constructing transmission lines and substations is delayed by various factors. If such a project is not in the scope of the investment in the power source development of an investor, it is considered extremely difficult for the investor to control the project concerned. Therefore, a mechanism that places the responsibility for the consequence of the delay of the project to its contractor has to be established.

22.2.5 Recommendations for Improvement

- PPA

A PPA will stipulate the standards of tariffs that sufficiently accommodate various risks associated with foreign exchange and international remittance. The privileges to receive electricity tariffs in US dollars and transfer the revenue in dollars received from the sale of electricity overseas without restriction will be granted to investors.

- Tax exemption for FDI

The tax exemption to be granted will include exemption from the customs duties on all the imported materials and equipment required for the plant construction, exemption from the corporate and personal income taxes for a certain period of time and exemption from the import tax on vehicles and heavy and specialized equipment to be used by contractors.

- Streamlining of procedures

It is not sufficient just to establish better rules. It is also necessary to reduce the time required for the issuance of licenses and permits.

- Credit enhancement to local enterprises by international organizations

A tripartite relationship of the political system, bureaucracy and private sector led by a local large-scale company has been formed in many of the successfully implemented IPP projects in Bangladesh. A foreign investor must form a JV with a local investor if the foreign investor intends to implement such a project because there is a law that does not allow purchase of land solely with a foreign currency in Bangladesh. Therefore, such a project will be implemented as a long-term joint investment project with a local company to ensure steady cash flow into the project and the financial credibility of such a local company may have significant influence on the decision of a foreign investor. For example, an international organization will enhance credit limit of a local company as a guarantor of its credit in order to improve its credibility in the local industry sector in a scheme to implement large-scale IPP project as a “model PPP project.” In practice, a mechanism that guarantees the payment of fees by guarantor in the case of breech of a provision in a PPA and fully covers damage to a developer will be established.

22.3 Economic Development

It has to be noted that the aforementioned economic projection is based on the assumption that the Government of Bangladesh (GoB) will implement appropriate policy measures for economic development. Currently, the economic development in Bangladesh is mainly driven by the steadily increasing export of ready-made garment (RMG) industry that takes advantage of low cost of labour. For achieving mid- and long-term economic development, it is indispensable that the national economy will shift from labour-intensive industries like RMG to more value-added industries, and it is necessary that policy support to promote these new industries.
Examples of policy support are the provision of incentives for promoting foreign direct investment (FDI) from overseas and the development of infrastructure like special economic zones. An example of soft measures to promote the development of high value-added industries is a capacity development programme for human resources in the industrial sector to help advanced technologies to take root in Bangladesh industries.

Following these observations, policy recommendations about economic development policy is summarized as follows.

(1) Infrastructure Development

1) Short term

In order to promote the high value-added of manufacturing, especially the advancement of industries through the attraction of FDI, development of fundamental infrastructure is indispensable, such as the utility structure like electricity, gas and water, and the public transport infrastructure for distributing materials and products. And the development and integration of production base that is equipped with these infrastructures is supposed to be the key factor of success. In addition, provision of incentives such as the waiver of tax and duty for mitigating the financial burden of huge amount of capital investment is also an effective tool. Development of production bases to promote these industries, such as EPZs (Export Processing Zones), SEZs (Special Economic Zones) and industrial parks is strongly desired.
In Bangladesh, development of PEZs started from 1980s for promoting export industries and currently right PEZs are in operation under the supervision of Bangladesh Export Processing Zones Authority (BEPZA). In addition, Bangladesh Economic Zones Authority (BEZA) was established in 2010 for fostering the development of SEZs eyeing for the diversification of Bangladesh industries. According to the JICA Survey Team's interview on BEZA in February 2016, there exist about 60 project plans of SEZs and BEZA has a target of developing 100 SEZs in 15 years. In order to realize these plans and targets effectively, this study suggests that a programme to develop the capacity of planning and policy implementation for government agencies like BEZA is also needed, which shall be discussed more in detail in the next section.

2) Mid/long term

Development of fundamental infrastructure for promoting industrial development may have limitations only with the "point-wise" development like SEZs, PEZs and industrial parks. Connecting these points into a trunk line, and then into a wide area, will enhance its effectiveness. Furthermore, improving the convenience of connection among production bases will also help improving the efficiency of supply chain in a manufacturing process and contribute to the "Banglazation" of supply chain of export industries (self-containment of value chain from material to final product).
From this point of view, it is strongly recommended to prepare plans of comprehensive wide-area infrastructure development that cover seaports, roads, railway, and energy supply and etc., and to implement these plans steadily.

In addition, reforms of economic structure will be indispensable for achieving long-term economic development, such as further deregulation and liberalization of industries for simplifying the licensing process and for enhancing the mobility of human resources and capital funds.

(2) Capacity Development

1) Short term

In order to promote the development of manufacturing bases for the advancement of manufacturing in Bangladesh, such as SEZs, EPZs and industrial parks, it is necessary to make effective and realistic plans of development and to implement them steadily.
Because the skills and experience of government agencies responsible for that may not be sufficient to fulfill this, capacity development programmes to support this are also considered to be necessary.
Japan has provided assistance to Bangladesh in this field, such as "The Project for Development Study and Capacity Enhancement of Bangladesh Economic Zone Development Plan Authority" (2015-2016) and "Study and Verification Survey on the Comprehensive Development of Southern Chittagong Region in Bangladesh" (2015-2016) that are sponsored by JICA. Technical support from abroad like that will help enhancing the capacity development of government administration.

2) Mid/long term

For the long-term sustainable development of Bangladesh economy through the advancement of industries, an overall bottom-up of human capacity in the industrial sector is essential. Examples of supporting programmes are the establishment of facilities for technology education/training and the project to assist the efficient acquisition of technologies through OJT (on-the-job training).

22.4 Domestic Natural Gas [Gas]

(1) Infrastructure

Gas production from existing gas field will be peaking out in 2017-18 and declining, while gas import in a form of LNG is forecast to increase significantly in near future. Under the circumstances issues in terms of infrastructure development to be reviewed and studied are as follows:

- Domestic gas price will be linked with international gas price and more strict control and monitoring of gas in/out flow will be required to avoid "lost profit opportunities", and system loss and/or leakage from the system should be minimized.
- Gas flow will be changed from the east-west current to the south-to the rest of the nation, The large amount of imported gas will be coming from Maheshkhali and/or Payra. Gas transmission infrastructure will need to be reinforced and existing distribution system will also need to be reinforced and re-constructed.
- Operation mode will be shifting from "Gas Allocation" basis to "Customer Demand" basis, and required to supply gas to meet the profile of each customer's demand. Current supply system needs to be reviewed.

Currently the three layers organizations are involved in gas supply, i.e., Gas Production Companies (BAPEX, BGFCL, SGFL etc.), Gas Transmission Company (GTCL), and Gas Distribution Companies (TGTDCL, BGDCL, JGTDSL, PGCL, KGDCL, SGCL). There is no integrated operation system since there is no necessity under gas allocation system at this stage

In order to solve the above listed issues the well-planned and systematic approach will be required.

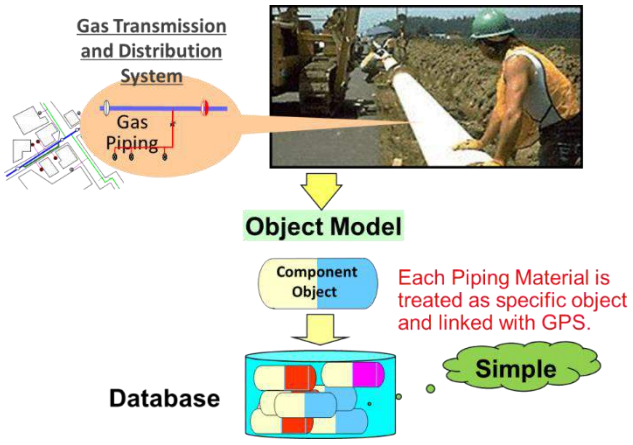
Industrial structure and lifestyle of people will be changing with development of economy. Role of gas based electric power generators will be changing from base load generation to middle/peak shaving generation, and numbers of new gas power plants will be constructed near metropolitan area (Dhaka). Gas infrastructure should be planned and installed to coincide with those power plant installation plans.

The most important is that Gas Sector and Power Sector should work together by organizing working group jointly and share issues and determine exact location of the power plant, and associated power grid and gas supply infrastructure.

On completion of gas and/or power infrastructure, more sophisticated operation system need to be in place and trained operator and maintenance personnel need to be ready for work. However, this capacity building task might not be easy. Assistance from Japan could be constructing and operating an "electronic gas infrastructure" which supports operation and maintenance of the infrastructure facilities, and transfer the system to the operating company at later stage (BOT). With this approach, project schedule will be shortened and more time can be used to train the staffs.

1) Short term

Most part of gas infrastructure will not be visible from surface because they are buried underground. Location of each gas piping components need to be identified by linking with GPS. First of all, object orientated advanced electronic mapping system need to be introduced, combined with appropriate SCADA (Supervisory Control and Data Acquisition) System. By this arrangement, Advanced Control, Preventive Maintenance, Operation Safety, Emergency Transaction, and Asset Management, will be attainable. Such system can be constructed and operated by Japanese entities and transferred at later stage (build-own-transfer: BOT). Technology transfer will be easily implemented under this proposed scheme.



Source: JICA Survey Team

Figure 22-3 Advanced Electronic Mapping - Object Model System

2) Mid term

As the imbalance of demand-supply situation improves with the increase of import LNG, operation mode is changing from "Gas Allocation" to "Customer Demand" basis. Gas supplier is required to supply gas to meet the demand profile of each customer. Gas supply source will be diversified. In addition to domestic gas, introduction of LNG via FSRU and/or Land LNG terminal and pipeline gas from India will be starting shortly. Gas customers will also be diversified with development of the economy. In order to manage such changes integrated supply system and central operation unit will

need to be constructed. Current gas supply organization may need to be reviewed and re-organized.

Introduction of IT is accelerated in future and operation system will be improved and need to be more flexible based on advanced data acquisition, processing and control system. JICA has assisted in introducing pre-paid gas meter to domestic users as part of yen-loan financed project. This system would be integrated into part of IT system in future.

(2) Human capital development and supporting organization (capacity building)

1) Short term

Currently, it is understood that the numbers of gas leak incidents are reported daily (details are not precisely understood at a gas distribution company). Most of which presumably are caused by poor maintenance, use of low grade materials, and/or poor construction practice. To enhance the reliability and integrity of the gas infrastructure system, it is necessary to set up design standard (such include piping material standard, standard construction drawings), construction work procedure and maintenance/safety procedures.

In order to bring up staffs who are able to manage advanced operation and maintenance of gas infrastructure, knowledge and skill based qualification system should be introduced. Personnel system may also need to be reformed.

2) Mid/long term

In addition to manage advanced operation and maintenance of gas infrastructure, managers are required to promote efficient use of gas. Wide range of knowledge and practical skills are required to be a manager. It is important to bring up internationally recognized professional engineers in the organization. Professional engineers will take such responsibility as they are seen in major oil companies and utility sector of advanced countries. Chartered Professional Institution in UK may be able to support the education and training programs.

Responsibility of such engineers will be extended to prepare operation and maintenance manuals to suit by themselves.

22.5 LNG Import [Gas]

FSRU Project is under progress and study of land based LNG terminal project has also started. However, each has its own characteristics and need to understand the differences. Prior to develop LNG project, following matters need to be taken into consideration:

- Price formula of LNG Long term Take or Pay contract
- Use of LNG spot market
- LNG Freight and tanker size
- Storage/gasification service fee
- Construction schedule and risk
- Operational risk and energy supply security

Construction schedule of FSRU is 3years at the most and construction risk is considered low, and therefore FSRU is considered reliable source of supply. LNG supply to FSRU will be based on "take or pay" and risk of "quantity" should be beard by Bangladesh. FSRU require more than 60 times of LNG delivery by shuttle tankers. Operation of FSRU is vulnerable to Cyclone and/or rough wave conditions because of ship to ship transfer operation of LNG.

Land based LNG terminal will play a role of supply optimization between supply and demand. It also plays important role in securing energy supply if it is used as a strategic storage, and considered inevitable energy infrastructure in Bangladesh. Compared with FSRU, freight unit cost will be lower since larger vessel such as Q-Flex and Q-Max class can be used to deliver LNG. Initial storage and gasification service fee is higher since it should support the initial infrastructure investment cost, however the fee will be lower and competitive with the expansion of storage capacity to meet the increasing demand. Construction will take 7-10 years to complete before commencement of commercial operation.

LNG terminal operation will be assigned to RPGCL (CNG & LPG Company), if it is planned by Petrobangla (a LNG terminal project under Power Cell and BPDB supported by IFC would be operated by different scheme. Further detail is described in the "LNG" Chapter). Gas produced at the LNG terminal will be handed over to GTCL (Transmission Company) and transmitted and handed over to Distribution Companies for supplying to customers. Gas allocation system worked under such system for long time.

Once large amount of gas is started to be delivered from LNG Terminal, gas allocation system will need to be changed to new delivery system, i.e., customer demand based supply system. This new supply system will work under integrated operation system connecting among LNG terminals, transmission lines, and gas distribution systems. Central operation unit with the task of controlling and monitoring all the in/out gas flow will need to be constructed. Current organization may need to be reviewed and restructured.

(1) Infrastructure

1) Short term

Industry of Bangladesh has suffered from shortage of gas supply and adversely affected economic growth of the country. The first FSRU should be constructed soonest and associated transmission line t as well. Design of current transmission line under construction is 90 km long, 30 inch diameter with pressure rating of #600, capable of transmitting 500-700 mmcfd at normal operating pressure of 900 psig. However, this pipeline is considered too small to accommodate further future gas delivery. New transmission system should be studied by the working group organized jointly between Gas Sector and

Power Sector, and share issues and determine future delivery plan.

Advanced gas supply system can work only under the sophisticated pressure/flow control system. Changing pressure of the transmission pipeline system may adversely affect performance of condensate recovery unit at gas field, as well as the operation performance in the downstream distribution. This potential impact needs to be investigated further.

2) Mid/long term

Land LNG terminal require 7-10 years to construct. It will play a role of supply optimization between supply and demand. It also plays important role in securing energy supply if it is used as a strategic storage, and considered inevitable energy infrastructure in Bangladesh. LNG storage capacity will continue to increase with the increase of demand. Gas transmission and distribution infrastructure will also be reinforced and expanded. Mid/long term plan should be prepared to minimize future cost and avoid duplication of works. Joint working group between power and energy sector to be organized for this purpose also.

(2) Human capital development and supporting organization (capacity building)

1) Short term

On completion of gas infrastructure, operation system needs to be in place and trained operator and maintenance personnel need to be ready for work. Assistance from Japan could be constructing and operating an "electronic infrastructure" which supports operation and maintenance of the infrastructure facilities, and transfer the system to the operating company at later stage (BOT). With this approach, project schedule will be shortened and more time will be used to train the staffs.

2) Mid/long term

As stated in the previous paragraph, it is important to bring up internationally recognized professional engineers in the organization. Professional Engineers will take responsibility of managing advanced operation and maintenance of gas infrastructure, and promote efficient use of gas. Major oil companies and utility sector of advanced countries relies on their operation on this type of people. Chartered Professional Institution in UK may be able to support the education and training programs.
Responsibility of such people will be extended to prepare operation and maintenance manuals to suit by themselves.

22.6 Renewable Energy [Introduction of energy storage technology]

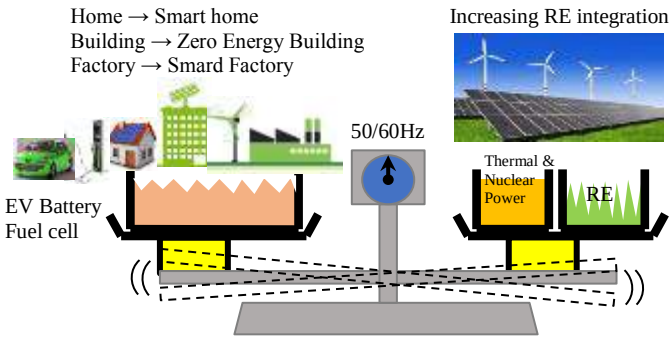
(1) Infrastructure

Integrating intermittent renewable energy resources, such as PV and Wind generation, to achieve CO2 emission reduction is a priority task for most countries worldwide. However, such renewable resources have high initial cost, low utilization rate and intermittent generation. Therefore, when integrated into the grid in large scale, they could put system frequency and voltage stability in jeopardy and cause technical problem.

On the other hand, in parts that have no access to the grid (off-grid areas), Solar Home System (SHS) or small-scale diesel generation provide electricity. However, SHS are expensive and cannot supply more than 3 to 4kW, also small-scale diesel generators have fuel running cost in addition to the initial cost. Therefore, off-grids areas have not only high failure rate but also a very high electricity cost.

To address such issues, increasing renewable energy integration while maintaining electricity supply stability, large-scale and safe energy storage technology is proposed as a supporting measure, and a practical introduction is highly expected.

< Frequency Fluctuation Image >



< Solar Home System (SHS) >



Source: JICA Survey Team

Figure 22-4 Introduction of energy storage technology (1)

1) Short term

- **Improved grid stability through integration of large scale and safe energy storage system**
  - ✓ As mentioned above, in case of integrating large scale intermittent renewable energy sources in power system, frequency and voltage fluctuations are anticipated.
  - ✓ Up to now, hydro pumped-storage units have been utilized to solve the above issues, however considering required construction cost, time and area, large scale energy storage systems have superior characteristics for absorbing power system fluctuation by electrical energy charge and discharge. Therefore, such solutions are being closely focused in North-America. A pivotal point in realizing large scale energy storage systems is its safety.
  - ✓ Considering above mentioned conditions, it is proposed to have a demonstration project F/S in order to connect safe large scale energy storage system to grid, develop operation and control technology and evaluate the integration effect.

- **Realizing safe, low cost and environment-friendly Off-Grid energy supply system through integration of large scale energy storage system**
  - ✓ In remote areas that don't have access to grid (off-grid), energy storage can be used to replace SHS and diesel generators through community energy schemes instead of providing energy system for each individual house. (Medium to large scale solar systems + large scale energy storage system for community). Using such scheme, it might be possible to addressee above mentioned issues. Therefore, F/S for evaluating the system integration effects is proposed.

Redox Flow battery is one of the most well-known large-scale and safe energy storage technologies. Some of the application samples can be shown as follows.

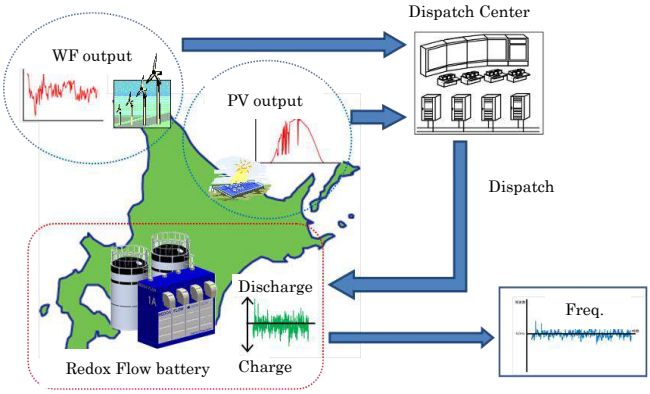
[1] Improved grid stability

- METI's demonstration project from FY 2013 to FY2018
- Installation site : Minami-Hayakita Substation at Hokkaido Electric Power Co., Ltd
- Sytem : Redox Flow battery system 15 MW / 60 MWh
- Application : Frequency regulation (Short duration)
  Surplus power adjustment (Long duration)

< System appearance >



< Demonstration image >



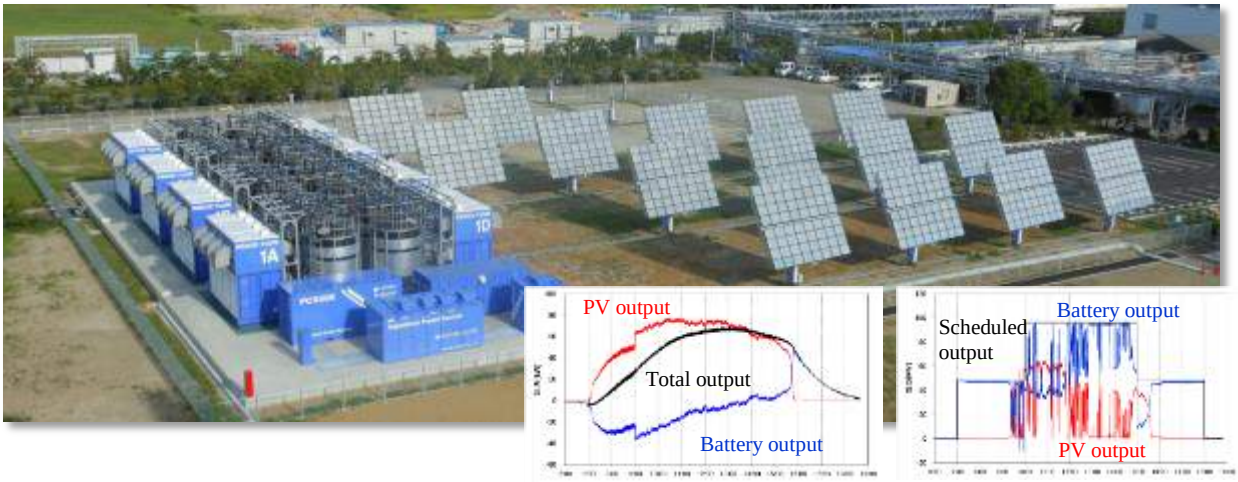
Source: JICA Survey Team

Figure 22-5 Introduction of energy storage technology (2)

[2] **PV + Large-scale energy storage**

- Sytem : Redox Flow battery system 1 MW / 5 MWh
- Application: Storage of PV surplus generation, PV output stabilization, etc.

Sysytem appearance



Source: JICA Survey Team

Figure 22-6 Introduction of energy storage technology (3)

2) Medium term
- Introducing large scale energy storage based on the F/S results

(2) Human capital development and supporting organization (capacity building)

1) Short term
- Training for operators and creating operational manuals

It is important for the large scale energy storage operator to have a sound knowledge about functions, responsibilities, operation and maintenance, economics of the systems and etc. Together with the above mentioned F/S study, there would be a training for the large scale energy storage operators and a manual would be provided form the achieved operation know-how. This will layout foundation for safe and low cost energy supply as well as suitable O&M support in Bangladesh.

2) Medium term
- Creating ancillary service market foundation

The need for ancillary services and large scale energy storage systems would be increased due to the expansion in renewable energy resources. To correctly evaluate this value and realize suitable balance of energy resources, creation of an ancillary service market would be necessary.

22.7 Power System Plan

(1) Infrastructure Arrangement

1) Transmission Plan

The projects listed in the table of on-going projects made by PGCB will be steadily implemented.
The funding sources should be identified soon for the projects that have not yet been funded, such as the expansion and strengthening of the network in DESCO's management area (400kV GIS substations and 230kV substations). Regarding the projects for the bulk power transmission system related to interconnections, such as Barapukuria, their funding sources should also be identified in adequate time, in cooperation with the progress of the discussions with the related neighboring countries. Regarding the projects for the transmission lines for power transmission from the large scale power stations in south Chittagong and Khulna that are identified in this MP, their FSs are implemented accordingly at suitable timings in order to match the construction schedule and urgent selection of the routes for transmission lines.

2) Rural Electrification

The projects listed in the table of on-going projects made by BREB will be steadily implemented. In the process, it is important that a distribution system which aims at high reliability in the future is constructed efficiently.

(2) Strong Institutional Arrangements

1) Transmission Plan

PGCB takes on the role of making plans for bulk power transmission lines and substations. Although consistency among the bulk power network plans and power demand forecasts, power generation plans and power distribution plans should be ensured, these plans and conditions are set by organizations other than PGCB. The power demand forecast for the whole of the nation is made by BPDB and the regional ones are made by power distribution companies. Power generation development plans are made by BPDB under the management of Power Division in MoPEMR. The power distribution plans are made by distribution companies such as DSCO and DPDC.
The results of the plan for the bulk power transmission system made by PGCB are reflected in the power transmission and distribution plans made by distribution companies and become the conditions for planning the 132kV system. The appropriate feedback should also be given to BPDB and Power

Division in MoPEMR on the power network plan made by PGCB, in order to reflect its results and correct information in the Government to Government projects. The following countermeasures should be implemented.

- The institutional frameworks should be established among BPDB, Power Division, Distribution Companies and PGCB to share the necessary information periodically in order to make the power network system plan.
- The reports on the power network system plan are published periodically (every half-year or annually) to share information on the status of making the plan among the abovementioned related organizations. PGCB reports on the future projects for transmission lines and substations required, from its technical viewpoint, to BPDB, Power Division and distribution companies.
- The rules for power network system planning should be clarified, published and open to the public as a part of the Grid Code.

2) Rural Electrification

In this sense, a good communication and coordination between BREB and IDCOL is required; however, it is observed that such communication or coordination is not taking place. IDCOL is communicating to BPDB for project planning, but BPDB seems not liaising with BREB properly. If the Government seriously pursue the achievement of "Electrification for All" by 2021, the good communication and coordination between BREB and IDCOL must be taken, and both parties (and BPDB as a coordinator too) need to improve in this area.

22.8 O&M Legal Framework [O&M]

(1) Human capital development and supporting organization (capacity building)

1) Short term
The Bangladeshi government would organize a specialized committee which legislate some act related O&M.
In terms of short term, the suitable method of bringing up talented person in specialized committee would be that they study to development some laws related to O&M under the specialist's instruction after the specialist for making O&M act in developed country, like Japan, invited from overseas to Bangladesh.
It is highly likely to be difficult to enact laws and regulations mandating regular inspection and to establish a system for the supervision of the facility maintenance by authorities in a short period of time. It is worth studying the feasibility of taking proactive measures such as introduction of various regulations and technical standards for the maintenance of power generation facilities used in Japan as the standards for the maintenance of power plants in Bangladesh and maintaining the plants using the introduced standards before the enactment of all the required laws and regulations. It is recommended that the power plants to be constructed, in particular, be operated in accordance with a schedule that includes the schedule for the maintenance from the beginning of their operation.

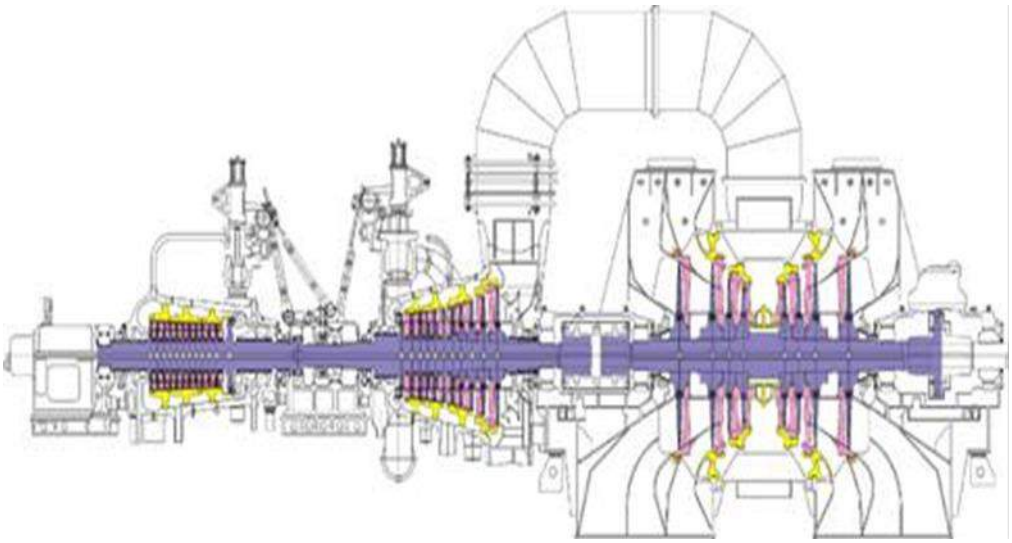
2) Mid/long term
In terms of mid-long term, one of solutions developing human resources is that the members of legislation committee would be dispatched to developed foreign country to learn the real O&M legal framework and actual situation of O&M in a power plant, and the members might bring back knowledge of the useful laws to Bangladesh. In addition that is better to continuous study the operation status of power plant in developed nation, and also research the history of O&M act reformation, that would become to good samples for Bangladeshi O&M act.

22.9 Thermal Power Plant O&M [O&M]

(1) Infrastructure

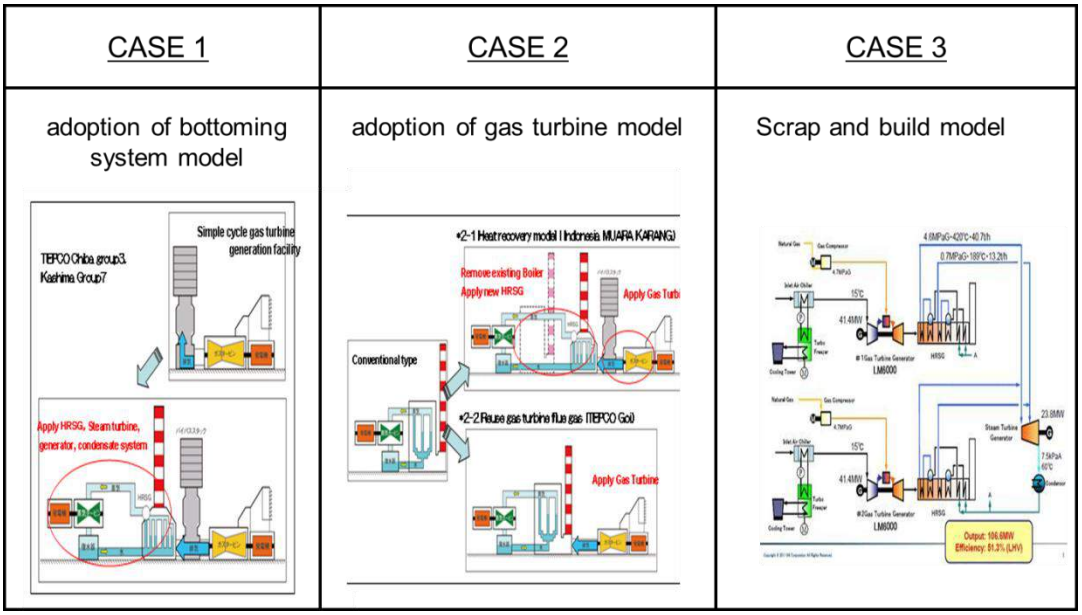
1) Short term

In the short term, we consider that enhancement of power generation capacity is a priority in order to meet the demand growth and requirements from the industrial sectors. In particular, some of the aging power facilities need to be replaced with, or converted into higher efficient units. The study team proposes two plans as power plant remodeling plans. One is a rehabilitation plan for old steam turbines which were built by Russia. The other consists of three different levels of conversion into combined cycle units. Those plans can be implemented with proven technologies of Japanese engineers.



Source: JICA Survey Team

Figure 22-7 Steam Turbine Rehabilitation Plan



Source: JICA Survey Team

Figure 22-8 Combined Cycle Power Generation Remodeling Plan

2) Mid/long term

Those proposals mentioned above can be a quick solution to the power shortage problem of Bangladesh for a short time period. After the completion of the remodeling works, application of proper maintenance is a key to successful capacity enhancement.

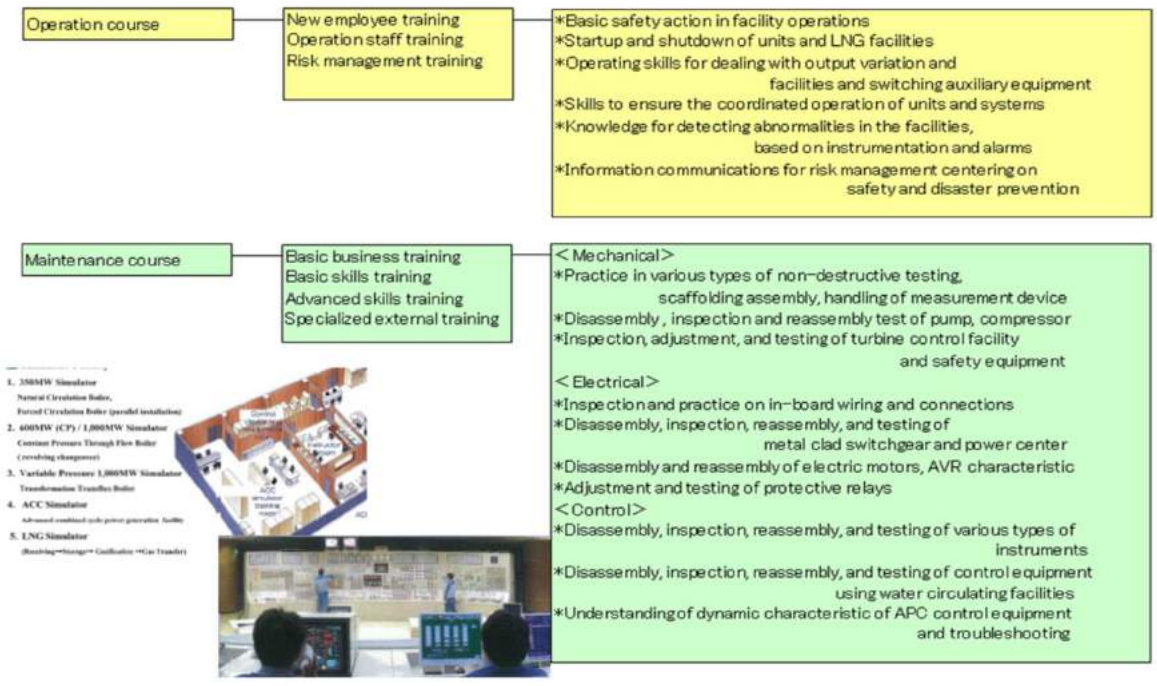
(2) Human Capital Development (capacity building)

1) Short term

In addition to measures to reinforce the capacities of power generation facilities, preventive maintenance of these facilities was considered important for the maintenance of their capacities and the maintenance and improvement of their operational efficiency in this survey. It is necessary to train maintenance engineers for the appropriate implementation of regular inspection as part of preventive maintenance. A study will be conducted on the possibility of establishing an independent organization specialized in the maintenance and repair of the facilities and using the human resource development service of this organization as a measure to cope with the problems of the shortage of the maintenance personnel and budget at the state-owned power generation facilities.

In general, the scarcity of skilled engineers undermines operational efficiency and lack of maintenance of facilities. To cope with this problem, the survey team suggests a training facility with equipment and materials which are actually used in power facilities, like a power plant silulator. While most of the trainings are carried out in a traditional classroom setting in Bangladesh, the proposal puts an emphasis on the practical exercises by using effective training materials. The proposed training has two main courses, one of which is a course for plant operators, and the other is a course for maintenance engineers. Both courses lead to certifications in the respective areas of the education. The proposals include the facility and training items described below.

A further study will be required before deciding whether such training will be provided by an independent organization to be established or by each power company.



Source: JICA Survey Team

Figure 22-9 Training Course Plan

2) Mid/long term

The training courses should be extended to higher levels of education for instructors. In the short term, instructors can be provided from other organizations; however, a scarcity of instructors will be the biggest problem in the future. In order to fill the gap between training demands and instructors provided, skilled workers at operating facilities can be utilized. A workforce rotation program should be introduced to enable new employees to learn from the skilled workers who have experiences with the actual equipment, while the career development plan for the instructors motivates them to take a leave from their positions at their power facilities. The introduction of job rotation is recommended as a measure to provide new employees with the opportunities both at power plants and at training centers to learn the practical work performed in power plants from engineers who have ample practical working experience.

(3) Thermal Power Plant O&M Information Management

1) Short term

After the completion of the development or enhancement works of power facilities, it is important to maintain their capacity and efficiency. The objective of the organization-wide information management system is to facilitate maintenance planning, budget control and procurement optimization. The functions of the system include the following.

- Maintenance Planning - To encourage plant managers to make feasible plans for maintenance.
- Budget Management - For prompt decision making on financial matters and reduction/removal of delay in maintenance activities.
- Maintenance Work Management - To keep maintenance projects within budget and timeframes.
- Failure History Management - To provide supporting data for budget and plans.

Expected results (Quantitative Effects) are:

- Reduction of maintenance cost
- Reduction of frequency of forced outage
- Reduction of forced outage hours

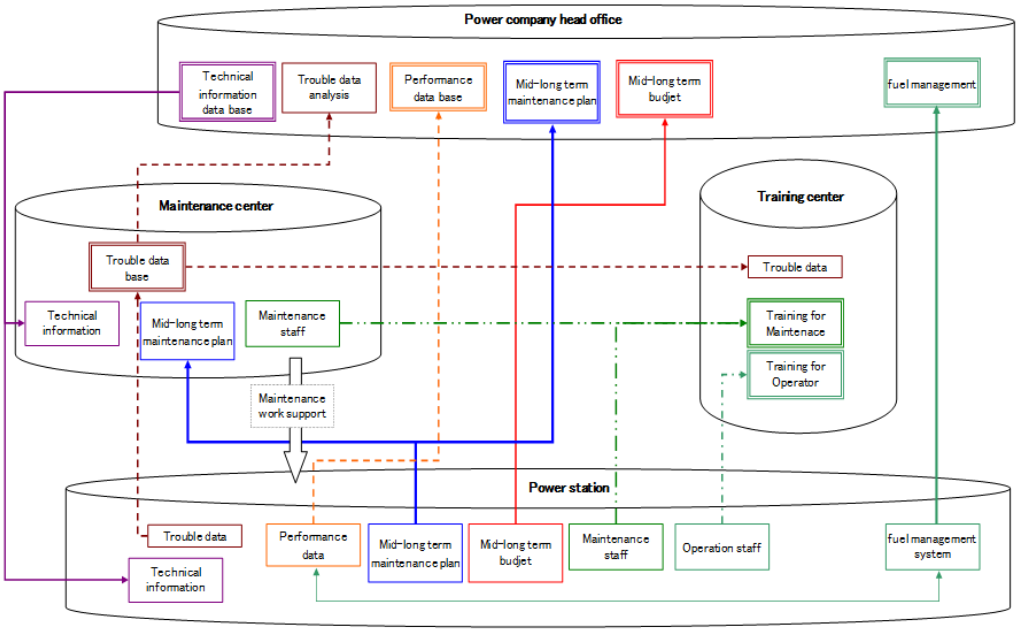
In order to maximize the effectiveness of implementation of information management, a feasibility study is expected to be carried out in pursuit of the following information items.

Table 22-1 Items Required in Feasibility Assessment

Category	Item	Details
Computer System and Network Infrastructure	Plant LAN	Local Area Network availability in power plants
	Enterprise network	Network availability, connectivity among business units and multiple locations, and its security, reliability and capacity.
	Data repository	Data center location, storage capacity and scalability
	Legacy systems and data integration	Legacy systems and legacy data.
Management	Business process	Business processes in Maintenance Planning, Budget Creation, Procurement, Work Planning, and their business requirements.
	Regulations and standards	Regulations, standards, public authority reporting guidelines.
Target Selection	Facility Requirement	Facility type/age/capacity, location, future plans for enhancement or replacement
		Connectivity between facility and data acquisition devices

Source: JICA Survey Team

The Information Management System connects the head office with power facilities and other related organizations such as Maintenance Center and Training Center. These organizations share facility information for analytical use which brings the power facility higher efficiency and reliability based on accumulation of historical data.



Source: JICA Survey Team

Figure 22-10 System Functions and Data Flows for a Power Plant in Bangladesh

2) Mid/long term

The scope of the Information Management System can be extended to Facility Management and Environmental Management. The functions of the system may contain:

- Facility Assessment - To optimize maintenance cost based on physical state of facilities.
- Procurement Management - To maintain spare inventory levels while reducing procurement cost.
- Tariff Management - To provide an accurate cost basis for appropriate pricing of electricity.
- Environmental Management - To ensure regulatory compliance while managing environment related cost.

Expected results (Quantitative Effects) are:
- Reduction of Total Ownership Cost of facilities
- Reduction of fuel cost
- Reduction of emissions, effluents and waste products
- Contribution to effective tariff setting

(4) Organization (capacity building)

1) Short term
To perform facility maintenance activities in compliance with laws and regulations, auditability of the work processes and work results, such as facility inspection reports, must be achieved. Maintenance crew must be familiar with the designated documentation and records, which need to be prepared in an accurate and timely manner when requested by the authority.
The maintenance planning processes require some knowledge in project management. Maintenance managers will be advised to learn work process management and budget control.
Apart from the above, the information assets need to be properly maintained and protected. IT/ICT

engineers are expected to keep the system fully operational; therefore, IT/ICT education is also important.

2) Mid/long term
As described in Chapter 19, the goal of this Study is to achieve a best practice in O&M in the power sector. Major power producers in Japan make use of a wide variety of software applications in daily operations of their facilities; however, their common focus is to maintain reliability of the facility with optimal cost. In the future, the education for plant workers may cover wider area which is more management oriented in terms of efficient use of organizational resources.

22.10 Tariff policy

(1) Human capital development and supporting organization (capacity building)

1) Short term
For implementing appropriate tariff policy including electricity tariff increase and gas price increase, capacity building for appropriate decision making of price level in consideration of accurate supply cost is required. Therefore donors are expected to provide capacity building support for BERC. In fact, ADB is considering to support BERC for capacity building. In addition, for grasping accurate supply cost, support of capacity building for each organization to develop sophisticated management plan is also important. Hence for enabling organizations such as BPDB to develop more sophisticated management plan and implement it, donors should support corporate management capacity building in them. Donors are expected to support BPDB, etc. to analyze financial situation in more detail, identify inefficient points, and remedy them.

2) Mid/long term
Above-mentioned support is expected to be continued until appropriate tariff level and ideal financial situation of BPDB, etc. are achieved.

22.11 Realization Of Low Energy Consumption Society

The target of energy projects in the developing countries is “stable supply of energy and electric power that meets the increasing demand for energy for the economic growth.” Therefore, they will need continuous power development. Meanwhile, the results of the analysis of the relationship between the economic and social activities and energy consumption was used for the projection of energy demand in the formulation of the supply plan in this master plan. The use of the technologies considered to be highly reliable in 2016 was assumed in the formulation of the supply plan. However, the validity of these assumptions is likely to change because the energy demand may not increase as projected and more advanced power generation technologies may be developed in future. These changes will be important factors to be investigated in the rolling monitoring of this master plan in future.

22.11.1 New Technologies for Power Generation with Different Energy Sources

The technological innovation in the energy and power sectors is advancing at a remarkable pace. A technology in the research stage at the time of the formulation of this master plan may become available for use in Bangladesh by 2041 with the progress of R&D in these sectors. The projects using such new technologies are classified into the two groups mentioned below and explained in the following.

(1) Energy Efficiency Project: EE
(2) Renewable Energy Project: RE

Table 22-2 Areas of research by type of energy

EE	Projects for the improvement of energy efficiency (EE)	
	Power generation	Power generation with the integrated coal gasification combined cycle, etc.
	Improvement and rehabilitation of power generation facilities	Renewal of the facilities for the improvement of power generation efficiency
	Power transmission and distribution	Establishment of power transmission and distribution facilities for the improvement of energy efficiency
	Activities for reducing power transmission and distribution losses	Renewal of the existing facilities for the improvement of energy efficiency
	Rural electrification	Conversion from the power generation with internal-combustion engines to more energy-efficient power generation, transmission and distribution facilities
	Demand side management (DSM) activities in the electric power industry	Introduction of energy-saving systems for the reduction of power consumption
	ESCO activities	Introduction of facilities and services for the improvement of energy efficiency through the ESCO activities
	Improvement of energy efficiency	Research for the improvement of energy efficiency and the development of energy-saving technologies
RE	Projects for power generation with renewable energy (RE)	
	Power generation activities (use of renewable energy)	Implantation of power plants using solar, wind, hydro, and geothermal energy and biofuel
	Hybrid power generation activities	Implantation of power plants that can be operated with both renewable energy and conventional energy sources
	Bio-energy activities	Implantation of power plants using bioenergy including biomass, biogas and biofuel for power generation
	Decentralized Energy Production & Distribution	Implantation of decentralized energy production systems using renewable energy
	Energy conservation	Research on the energy conservation technology

Source: JICA Survey Team

22.11.2 New technologies in the electric power infrastructure sector

Table 22-3Areas of assistance in research in the electric power infrastructure sector

Classification	Technology
Thermal power generation	Integrated coal gasification combined cycle (IGCC) power generation
Renewable energy	Biomass gasification power generation
	Power generation using the methane gas generated by fermenting biomass
Power transmission and transformation	Improvement of the power factor
	Improvement of the power flow (increasing the number of transmission lines)
	Increasing the diameter of power cables
	Introduction of an upper level voltage (increasing the transmission voltage)
	Superconducting cables
	Superconducting transformers
	Insulated strand cables
	Use of low loss transmission cables

Classification	Technology
Power distribution	Distribution loss reduction technology (improvement of power factors: reduction of lagging power factors)
	Distribution loss reduction technology (low-loss distribution transformers, "Top Runner Transformers")
	Distribution loss reduction technology (amorphous core transformers)
	Distribution loss reduction technology (improvement of measuring equipment)
	Distribution loss reduction technology (increasing the diameters of power cables)
DSM	Heat pump technology (Heat pump hot water supply systems with CO_2 natural refrigerant)
	Thermal storage air conditioning systems
	Electric automobiles
	Cogeneration systems (combined with thermoelectric systems)
	Fuel cells (polymer electrolyte fuel cells: PEFCs)
	Fuel cells (solid oxide fuel cells: SOFCs)
Energy conservation in storage batteries	Power storage technology (load-levelling)
	Energy conservation in battery cells
	Superconducting magnetic energy storage system (SMES)

Source: JICA Survey Team

22.11.3 Responsible Energy Consumption and Development of Bangladesh into a "Developed Country"

The record of energy consumption in Bangladesh in the past and the relationship between the economic development and energy consumption in the countries in Southeast Asia, especially the relationship in Thailand, in the past were used for the long-term projection of the energy demand in Bangladesh in the formulation of this master plan.

There is no doubt that Bangladesh has to develop its economy further in future. On the other hand, it is required to achieve the economic growth while saving the energy consumption (or, to achieve both development and environmental conservation simultaneously). In the formulation of this master plan, the 3E evaluation, more specifically, an analysis using the CO2 emission as a variable, of the power development plan was used for the quantitative evaluation of its commitment to the environmental conservation. If the environmental regulations in the international community become stricter and more diversified, Bangladesh will have to endeavor to comply with them as a responsible member.

In addition, a "developed country" in 2041 may not be a large energy consumer like the developed countries at present in 2016. Large energy demand has already been a condition for a developed countrysation in the past. In fact, as mentioned in Chapter 5, the *per capita* energy consumption of Bangladesh is smaller than those of Thailand, Indonesia and Vietnam. Meanwhile, the differences in the *per capita* energy consumption between Bangladesh and the three countries are larger than the difference in the *per capita* energy consumption per GDP between them. This observation indicates that Bangladesh consumes a smaller amount of energy than the other three countries to create the same economic value and that the economy in Bangladesh has grown with relatively small energy input. Although the changes in the industrial structure expected in future are predicted to increase the energy demand rapidly, Bangladesh can be proud of its more energy-efficient economic growth than the other Asian countries.

Furthermore, the government and the people of Bangladesh to develop their country into a developed country is to create an image of a "developed country" in 2041 including the scale of economy and the lifestyle of people that they aim at, prepare an ideal way to use energy resource for economic development that is efficient and energy-saving in the way like they have, as mentioned above, by themselves and realize the ideal way in a responsible manner.

Category No.	Title	Source	File type	File name
Energy Cost - 14	Planning Commission "ANNUAL DEVELOPMENT PROGRAMME FOR 2014-2015" http://www.plancomm.gov.bd/adp/	The Bangladesh Planning Commission	URL	COST-14
Energy Cost - 15	Planning Commission "ANNUAL DEVELOPMENT PROGRAMME FOR 2015-2016" http://www.plancomm.gov.bd/adp-2014-2015-bangla/	The Bangladesh Planning Commission	URL	COST-15
Energy Cost - 16	Asian Development Fund: FAQs http://www.adb.org/site/adf/faqs	Asian Development Bank	URL	COST-16
Energy Cost - 17	IDA Terms (Effective as of July 27, 2016)	World Bank	PDF	COST-17
Energy Cost - 18	Lending and relending terms of local/Foregin currency loans	Ministry of Finance	PDF	COST-18
Energy saving - 1	Draft Energy Efficiency and Conservation Master Plan	JICA	PDF	ES-1
Energy saving - 2	Energy Efficiency and Conservation Rules, Draft October 2012	SREDA,	PDF	ES-2
Energy saving - 3	Interim Action Plan for Improvement of Energy Efficiency & Conservation	Power Division	PDF	ES-3
Energy saving - 4	Energy Efficiency Initiatives	Power Division	PDF	ES-4
Demand - 1	Bangladesh Map	Bangladesh Bureau of Statistics HP	PDF	EPD-1
Demand - 2	POPULATION AND HOUSING CENSUS 2011	Bangladesh Bureau of Statistics HP	PDF	EPD-2
Demand - 3	Population in Bangladesh	Bangladesh Bureau of Statistics HP	PDF	EPD-3
Demand - 4	Bangladesh Population 2014	United Nations HP	PDF	EPD-4
Environment - 2	IPCC AR5, WG3 report Chapter6	IPCC	PDF	ENV-1
Environmet - 3	Intended Nationally Determined Contributions (INDC)	Ministry of Environment and Forests (MOEF)	PDF	ENV-2
Environmet - 4	Mitigation of Short Lived Climate Pollutants (SLCPs) in Bangladesh and Integration in National Policies and Strategies	CCAC (Climate and Clean Air Coalition) Department of Environment	PDF	ENV-3
Environmet - 5	Second National Communication of Bangladesh to the UNFCCC	Ministry of Environment and Forests (MOEF)	PDF	ENV-4
Gas - 1	Field wise Gas Production	Petrobangla HP	PDF	Gas-1
Gas - 2	Five year Gas Production Strategy 12-03-2015	Petrobangla HP	PDF	Gas-2
Gas - 3	Five year Gas Production Strategy 12-03-2016	Petrobangla HP	Word	Gas-3

PART VII APPENDIX

Chapter 23 Appendix

23.1 1st Seminar (1st Steering Committee)

- Date: 29 October 2014
- Venue: Board Room of BPDB at Buddyut Bhaban, Dhaka
- Discussion Point: Explain for Inception Report
  - ✓ Establishment of Steering Committee (SC) and the Working Group (WG) for the Survey.
  - ✓ Explained the survey objectives, methodologies, member, and implementation schedule





- Participants

Participants are shown below table.

No	Name	Designation	Organization
1	Mr. Mustak Ahmed,	Director	Bangladesh Energy Regulatory Commission (BERC)
2	Mr. Md. Bellal Hossain	Executive Engineer, System Planning	BPDB
3	Mr. Md. Mizanur Rahman	Chief Engineer (P&D)	BPDB
4	Mr. Kaisar Ahmed	Chief Engineer (P&O)	BREB
5	Brig. General Moin Uddin	Chairman	BREB
6	Mr. Md. Nazrul Islam	Member (P&D)	BREB
7	Mr. Md. Monirul Islam	DGM (Planning)	Coal Power Generation Co. Ltd
8	Mr. Ramiz Uddin Sarker	Executive Director (Engineering)	DPDC
9	Mr. Md. Mojibur Rahman	Executive Engineer	DPDC
10	Mr. Mohabbat Ullah	Director	FBCCI
11	Mr. Md. Nur Alam Siddique	Asst. Secretary	Ministry of Water Resources
12	Mr. Harendra Nath Mondal	Executive Director	NWPGCL
13	Mr. Md. Kamrul Islam	Sub Divisional Engineer (P&D)	NWPGCL
14	Mr. A.D.M. Fariduzzaman	DGM (Strategic Planning)	Petrobangla
15	Mr. Md. Lutfar Rahman	General Manager	Petrobangla
16	Mr. Md. Monjurul Alam	Deputy Director	Power cell
17	Mr. Md. Abdur Rouf Miah	Director	Power Cell
18	Mr. Md. Shafiqul Islam	Asst. Chief (Planning-2)	Power Division
19	Mr. Tapos Kumar Roy	Additional Secretary	Power Division, MoPEMR
20	Mr. Shyamal Kumar Ghosh	Superintending Engineer	WZPDCL
21	Mr. Md. Abul Kalam Azad	Managing Director	WZPDCL

(Alphabetical order)

- Presentation materials

Presentation materials are as next pages.

Survey on Power System Master Plan 2015

1st Seminar
Overview Session

December 2, 2014

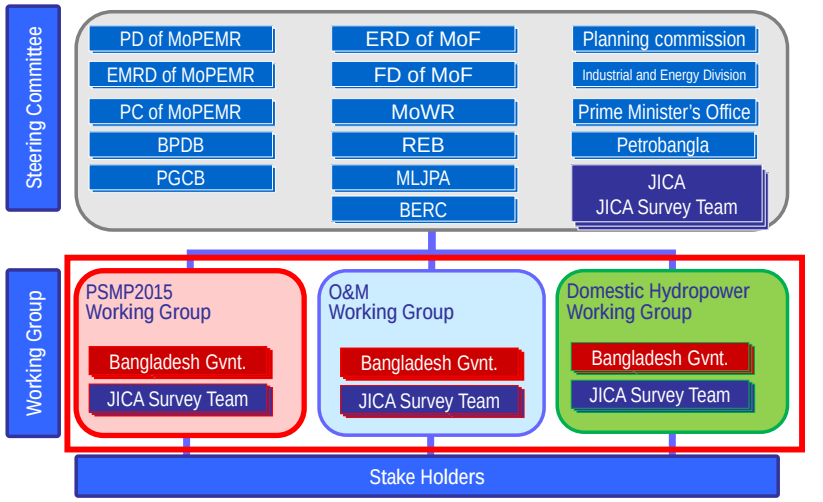
Tokyo Electric Power Services Co., Ltd.
Tokyo Electric Power Company.

1. Survey Objectives

Three major objectives

- To review Power System Master Plan 2010 (update to PSMP2015)
- To pursue optimum O&M system
- To explore domestic hydropower

2. Implementation framework



Working Group (WG) is a main body to work together

3. Implementation Schedule

	2014			2015								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep
In Bangladesh	1st		2nd		3rd		4th		5th		6th	
Seminar		1st	11/27				2nd			3rd		
Report	IcR					ItR				DFR		F/R
7th 5year Plan												

4. Key issues for power sector

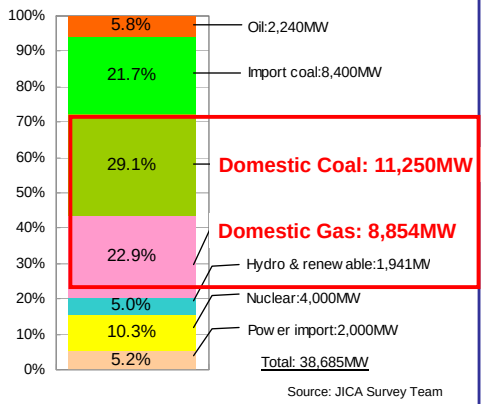
Key Issues

- Challenge for primary energy supply
- High cost liquid fuel-based power generation increase
- Challenge for realizing large scale base load generation
- Power plants unable to stop for maintenance
- Domestic hydropower potential little explored
- BIG-B Initiative (The Bay of Bengal Industrial Growth Belt)

4. Key issues for power sector

1. Challenge for primary energy supply [PSMP]

- Domestic coal no further development
- Domestic natural gas reserve to be depleted in 10 to 15 years
- For short term solution, dependency on import LNG, LPG and coal is inevitable
- For mid to long term, untapped domestic gas exploration and development is required



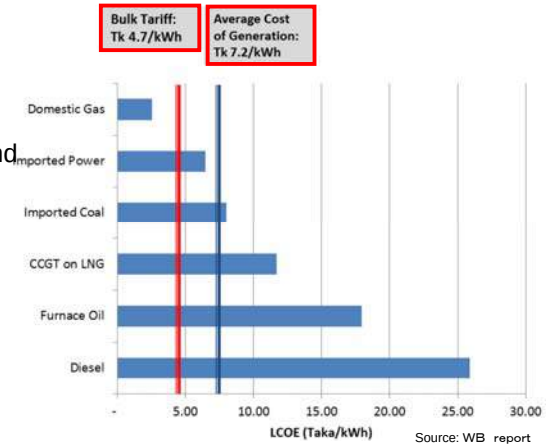
Source: JICA Survey Team

Power Configuration as of 2030 by PSMP2010

4. Key issues for power sector

2. High cost liquid fuel-based power generation increase [PSMP]

- Bulk Supply Tariff: **Tk 4.7/kWh**
- Average generation cost: **Tk 7.2/kWh**
- Gap between revenue and cost is large
- Need to be considered;
  - ✓Exit strategy for small scale high cost generation (oil and diesel)
  - ✓Acceleration of large scale base load generation (coal and C/C gas)



Source: WB report

Change of Power Configuration from 2011 to 2014

4. Key issues for power sector

3. Challenge for realizing large scale base load generation [PSMP]

Small scale high cost generation (oil and diesel)

- CAPEX: appropriate profit is secured = no CAPEX risk
- OPEX: fuel pass through system = no fuel risk
- Successful, but high cost

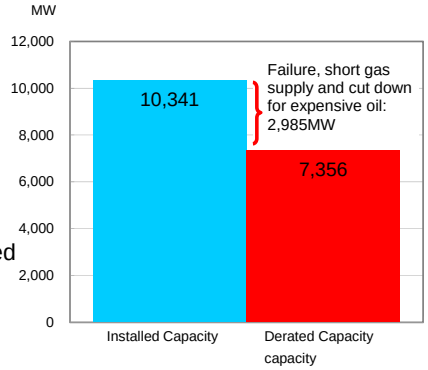
Large scale base load generation (coal and gas)

- Difficulty of securing fuel supply
- Need to explore not only public financial source but also private financial source

4. Key issues for power sector

4. Power plants unable to stop for maintenance [O&M]

- Installed capacity: 10,000MW
- Derated capacity: 7,000MW
- Gap: 3,000MW
  =huge loss of investment cost
- 10% : gas shortage
- **20% : due to O&M**
- Current situation:
  Even new power generation installation is constructed, it will become derated to 70 to 80% of rated capacity.
- **Optimum situation**
  - ✓ **Installed capacity = actual capacity**
  - ✓ **Legal framework and actual practice need to be established**

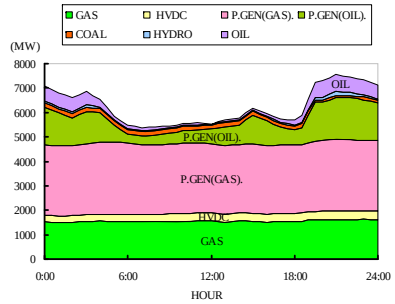


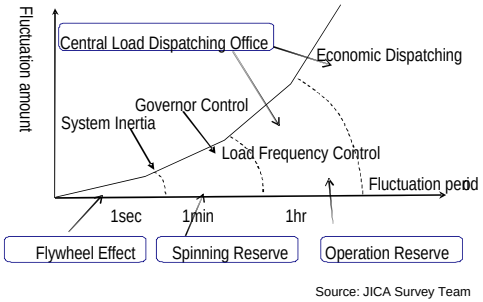
Difference of Installed Capacity and Derated Capacity (March 31st, 2014)

4. Key issues for power sector

5. Domestic Hydropower potential little explored [Hydro]

- Hydro installation is very small (2%); Frequency capacity is very limited
  - ✓Therma : medium control (few minutes), or not designed for such control
  - ✓Hydro: rapid control (few seconds)
- Authority of NLDC is very limited for quality power system operation
- Off-grid small / micro hydro power can contribute to rural electrification





Source: JICA Survey Team

4. Key issues for power sector

6. BIG-B Initiative (The Bay of Bengal Industrial Growth Belt)

Accelerating industrial agglomeration in Dhaka–Matarbari belt and beyond to shape a value chain hub for South Asia and Southeast Asia

Energy & Power	Supplying reliable energy & power for industries
Trans-port	Fostering connectivity as a regional node and hub
Invest-ment Climate	Promoting domestic & foreign direct investment
Others	Enhancing sustainable socioeconomic development



Thank you for your attention

This file with minor modifications from the distributed hand-outs will be sent later to the working group members.

Japan International Cooperation Agency (JICA)
People's Republic of Bangladesh

Survey on Power System Master Plan 2015

1st Seminar
Working Group Session

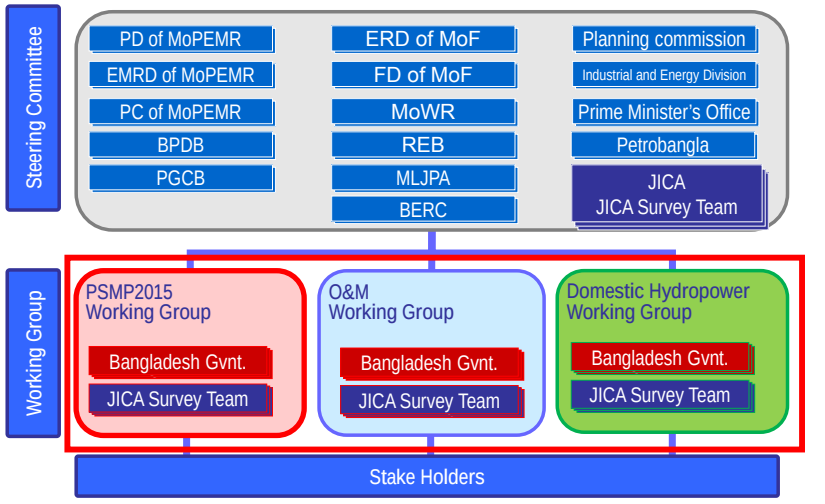
December 2, 2014

Tokyo Electric Power Services Co., Ltd.
Tokyo Electric Power Company.

Agenda Today

1. Implementation Framework
2. PSMS 2015 WG
   - 2-1 Gas supply and demand
   - 2-2 Coal supply and demand
   - 2-3 Power Demand Forecast
   - 2-4 Power Development Plan/Power System Planning
   - 2-5 Financial Analysis
3. O&M WG
4. Hydropower Development

1. Implementation framework



Working Group (WG) is a main body to work together

PSMP2015 Working Group

Gas

2-1 Gas supply and demand

(1) Domestic natural gas supply

(2) Natural gas balance after alternative energies

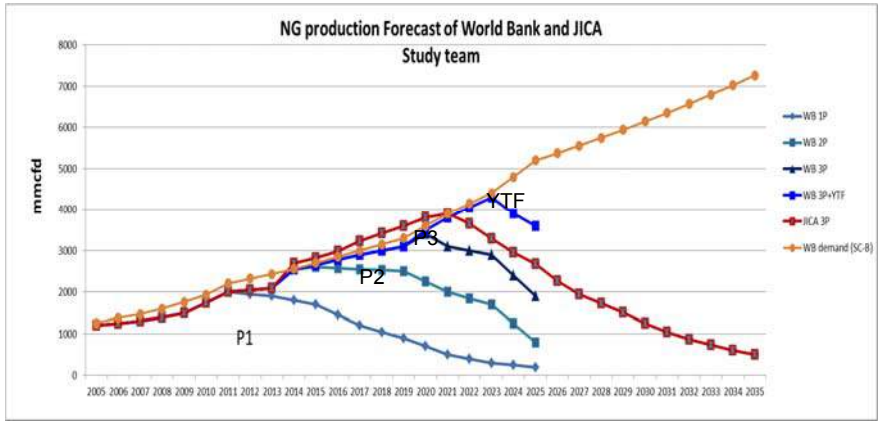
(3) Natural gas supply plan images

(4) Required policies for future primary energies

(5) Cost estimations

2-1 Gas supply and demand

(1) Domestic Natural gas Supply

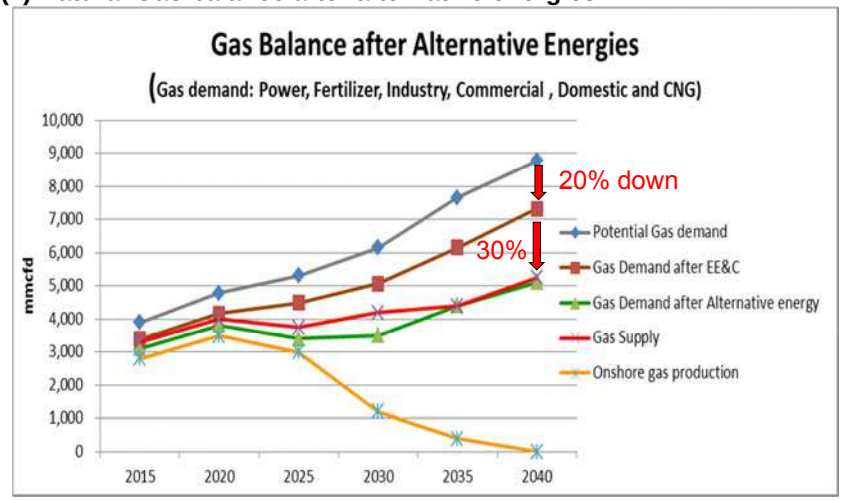


Source : Bangladesh Gas Master Plan 2006 , World Bank, ICA Survey Team

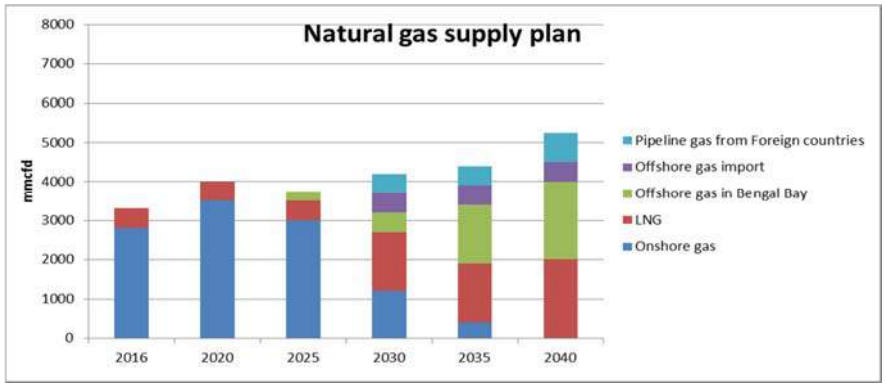
No major change between World Bank in 2006 and JICA trial estimation

2-1 Gas supply and demand

(2) Natural Gas balance after alternative energies



(3) Natural Gas supply plan images (supply breakdown)



(4) Required policies for Future primary energies

- Make efforts to develop remaining gas reserves
- Energy diversification is required
- Network connection to neighboring countries
- Energy efficiency & conservation policy
- Natural Gas import plan (LNG and Pipeline)
- Establish coal supply chain

(5) Cost estimation

Principal data and information required

【Original】

- Gas Field Data
  - ✓ Field name
  - ✓ Well fluid composition
  - ✓ **Expected future production rate**, pressure and temperature
  - ✓ Sales gas quality, etc.

Not available

- Data of Planned LNG Supply Pipeline
  - ✓ Pipeline route map
  - ✓ Pipe ID (length, diameter, wall thickness, etc.)
  - ✓ Operating condition (flow rate, pressure and temperature)

【Alternative】

- Investment cost of gas production facility vs. gas reserves

  The Investment cost and gas reserves in onshore gas field should be provided based on past gas field development experience in Bangladesh.

Can you provide this data?

(5) Cost estimation

Cost Estimation Procedure

STEP 1 Collection of Required Data and Information
- •Collection of "QUESTIONNAIRE" reply
- •Data survey in Bangladesh
- •Check of the data and information

STEP 2 Study for Gas Processing Facility, LNG Receiving Terminal and Related Pipelines
- •Examination of gas development concept
- •Examination of gas treatment process

SKIP

STEP 3 Cost Estimation
- •Establishment of estimation basis and philosophies
- •Execution of cost estimation

2-1 Gas supply and demand

(5) Cost estimation
a. YTF=8.4tcf

For the purpose of supply planning Wood Mackenzie recommends that the P95 Yet to Find resource estimate of 8.4 tcf be used. It is also recommended that a prospect inventory be compiled and that plans are made to systematically define and drill these prospect to prove up the potential undiscovered volumes. This needs to be done on an ongoing basis to ensure that the potential resource is converted into proved reserves and developed in time to meet the supply shortfall.

The YTF resource has an even greater level of uncertainty than possible reserves. The USGS report used a probabilistic methodology to determine the potential resource range. Wood Mackenzie would recommend that it is prudent not to rely on anything more than the 95% probability value of 8.4 tcf. Wood Mackenzie has used the 8.4 tcf YTF resource to develop the supply-demand balance for the three demand cases (A, B, C) and for the full range of reserves (1P, 2P, 3P and YTF). The supply-demand balance forecasts are shown in the figures below and tabulated in *Statistical and Background Information Document*.

According to the report, preparation and development of gas sector master plan 2006, Yet To Find (YTF) reserve is estimated to be around 8.4tcf.

2-1 Gas supply and demand

(5) Cost estimation

Since 2001, when the USGS (Ultra Sonic Geologic Survey) was implemented, four (4) gas filed had been developed as follows;

[BCF]

SL. No.	Fields	Year of Discovery	Reserve Estimated By		GIIP	Recoverable Proved (1P)	Recover able Proved + Probabl e (2P)	Recoverable Proved + Probable+P ossible (3P)	Cumulati ve Producti on (June, 2014)
18	Bangura	2004	Tullow	2011	1198	379	522	941	263.8
19	Sundalpur Shahzadpur	2011	BAPEX	2012	62.2		35.1	43.5	7.12
20	Srikail	2012	BAPEX	2012	230		161	161	17.1
23	Rupganj	2014	BAPEX	2014	48		33.6		

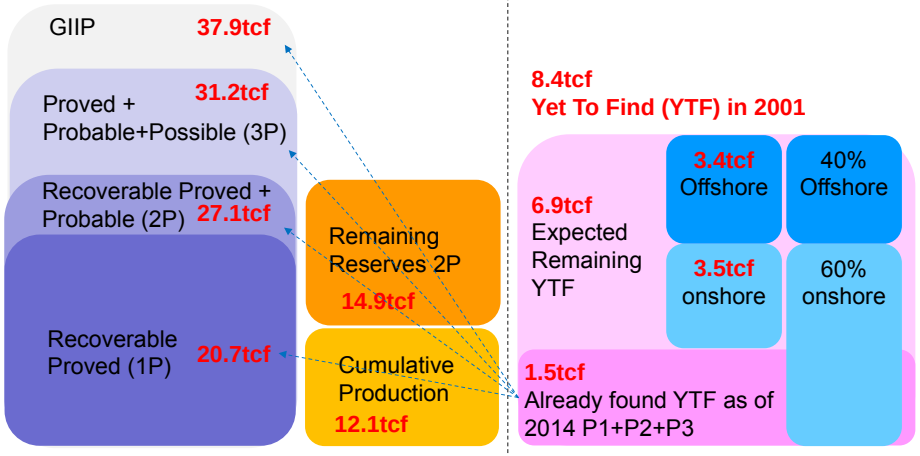
Total: approx. 1.5tcf

Total GIIP of no.18 to 23 indicated in the table above is around 1.5tcf. That means that 8.4 – 1.5 = 6.9 tcf remaining at present.

2-1 Gas supply and demand

For Discovered Gas field, Definition of gas reserves

For **Un**-discovered Gas field, Definition of gas reserves



Sources: Field-wise natural gas reserve estimates (Petrobangla, Nov. 2014)

2-1 Gas supply and demand

(5) Cost estimation



According to the WB gas master plan 2006,
60 per cent of total YTF is onshore,
whereas 40 per cent of those is offshore;

Therefore,
Onshore: 8.4 tcf times 60 per cent = 5.0 tcf
Offshore: 8.4 tcf times 40 per cent = 3.4 tcf

However, since 1.5 tcf onshore has been already developed, onshore reserve is estimated at around 3.5 tcf.



Hence,
Onshore = 3.5 tcf
Offshore = 3.4 tcf

Current Remaining YTF

JICA Survey Team would like to grasp the investment cost for the above.

2-1 Gas supply and demand

(5) Cost estimation

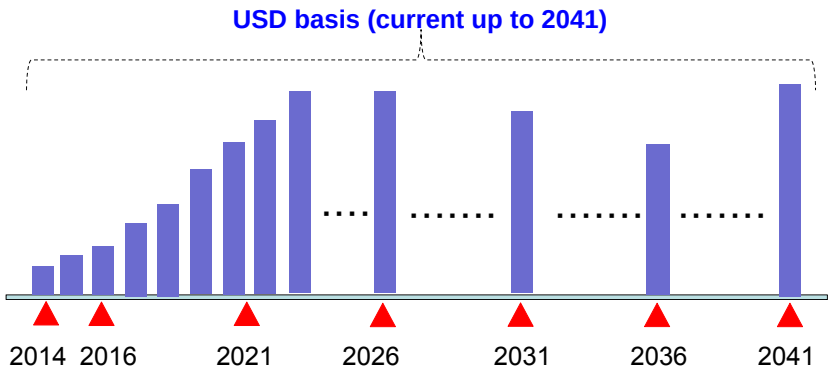


Image of investment cost for gas development

Coal

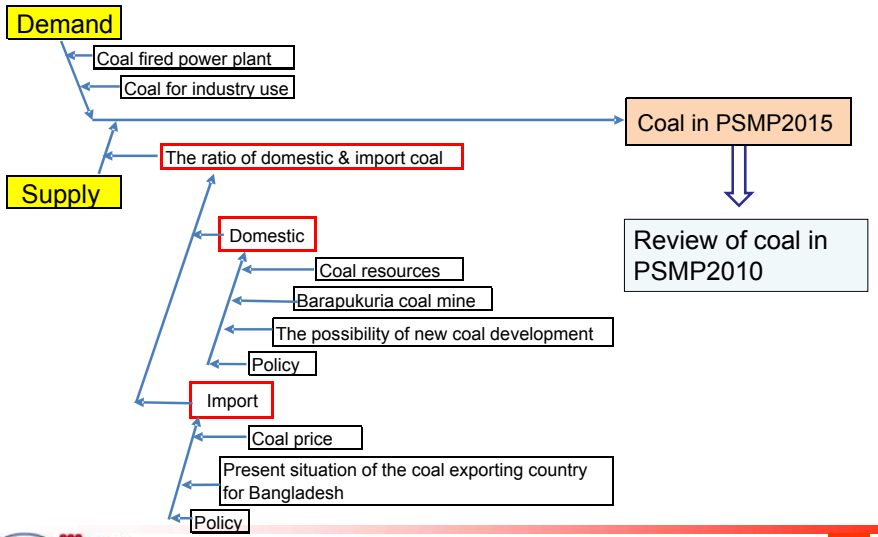
2-2 Coal supply and demand

(1) Making coal balance

(2) Output of the Survey of Coal

2-2 Coal supply and demand

(1) Making coal balance



2-2 Coal supply and demand

(2) Output of the Survey of Coal

- ✓ Coal demand until 2041 in Bangladesh
- ✓ Coal supply and the ratio of domestic & import coal
- ✓ Revised coal price until 2041
- ✓ Issues for a new domestic coal development
- ✓ Issues for importing coal in Bangladesh

Power Demand Forecast

2-3 Power demand forecasting

2-3 Power demand forecasting

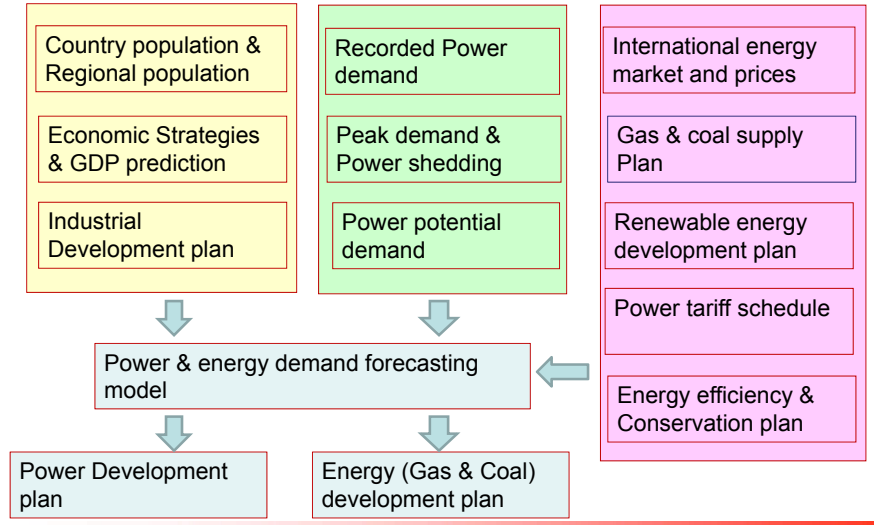
(1) Forecasting Flows

(2) Power and Energy Demand

(3) International Comparison

2-3 Power demand forecasting

(1) Power Demand Forecasting Flows

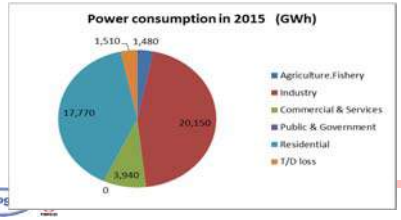


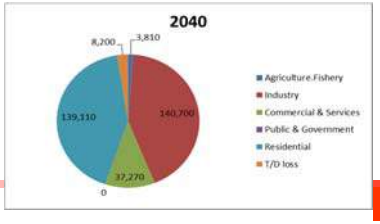
2-3 Power demand forecasting

(2) Power & Energy Demand

< Power demand forecast by sector >

		Unit	2015	2020	2025	2030	2035	2040	2040/15
Power demand	Total	GWh	44,850	70,950	104,720	152,820	223,920	329,090	8.3
by Sector	Agriculture.Fishery	GWh	1,480	1,830	2,240	2,690	3,200	3,810	3.9
	Industry	GWh	20,150	31,500	46,440	67,520	97,700	140,700	8.1
	Commercial & Services	GWh	3,940	7,020	11,410	17,290	25,620	37,270	9.4
	Residential	GWh	17,770	28,440	41,740	61,510	91,820	139,110	8.6
	T/D loss	GWh	1,510	2,160	2,890	3,810	5,580	8,200	7.0
Share	Total	S%	100.0	100.0	100.0	100.0	100.0	100.0	
	Agriculture.Fishery	S%	3.3	2.6	2.1	1.8	1.4	1.2	
	Industry	S%	44.9	44.4	44.3	44.2	43.6	42.8	
	Commercial & Services	S%	8.8	9.9	10.9	11.3	11.4	11.3	
	Residential	S%	39.6	40.1	39.9	40.2	41.0	42.3	
	T/D loss	S%	3.4	3.0	2.8	2.5	2.5	2.5	





2-3 Power demand forecasting

< Peak demand >

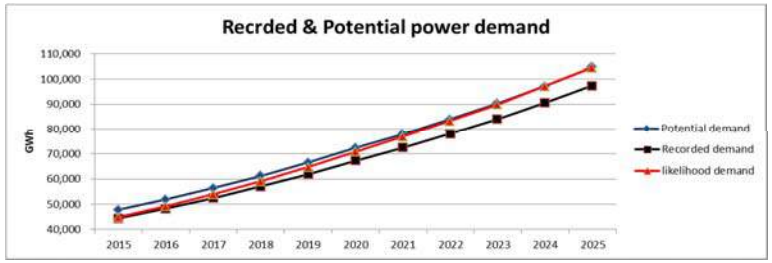
Items	Unit	2015	2020	2025	2030	2035	2040
Load Factor	%	59.2	61.7	64.2	65	65	65
Gross Peak demand	MW	9,800	14,100	20,000	28,900	42,300	62,100
Installed capacity	MW	11,300	16,200	23,000	33,200	48,600	71,500
Net power demand	GWh	44,900	71,000	104,700	152,800	223,900	329,100
Net Peak demand	MW	8,600	13,100	18,600	26,800	39,300	57,800
Contracted capacity	MW	9,500	14,400	20,500	29,500	43,300	63,600

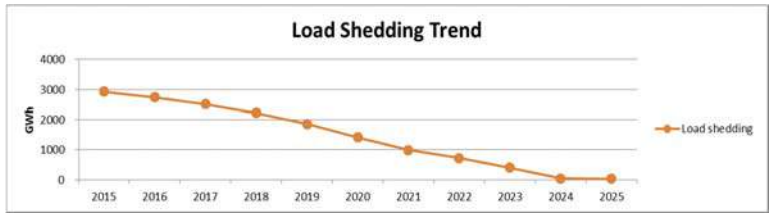
< Growth rate of Peak demand >

	2015/10	2020/15	2025/20	2030/25	2035/30	2040/35	2025/15	2035/15	2040/15
Load Factor	0.7	1.5	0.0	0.0	0.0	0.0	0.8	0.4	0.3
Gross Peak demand	15.3	7.9	8.1	7.9	7.9	8.0	8.0	8.0	8.0
Installed capacity	9.6	17.1	3.0	8.2	2.5	5.0	9.8	7.6	7.0
Net power demand	9.4	9.6	8.1	7.9	7.9	8.0	8.8	8.4	8.3
Net Peak demand	13.0	7.9	8.1	7.9	7.9	8.0	8.0	8.0	8.0

2-3 Power demand forecasting

< Recorded & Potential Power demand >

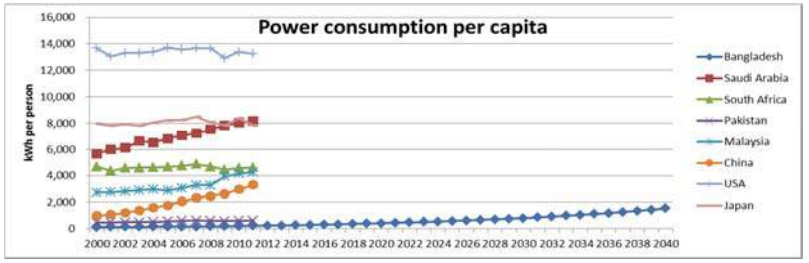


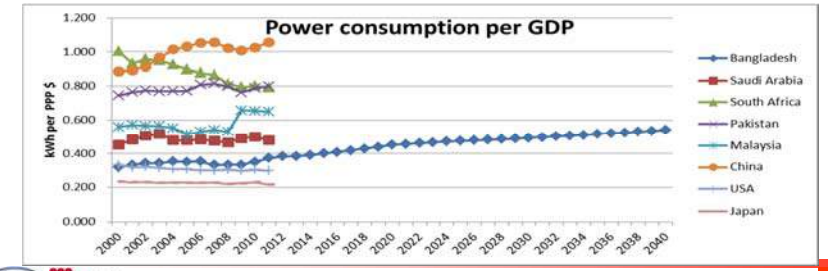


Potential demand = Recorded demand + Power Shedding

2-3 Power demand forecasting

(3) International Comparison of Power demand





System Planning

2-4 Power System Planning

(1) Outline Power System Planning

(2) Survey Procedure of Power Network System Planning

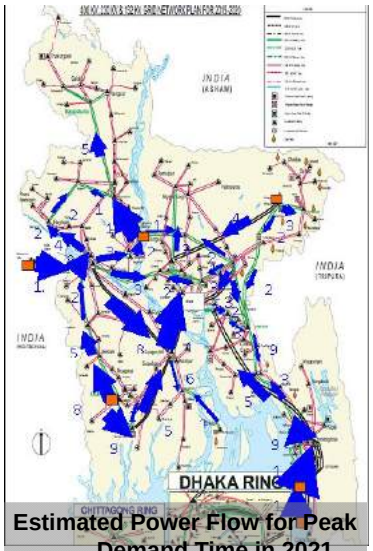
(3) Power System Analysis

(4) Identifying the necessary route

2-4Power System Planning

(1) Outline Power System Planning

- The power network system planning will be examined by categorizing its phases into short-term (2015 to 2020), mid-term (up to 2025) and long-term (up to 2041) and reviewing PSMP2010.
- The required power system analysis will be carried out using PSS/E software. The Survey should take notice of the following issues.
  - ✓ Power supply-demand Imbalance among the regions
  - ✓ The transmission Lines connecting east to west
  - ✓ Power imports and exports by interconnections

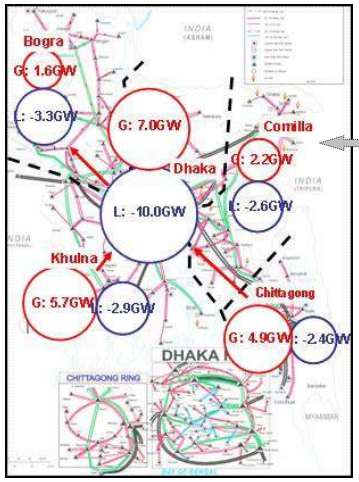


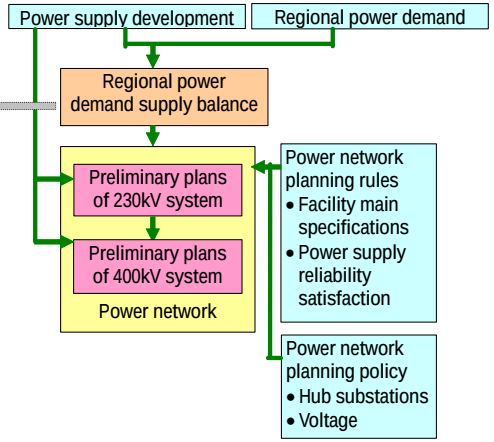
Estimated Power Flow for Peak Demand Time in 2021

Source: Dhaka, Bangladesh - Chittagong Backbone Transmission Lines Strengthening Business Preparatory Survey

2-4Power System Planning

(2) Survey Procedure of Power Network System Planning

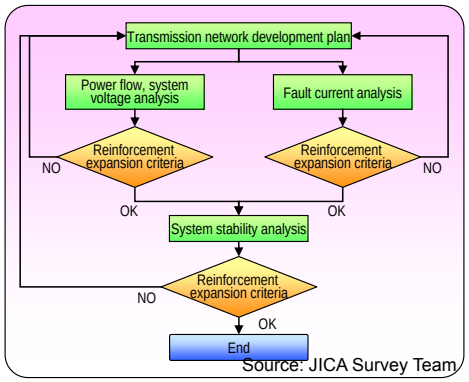




Source: JICA Survey Team

(3) Power System Analysis

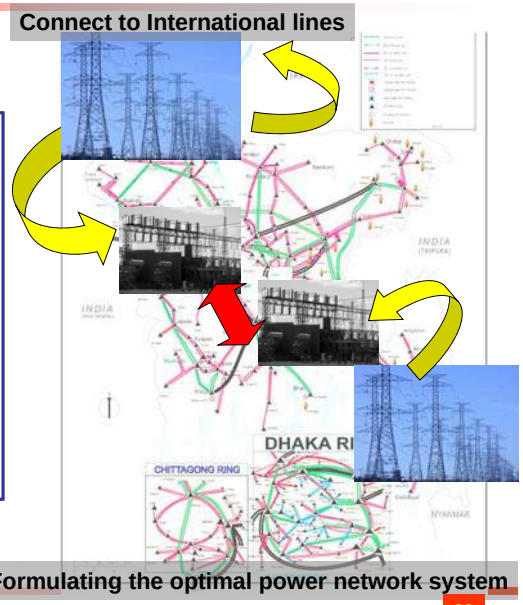
- PSS/E will be used for power system analysis from the preliminary study.
- **The evaluation will be carried out taking into account the following points**
  - ✓ Power flow / system voltage analysis
  - ✓ Fault (short circuit) current analysis
  - ✓ System stability analysis



Source: JICA Survey Team

(4) Identifying the necessary route

- The 400 kV and 230 kV transmission lines based on the information about the locations of large scale power plants and regional power demand forecast
- Making preliminary plans of transmission lines and substations
- Formulating the optimal power network system development plan including generation plan

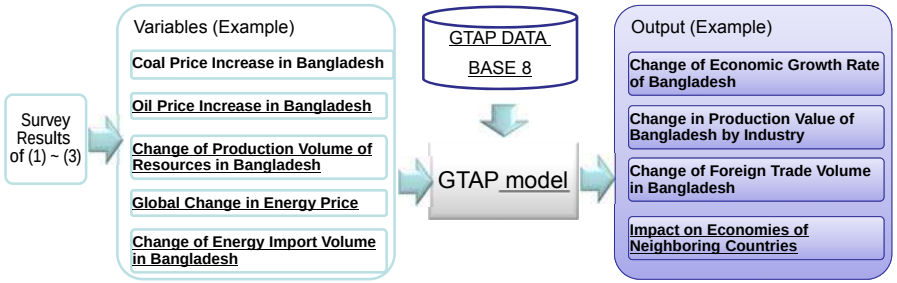


Economic Impact

2-5 Economic Impact and Mitigation Measures

2-5 Economic Impact and Mitigation Measures

■ **By utilizing the GTAP model, macroeconomic impacts due to the energy price increase and economic impact mitigation measures will be quantified.**



Source: JICA Survey Team

O&M Working Group

Examining rehabilitation and combined cycle projects

3. O&M

(1) Objectives

a. Examining rehabilitation and combined cycle projects

b. Examining legal framework for optimum maintenance

3. O&M

(1) Objectives

(2) Selection flow and criteria

(3) List of site selection (tentative)

(4) Investigating present situation

(5) Site survey

(6) <Goal> B-1 Recovering the power/efficiency by O&M-2

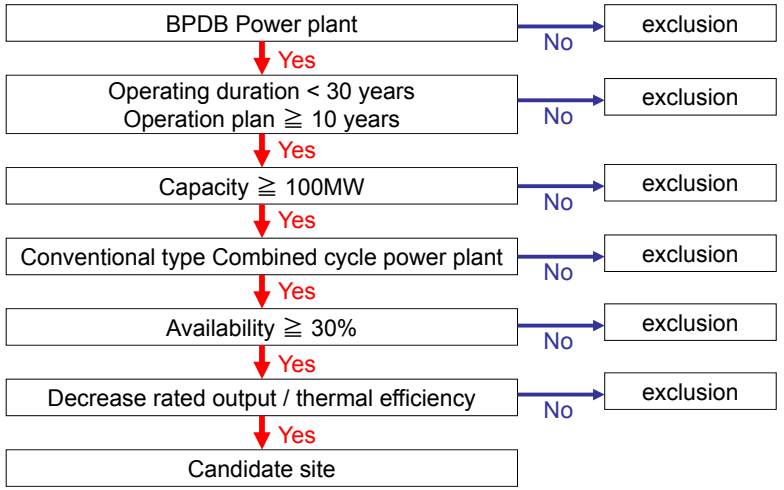
(7) <Goal> B-2 Making a plan of combined cycle conversion

(8) Approach B-3 O&M legal framework

(9) <Goal> B-3 O&M legal framework

3. O&M

(2) Selection flow and criteria



3. O&M

(3) List of site selection (tentative)

Name of power plant	COD (Year)	Type	Fuel	Installed (MW)	Derated (MW)	Plant factor (%)	Efficiency (NET) (%)	Working group	World Bank
Barapukuria #1,#2	2009/2009	ST	Coal	250(125*2)	200	75.37	31.47		
Ashuganji #4,#5	1987/87/88	ST	Gas	450(150*3)	390	97.64	36.16		
Ghorasal #3,#4	1987/89	ST	Gas	420(210*2)	360	69.53	33.68	×	○
Ghorasal #5,#6	1995/99	ST	Gas	420(210*2)	380	33.72	31.54	×	○
Shahjibazar		GT	Gas	70(35*2)	66	76.36	25.63		○
Siddhirganj	2004	ST	Gas	210	150	56.98	32.63		
Fenchuganj	2011	CC	Gas	104	104	49.08	31.95		
Chandpur	2012	CC	Gas	163	163	49.68	39.38		
Tongi	2005	GT	Gas	105	105	38.38	27.07	○	

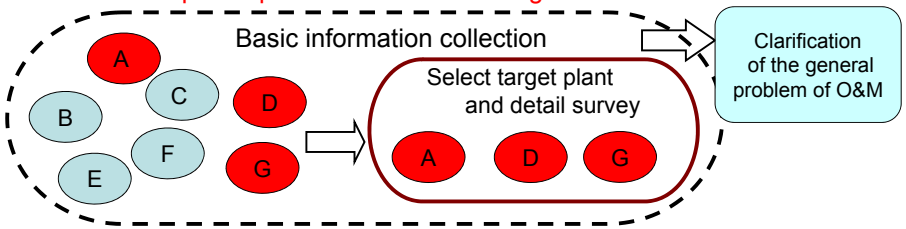
- JICA Survey Team would like to discuss the tentative results, which was reviewed among 1st working group, dated on Dec.1, 2014.
- JICA Survey Team recognize the importance of well consultation with stakeholder, such as WB.

3. O&M

(4) Investigating present situation

Step1

Select model power plant → Detailed investigation



Step2

Focus on target facilities, such as;

air heater , feed water heater, turbine rotor, etc., and make a repair/replace plan

Step3

Calculate the effectiveness of making a maintenance plan and O&M enforcement

3. O&M

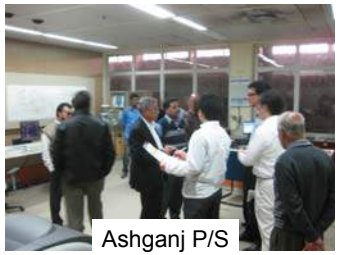
(5) Site survey



Rauzan P/S

Collect basic information
>site survey
>discussion
*Questionnaire sheet

Collect basic information
>site survey
>discussion
*Questionnaire sheet



Ashganj P/S

3. O&M

(6) <Goal> B-1 Recovering the power/efficiency by O&M-2

Make basic idea of O&M plan and cost estimation

- Timing of periodical maintenance
  - ✓ Combustion inspection, turbine inspection, major overhaul, etc.
- Spare parts management
- Data sharing
- Maintenance cost;

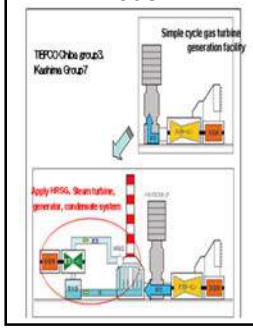
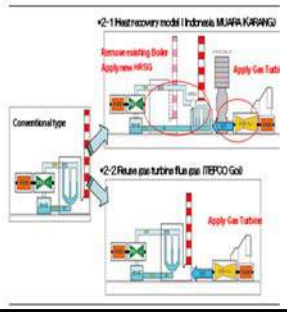
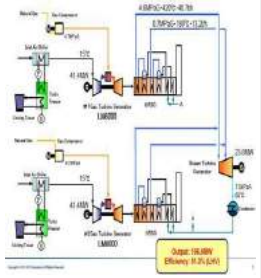
O&M rehabilitation plan with periodical aintenance

		Year X												Year X+1												Year X+2											
		7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Site A	Plant a																																				
	Plant b																																				
	Plant c																																				
Site D	Plant a																																				
	Plant b																																				
Site G	Plant a																																				
	Plant b																																				
	Plant c																																				
	Plant d																																				
	Plant e																																				

3. O&M

(7) <Goal> B-2 Making a plan of combined cycle conversion

Make concept level plan and layout of the combined cycle

CASE 1	CASE 2	CASE 3
Adoption of bottoming system model	Adoption of gas turbine model	Scrap and build model
		

Examining legal framework for optimum maintenance

(8) Approach B-3 O&M legal framework

Investigate the Electricity Act of Bangladesh

Step1 : Check and review the Electricity Act under revision

Bangladesh Electricity Act and revise plan — check

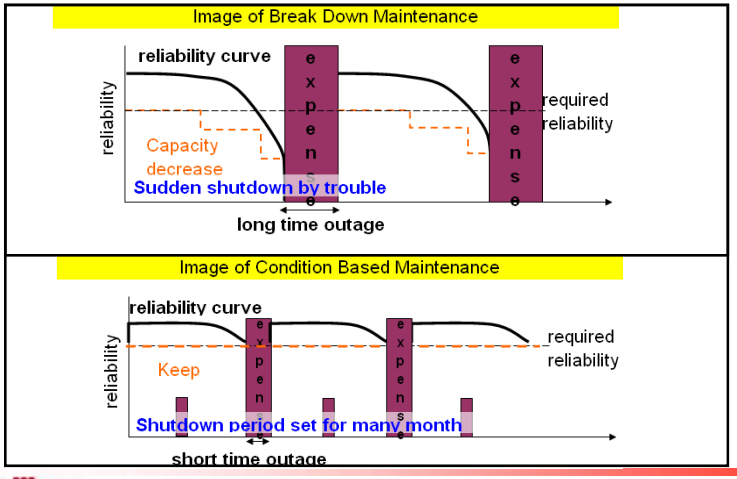
Step2 : Compare with electrical utility law of Japan and other neighboring countries

Step3 : Examine overall legal framework (Act, Rule, Regulation) in terms of appropriate O&M

Comparing other countries Electrical Utility Law ⟷ compare ⟷ **Bangladesh Electricity Act and revise plan**

(9) <Goal> B-3 O&M legal framework

Examine legal framework to secure continuous enforcement



Domestic Hydropower Working Group

4. Hydropower development

(1) Adjustability of each Power Sources

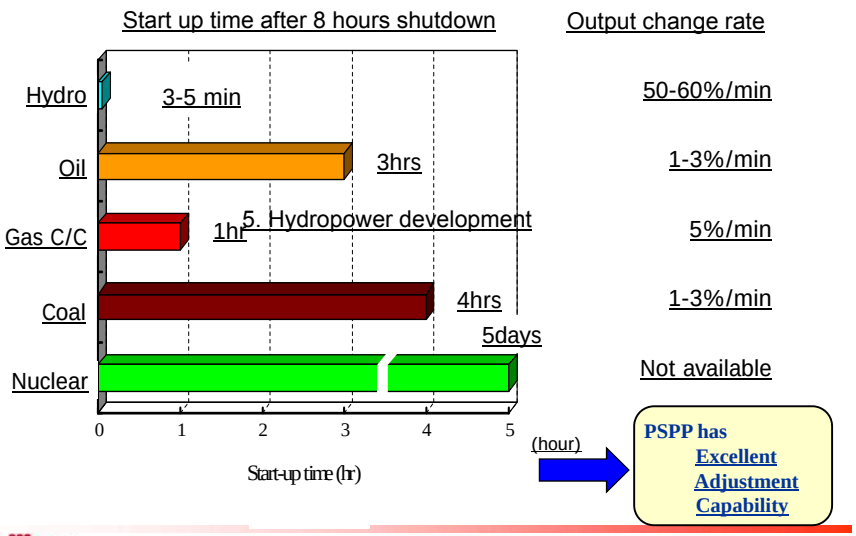
(2) Leveling Load Curve

(3) Planning Flow

(4) Small Scale Hydropower Plant (SSHP) Project

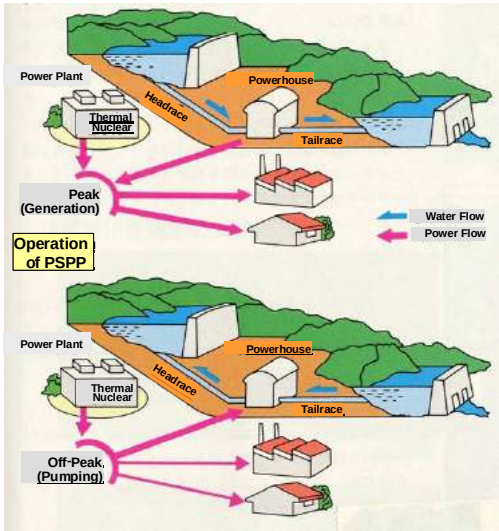
4. Hydropower development

(1) Adjustability of each Power Sources



4. Hydropower development

(1) Adjustability of each Power Sources



Function

- Leveling Load Curve
- Improve Efficiency of Generation System
- Stabilizing Whole Power System

Operation

Peak Hours

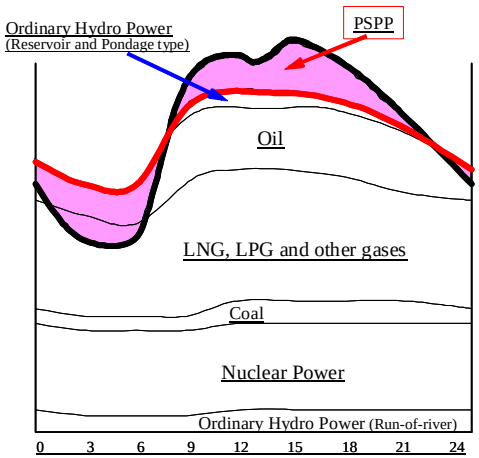
- Generating Operation
- Stored water in the upper reservoir moves to the lower reservoir.

Off-peak Hours

- Pumping Operation
- Stored water in the lower reservoir moves to the upper reservoir.

4. Hydropower development

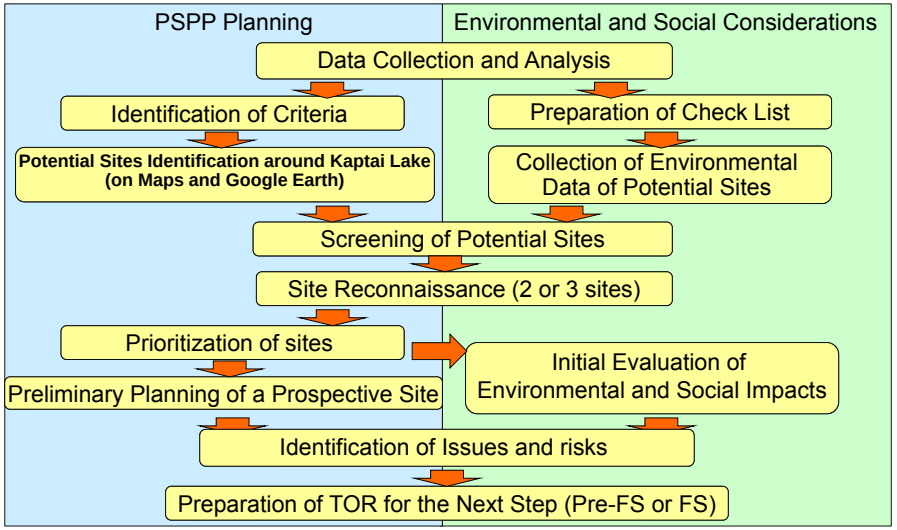
(2) Leveling Load Curve



Source: TEPCO materials

4. Hydropower development

(3) Planning Flow



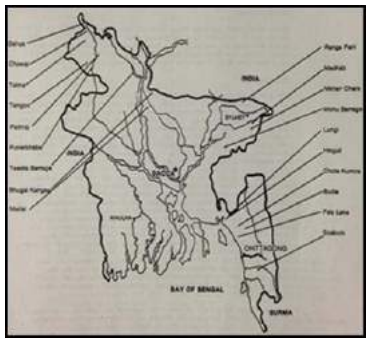
(4) Small Scale Hydropower Plant (SSHP) Project

■ Identification of Small Scale Hydropower Plant (SSHP) Projects

■ Data Collection
- ✓ Existing reports and documents for SSHP potential sites,
- ✓ Information of SSHP Projects assisted by donor agencies,

■ Site visit of a several potential project sites,

■ Selection of candidate project sites for the next step, if any.



Source: Bangladesh An assessment of small hydropower potential, NRECA, November 1981

(sample)
SSHP Potential Sites

Thank you for your attention

This file with minor modifications from the distributed hand-outs will be sent later to the working group members.

23.2 2nd Seminar (2nd Steering Committee)

- Date: 4 Jun 2015
- Venue: Board Room of BPDB at Buddyut Bhaban, Dhaka
- Discussion Point:
  - ✓ Primary Energy Balance for Power Sector
  - ✓ Power Demand Forecast
  - ✓ Power Development Plan





- Participants

Participants are shown below table.

No	Name	Designation	Organization
1	Md. Mizanur Rahman	Chief Engineer (P&D)	BPDB
2	Muhammad Bellal Hossain	Executive Engineer, System Planning	BPDB
3	Jorifa Khatun	Executive Engineer, System Planning	BPDB
4	Sayeed Ahmed	Director, System Planning	BPDB
5	Anwarul Maruf	Sub-Divisional Engineer, System Planning	BPDB
6	Sk. Nurul Absar	Member (Engg.)	BREB
7	Yeasir Arafat	Asst-Professor (EEE)	BUET
8	S.M. Habibur Rahman	Chief Engineer (Dev. & Prg)	DESCO
9	A.K.M. Mahiuddin	Chief Engineer (P&D) in charge	DESCO
10	Brig. Gen. Shahid Sarwar	Managing Director	DESCO
11	Fazilatun Nessa	Executive Engineer (Design Circle)	DPDC
12	S.K. Ramizuddin Sarker	Executive Director, Engineering	DPDC
13	A.S.M. Hafizur Rahman	Chief Engineer, P&D	DPDC
14	A.M. Monsurul Alam	Executive Director (Finance)	EGCB
15	Md. Hasan Zahidul Islam	Executive Engineer (P&D)	EGCB
16	A.K.M Mostafizur Rahman	Superintending Engineer (P&D)	EGCB
17	Santi Ram Roy	Executive Director (Engg.)	EGCB
18	Mohammad Yamin Chowdhury	Joint Secretary	ERD
19	Kazi Sakhawat Hossain	Joint Secretary	Ministry of Water Resources
20	Harendra Mondal	Executive Director (Engg.)	NWPGCL

No	Name	Designation	Organization
21	Md. Mainuddin Sarker	Sub-Divisional Engineer (P&D)	NWPGCL
22	Md. Zahirul Islam	Deputy General Manager (Strategic Planning)	Petrobangla
23	Arun Kumar Saha	Chief Engineer (P&D)	PGCB
24	Md. Nuruzzaman	Superintending Engineer, Planning	PGCB
25	Md. Rafiqul Islam	Joint Chief, GED	Planning Commission
26	Md. Shafique Uddin	Managing Director	WZPDCL

(Alphabetical order)

■ Presentation materials

Presentation materials are as next pages.

PSMP2015
2nd Steering Committee

JICA PSMP2015 Team
4th June, 2015

Agenda

Opening Remarks

Presentation and Discussions
1. Primary Energy Balance for Power Sector

2. Power Demand Forecast

3. Power Development Plan (Supply Scenario)

Closing Remarks

Today's Decision Making Points

1. Primary Energy Balance for Power Sector
- Gas Demand and Supply for Power Sector (Domestic/Import)
- Coal Supply (=Demand) for Power Sector (Domestic/Import)

2. Power Demand Forecast
- Preconditions: GDP Scenario
- Built-in Factors: Captive Power Estimated Demand, RE Demand
- Electrification Ratio (Grid and Off-Grid) and Per Capita Power Consumption
- Power Demand Forecast

3. Power Development Plan
- Fixed Factors of PDP
- Impacts and Valuable Indices
- O&M Impact Assumption for PDP
- Percentage of Reserve Margin

1. Primary Energy Balance for Power Sector

Probable Scenario of Energy Balance

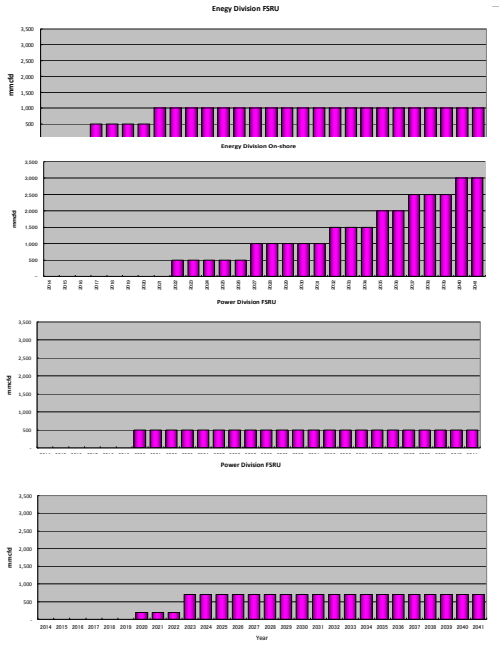
Gas	Coal	Oil
Domestic gas is supposed to decrease after its peak production in 2018	Domestic coal production is not expected to be increased substantially	Oil import is necessary as previously
Larger dependence on gas import is unavoidable	Expansion of coal import is necessary to cover new coal power stations	No substantial change

Evaluate maximum amount of gas and coal to be imported

Establish probable scenario of primary energy balance

Maximum Gas Import Scenario

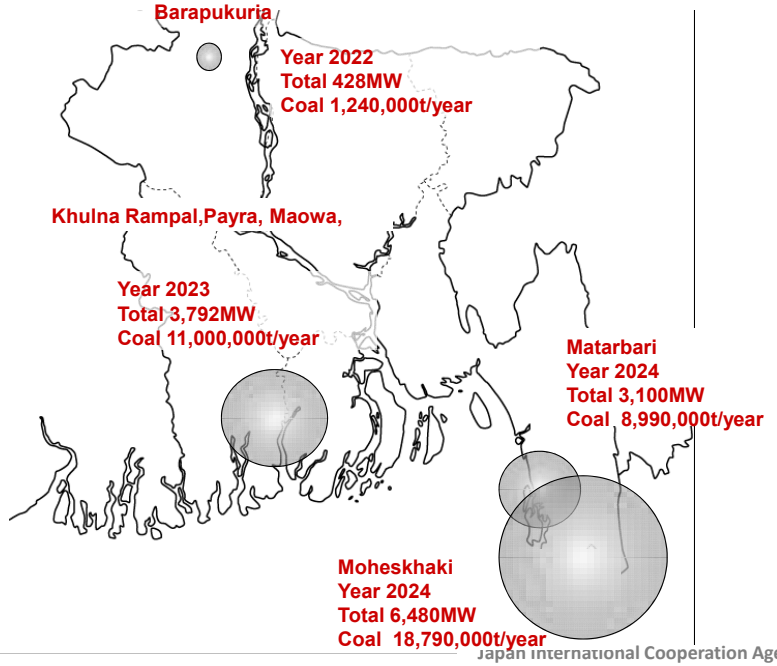
1. **Energy Division**
   FSRU→ 1,000mmcfd
2. **Energy Division**
   On-shore → 3000mmcfd
3. **Powe Division**
   FSRU → 500mmcfd
4. **Power Divsion**
   On-Shore → 700mmcfd



Maximum Gas Import Scenario

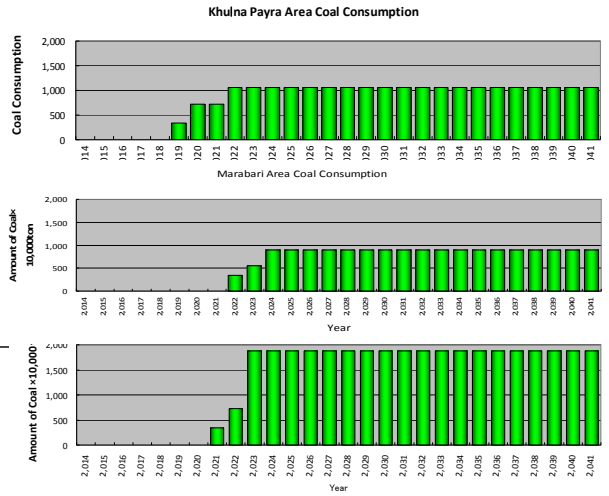
FY	Supply														Demand					Balance
	Domestic				Import									D+In E+P	Energy Div			power		
	Energy Division				Energy Division						Power Division				Non-power			Power		
	Existing Domestic Gas (DG)	New Domestic gas (5 wells)	Off shore develop-ment	Total Domestic	Confirmed FSRU import	Not Yet Planned FSRU import	Not Yet Planned On shore LNG	Total Import	Total supply (D+I)	Supply to Power Sector	Planned FSRU import	Planned On shore LNG	Total Import	Total Supply	Supply to Power Sector	BAU	Scenario 1	Scenario 2	Power Demand	Total Demand	
2014	2,443	-	-	2,443	-	-	-	-	2,443	909	37%	-	-	-	2,443	909	1,534	1,534	1,534	909	2,443	-
2015	2,594	-	-	2,594	-	-	-	-	2,594	983	38%	-	-	-	2,594	983	1,611	1,611	1,611	983	2,594	-
2016	2,793	-	-	2,793	-	-	-	-	2,793	1,131	40%	-	-	-	2,793	1,131	1,693	1,676	1,662	1,131	2,793	-
2017	2,859	-	-	2,859	500	-	-	500	3,359	1,644	49%	-	-	-	3,359	1,644	1,781	1,744	1,715	1,644	3,359	-
2018	2,802	-	-	2,802	500	-	-	500	3,302	1,531	46%	-	-	-	3,302	1,531	1,875	1,817	1,771	1,531	3,302	-
2019	2,698	-	-	2,698	500	-	-	500	3,198	1,367	43%	-	-	-	3,198	1,367	1,976	1,894	1,831	1,367	3,198	-
2020	1,737	170	-	1,907	500	-	-	500	2,407	515	21%	500	200	700	3,107	1,215	2,083	1,976	1,893	1,215	3,107	-
2021	1,401	170	-	1,571	500	500	-	1,000	2,571	613	24%	500	200	700	3,271	1,313	2,199	2,065	1,958	1,313	3,271	-
2022	1,126	200	-	1,326	500	500	500	1,500	2,826	777	28%	500	200	700	3,526	1,477	2,323	2,164	2,049	1,477	3,526	-
2023	955	300	-	1,255	500	500	500	1,500	2,755	611	22%	500	700	1,200	3,955	1,811	2,456	2,267	2,144	1,811	3,955	-
2024	983	400	-	1,383	500	500	500	1,500	2,883	640	22%	500	700	1,200	4,083	1,840	2,599	2,375	2,243	1,840	4,083	-
2025	887	500	-	1,387	500	500	500	1,500	2,887	541	19%	500	700	1,200	4,087	1,741	2,753	2,486	2,346	1,741	4,087	-
2026	868	500	-	1,368	500	500	500	1,500	2,868	414	14%	500	700	1,200	4,068	1,614	2,918	2,602	2,454	1,614	4,068	-
2027	860	500	-	1,360	500	500	1,000	2,000	3,360	794	24%	500	700	1,200	4,560	1,994	3,096	2,720	2,565	1,994	4,560	-
2028	779	500	-	1,279	500	500	1,000	2,000	3,279	599	18%	500	700	1,200	4,479	1,799	3,287	2,840	2,680	1,799	4,479	-
2029	767	500	-	1,267	500	500	1,000	2,000	3,267	469	14%	500	700	1,200	4,467	1,669	3,494	2,961	2,798	1,669	4,467	-
2030	759	500	500	1,759	500	500	1,000	2,000	3,759	840	22%	500	700	1,200	4,959	2,040	3,716	3,081	2,919	2,040	4,959	-
2031	757	500	500	1,757	500	500	1,000	2,000	3,757	780	21%	500	700	1,200	4,957	1,980	3,939	3,143	2,978	1,980	4,957	-
2032	763	500	500	1,763	500	500	1,500	2,500	4,263	1,226	29%	500	700	1,200	5,463	2,426	4,175	3,206	3,037	2,426	5,463	-
2033	740	500	500	1,740	500	500	1,500	2,500	4,240	1,142	27%	500	700	1,200	5,440	2,342	4,426	3,270	3,098	2,342	5,440	-
2034	763	500	500	1,763	500	500	1,500	2,500	4,263	1,103	26%	500	700	1,200	5,463	2,303	4,691	3,335	3,160	2,303	5,463	-
2035	744	500	500	1,744	500	500	2,000	3,000	4,744	1,521	32%	500	700	1,200	5,944	2,721	4,973	3,402	3,223	2,721	5,944	-
2036	720	500	500	1,720	500	500	2,000	3,000	4,720	1,433	30%	500	700	1,200	5,920	2,633	5,271	3,470	3,288	2,633	5,920	-
2037	720	500	500	1,720	500	500	2,500	3,500	5,220	1,867	36%	500	700	1,200	6,420	3,067	5,588	3,539	3,353	3,067	6,420	-
2038	720	500	500	1,720	500	500	2,500	3,500	5,220	1,800	34%	500	700	1,200	6,420	3,000	5,923	3,610	3,420	3,000	6,420	-
2039	720	500	500	1,720	500	500	2,500	3,500	5,220	1,732	33%	500	700	1,200	6,420	2,932	6,278	3,682	3,489	2,932	6,420	-
2040	720	500	500	1,720	500	500	3,000	4,000	5,720	2,162	38%	500	700	1,200	6,920	3,362	6,655	3,756	3,558	3,362	6,920	-
2041	720	500	500	1,720	500	500	3,000	4,000	5,720	2,091	37%	500	700	1,200	6,920	3,291	7,054	3,831	3,630	3,291	6,920	-

Coal Demand Forecast



Coal demand Forecast

1	【Domestic Coal】 **Barapukuria (524MW)** **Coal→1,240,000 t/year** 125×2unit、 275 MW (3rd Unit)
2	【Import Coal】 **Khulna&Payra Area(3,792MW)** **Coal→11,000,000 t/year** 630 MW 、Maowa 522 MW, Rampal,, Potuakhali 1200-1320
3	【Import Coal】 **Matabari Area(3100MW)** **Coal→8,990、000 t/year**
4	【Import Coal】 **Moheskhali Area(6490MW)** **Coal→19,790、000 t/year**

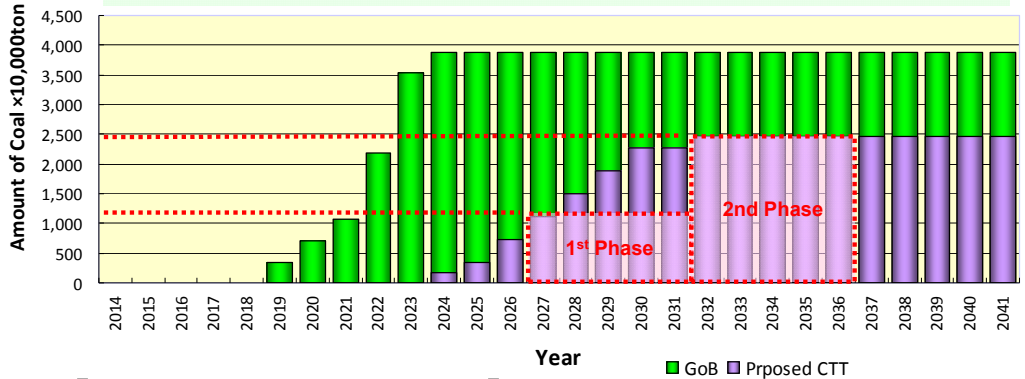


Matabari Coal Terminal

	Name of Power Plant		Capacity (MW)				Amount of Coal (ton/Year)	Coal procurement
	Barapukuria 2x125 MW ST (COAL)	Dom.	250	200	154	428	1,240,000	Conveyor
	Barapukuria 275 MW (3rd Unit)	Coal	274	274	274			
khulna	Khulna 630 MW Coal Fired PP (Orion)	Imp. Coal	630	630	630	3,792	1,100,000	
	Maowa, Munshiganj 522 MW Coal Fired PP	Imp. Coal	522	522	522			
	BIFPCL, Rampal, Coal Fired Power Plant	Imp. Coal	1,320	1,320	1,320			Matabari Coal Terminal Phase-2
	Payra, Potuakhali 1200-1320 MW Coal PP	Imp. Coal	1,320	1,320	1,320			
Matabari	Matarbari 1200 MW Coal PP	Imp. Coal	1,200	1,200	1,200	3,100	8,990,000	Coal Terminal Phase-1
	Matarbari 700 MW Coal PP	Imp. Coal	700	700	700			Coal Terminal Phase-2
	Matarbari 1200 MW Coal PP	Imp. Coal	1,200	1,200	1,200			
Moheskhali	Moheskhali 1200 MW Coal PP	Imp. Coal	1,200	1,200	1,200	6,480	18,790,000	
	Moheskhali 1200-1320 MW Coal PP	Imp. Coal	1,320	1,320	1,320			Matabari Coal Terminal Phase-1
	Moheskhali 1200-1320 MW Coal PP	Imp. Coal	1,320	1,320	1,320			
	Moheskhali 1200-1320 MW Coal PP	Imp. Coal	1,320	1,320	1,320			Coal Terminal Phase-2
	Moheskhali 1200-1320 MW Coal PP	Imp. Coal	1,320	1,320	1,320			
	Total					13,800	30,120,000	

Annual Coal Consumption

Target
GoB 2024 13,500,000MW 39,000,000ton/year



【Coal Transport Terminal】

Estimated Handling import coal Volume

1st Phase -FY2027 -1,100,000ton/Year

2nd Phase -FY2032 -2,500,000ton/Year

2. Power Demand Forecast

Precondition for Scenario for PSMP2015

Population growth rate



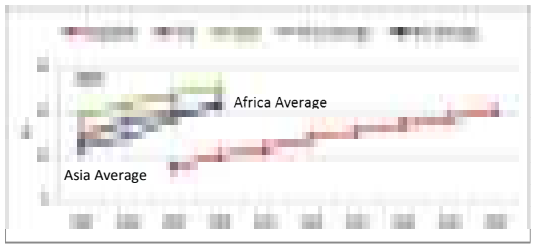
Source : UN projection

GDP growth rate



Source: JICA study team

Electric power ratio in final energy demand



Note: Power ration = power (toe) / Final energies (toe)
Source: Countries : The energy economics, Japan
Bangladesh : JICA Study team

Energy efficiency for Intensity

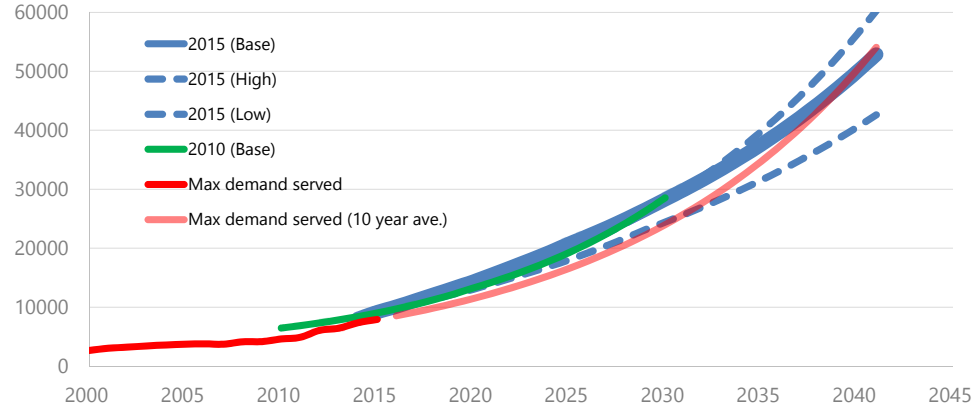


Note: Intensity for Ind. Com. = Consumption / GDP
Note: Intensity for Residential = Consumption / population
Source : Reference of JICA Energy Efficiency Projects

Demand Forecast w/o Captive & RM

PSMP2015 Base Case Scenario aligned with PSMP2010 Base as well as Max Demand Served Trend

Power Demand Forecast (MW)



(Source: JICA PSMP2015 Team, PSMP2010)

Captive Power Shifting to Grid

Estimated Captive Power Demand 2000MW Gradually Shifting to Grid Demand for next 10 years (2015-2024)
** PSMP2010 demand projection not incorporating Captive Power*

Captive Power Capacity Estimation

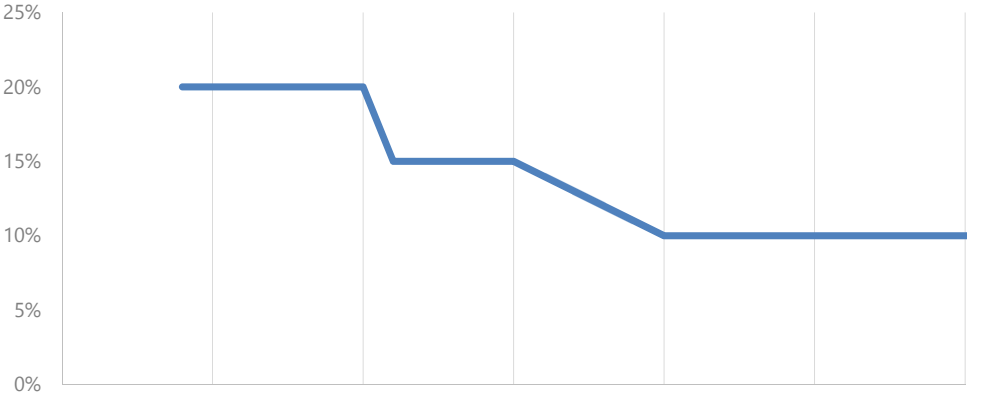
Item	Unit	2008	2009	2010	2011	2012	2013	2014
Gas Consumption	MMCM	2,271	2,695	3,178	3,432	3,516	3,798	4,071
	MMCF	80,215	95,187	112,256	121,231	124,192	134,158	143,777
Efficiency	%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Heat Rate	KCL/kWh	2,867	2,867	2,867	2,867	2,867	2,867	2,867
Energy Generation	GWh	6,699	7,949	9,375	10,124	10,371	11,204	12,007
Per Capita Generation	kWh	47	55	64	68	68	73	77
Plant Factor	%	70%	70%	70%	70%	70%	70%	70%
Expected Capacity	**MW**	**1,100**	**1,300**	**1,600**	**1,700**	**1,700**	**1,900**	**2,000**

Assumption: Annual-equally integrated into grid demand for next 10 years (2015-2024)
30% captive remains as off-grid

Reserve Margin Assumption

Reserve Margin kept at 20% until 2020, then decrease to 15% by 2023 when large base-load coal-fired power plants realized, and down to 10% by 2030 along with power development

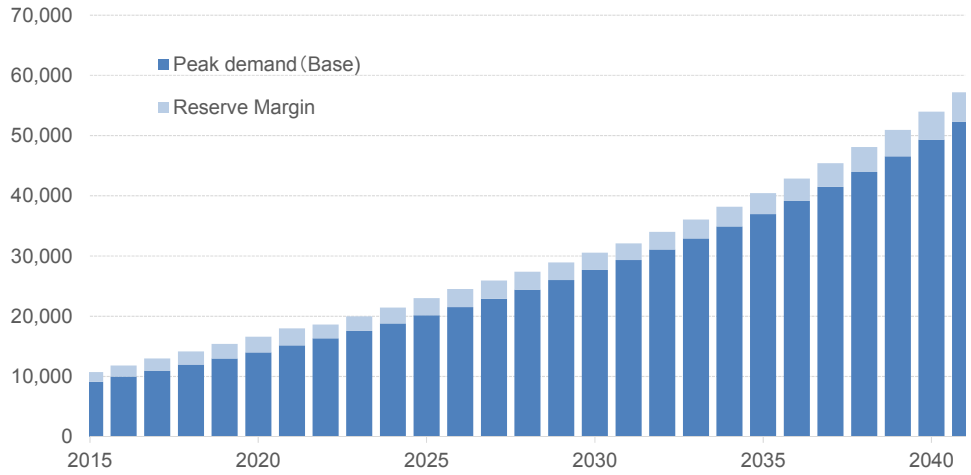
Reserve Margin Condition (%)



(Source: JICA PSMP2015 Team)

Combined Demand Forecast

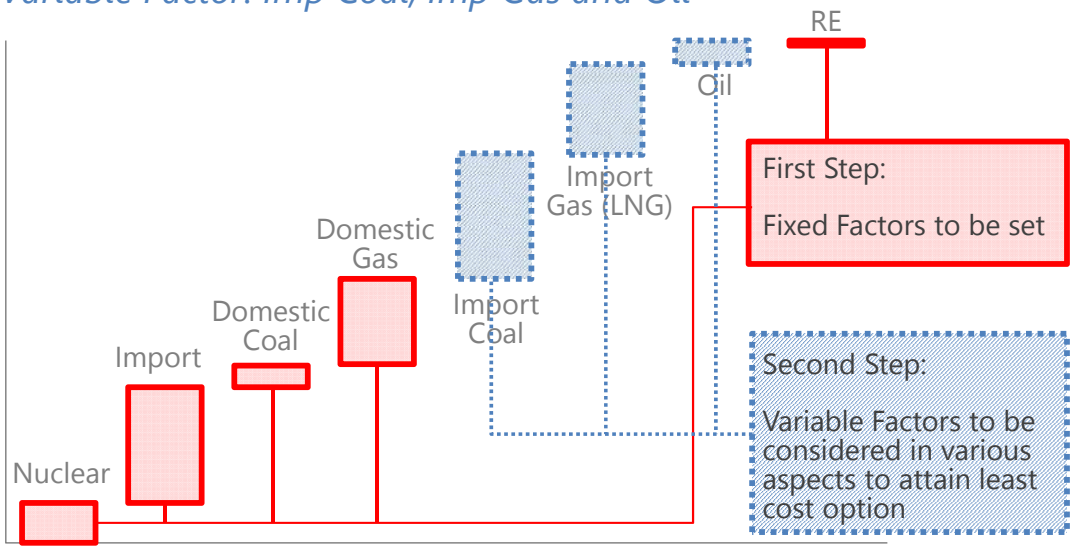
Combining Reserve Margin, Power Supply Requirement Revealed 17,000MW in 2020, 23,000MW in 2025, 30,000MW in 2030, 40,000MW in 2035 and more than 57,000MW by 2041



3. Power Development Plan

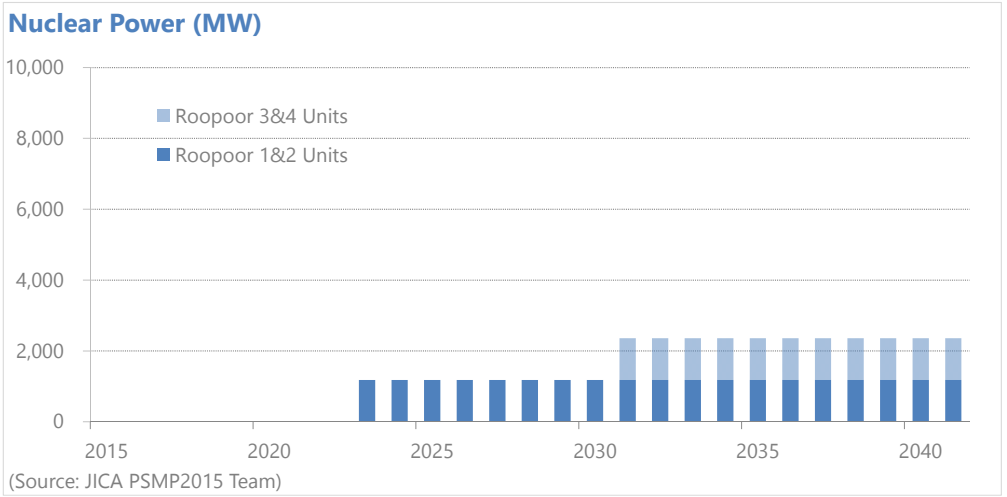
Fixed and Variable Factors for PDP

Fixed Factor: Nuclear, Power Import Dom Coal and Dom Gas
Variable Factor: Imp Coal, Imp Gas and Oil



Fixed Factor for PDP: Nuclear

Roopoor Nuclear Power Project 1st & 2nd Units Estimated to Start Operation from 2023, followed by 3rd & 4th Units from 2031

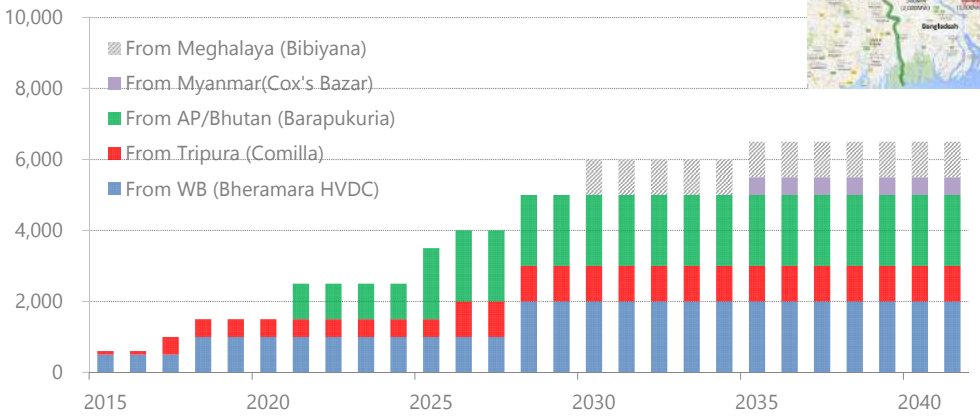


Fixed Factor for PDP: Power Import

Power Import from Neighboring Countries including Bhutan/Nepal/Myanmar Gradually Increasing



Power Import from Neighboring Countries (MW)

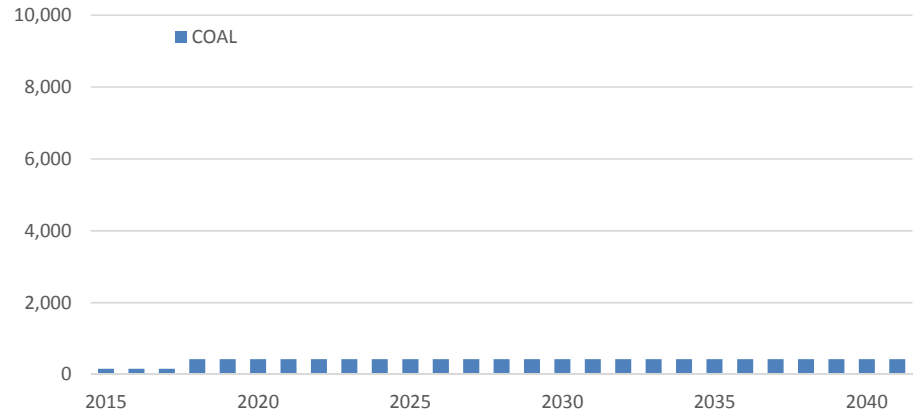


(Source: JICA PSMP2015 Team)

Fixed Factor for PDP: Domestic Coal

Domestic Coal do not increase so much

Domestic Coal (MW)

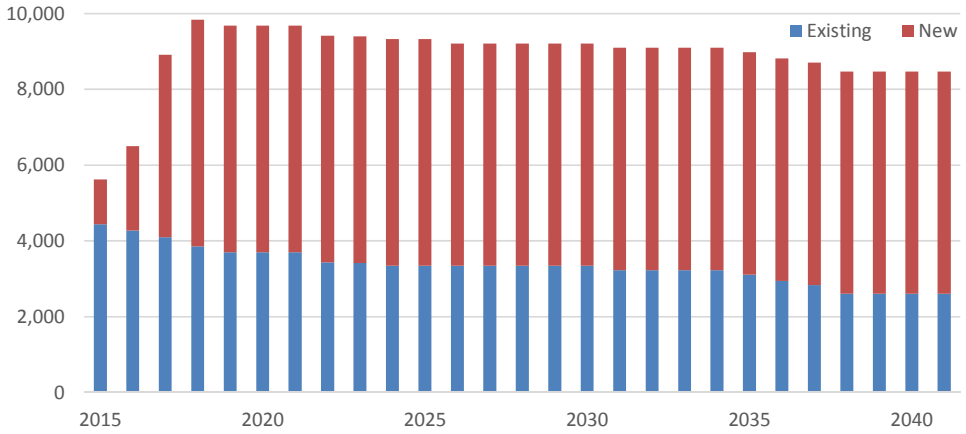


(Source: JICA PSMP2015)

Fixed Factor for PDP: Domestic Gas

New Domestic Gas is increased from 6,000MW to 10,000MW at 2018.

Domestic Natural Gas (MW)

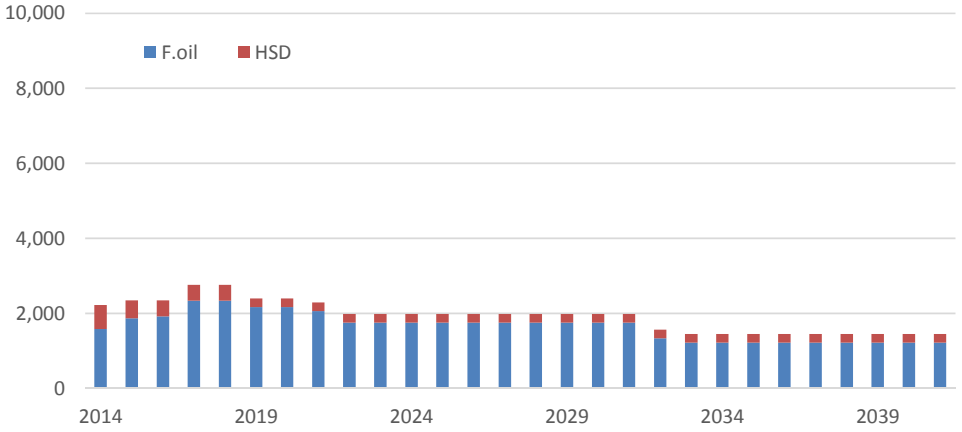


(Source: JICA PSMP2015)

Fixed Factor for PDP: Import Oil

Import Oil is almost stable.

Import Oil (MW)



(Source: JICA PSMP2015)

Fixed Factor for PDP: Renewable

PSMP2015
KW value = not considered
kWh value = considered

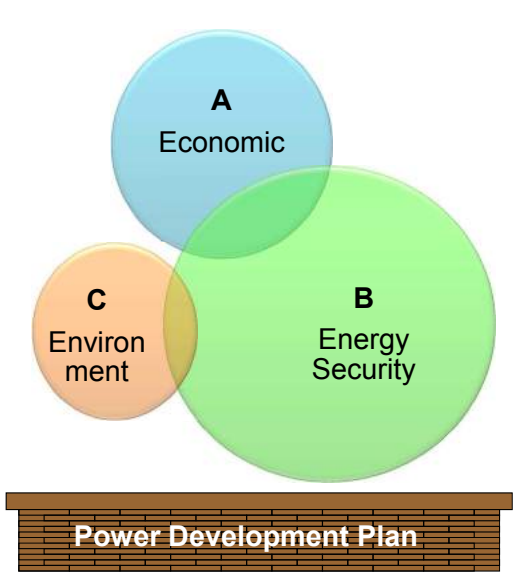
JICA study team suggests to adopt the following coefficients;

Solar: 0 - 21% x Total installed capacity
(Coefficient is changed at each month)

Wind: 0 – 7% x Total installed capacity

Factors to Consider Optimum PDP

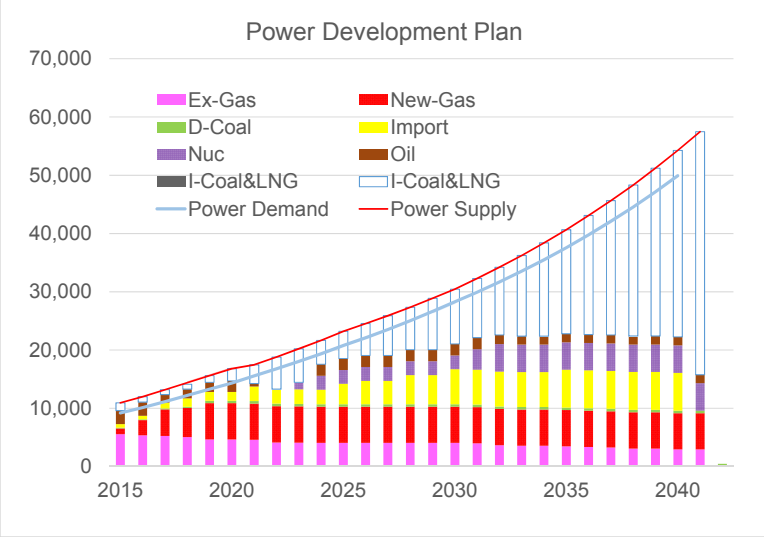
Maximization of 3E (Economic, Energy Security, and Environment)



A Economic	• Minimization of Supply Cost
B Energy Security	• Import Coal • Import Gas • Minimization of
C Environment	•Minimization of CO2 Emission

PDP Scenario: Fuel Diversification Option

Seeking maximization of 3E value

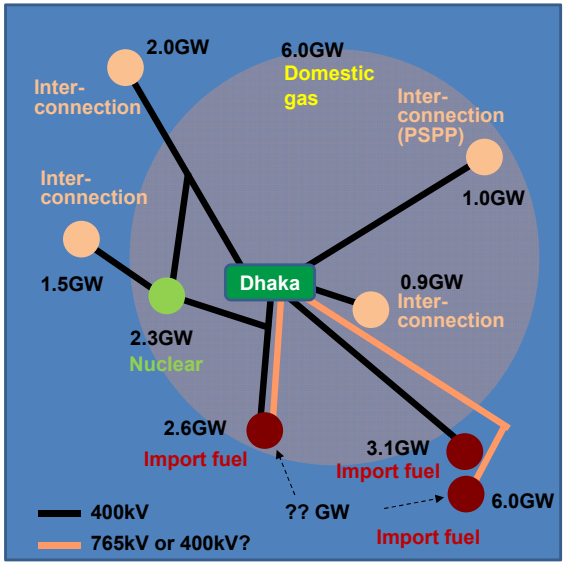


2030 System Configuration

	Peak load	Generation
2015	9GW	
2020	13GW	
2025	19GW	
2030	26GW+2GW*	→34GW

* Load currently from captive power

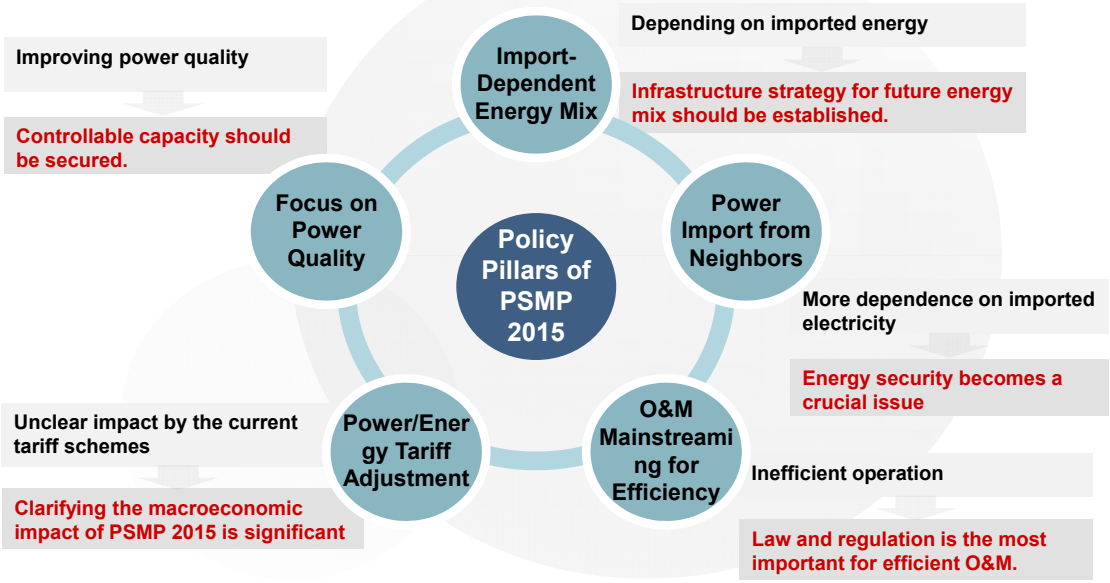
(Image) Incremental Power Unit & Transmission Lines



4. Policy Pillars (Challenges) of PSMP2015

(Proposed by JICA Survey Team)

Abstract of Policy Pillars of PSMP2015



Import-Dependent Energy Mix

Is further dependence on imported energy unavoidable?

If so, a long term energy import strategy as well as a long term infrastructure development plan are to be established urgently. Such infrastructure as port, road or railway will facilitate import of different energy but certain time is necessary for construction.

Location of power plants as well as transmission lines will be subject to the selected location of energy entry point.

Measures will be also needed in order to diminish negative impacts of future high international cost of imported energy, taking into account the financial affordability of Bangladesh people.

Power Import from Neighbors

- Policy on the balance between percentage of power import and energy security.
- Policy on balance between purchase of available surplus power and new power to be produced jointly by neighboring countries and Bangladesh. In the latter case, long preparation time and construction period are necessary to open new hydropower stations.
- Measures and structure to strengthen stable and continuous power supply from neighboring countries, avoiding as much as possible political negative impacts. Establishment of an international organization (=SPC to construct and operate triangle power station(s)) is an example.

Problems and O&M Legal Solutions

① Problems
- η Down (Efficiency)
- MW Down (Output)
- Re Down (Reliability)

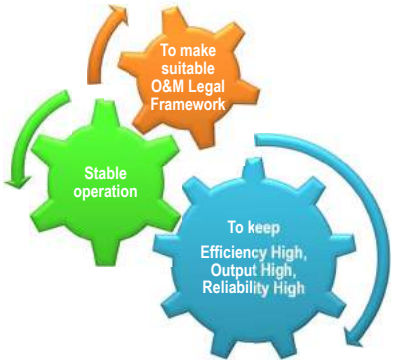
② Main Reasons
- ◆Insufficient Maintenance
- ◆Insufficient Inspection
- ◆Insufficient ηmanagement

③ Why ?
- ◆ Lack of budget
- ◆ Lack of technical skill
- ◆ Lack of time
  - ✓ It is not easy to stop for maintenance due to power shortage.

④ O/M Solutions
- ◆Earning more
  - ✓Efficiency management
  - ✓Reduction of maintenance period
- Personal skill-up
  - ✓Training
  - ✓ Education
- Efficient maintenance
  - ✓CBM
  - ✓Daily maintenance
  - ✓Patrol inspection

⑤ O&M Legal Solutions
- ◆To build the mechanism for O/M legal solutions
  - ✓Structure
  - ✓Formation of organization
  - ✓Clarification of responsibility
  - ✓Sustainability, PDCA
  - ✓Incentives and penalty

Challenging for O&M by legal approach



Power/Energy Tariff Adjustment

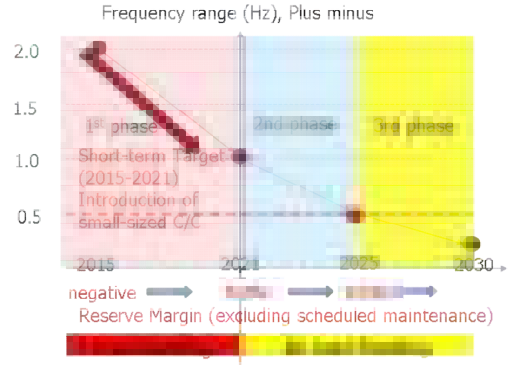
Current Issues	Countermeasures
A gap between electricity tariff and generation cost is covered by financial support of GoB	By increasing electricity tariff, the gap should be eliminated in a longer run.
Generation cost is kept low due to financial support of GoB for domestic gas tariff and other primary energy tariff.	By adjusting tariffs of primary energy to their international price, fiscal burden of GoB should be eased.
With more dependence on imported primary energy, Bangladesh economy becomes more vulnerable to their international price fluctuation.	Power and energy tariffs should be adjusted to international market prices accordingly.

Focus on Power Quality

***Frequency Quality Improvement** requires*
to secure controllable generation capacity .
- *Reserve Margin*
- *Upper-lower control ranges of generation units provided for NLDC for AFC (secondary control) in whole network system*

-- How much amount? How to allocate to each unit? (IPP refuses it??) should be studied.
-- NLDC system Improvement
-- Establishment of its rules

- ***Short Term*→Improvement of the understock chronic power by the lock of maintenance.**
- ***Long term*→Development of power and repair plan based an appropriate demand forecast.**



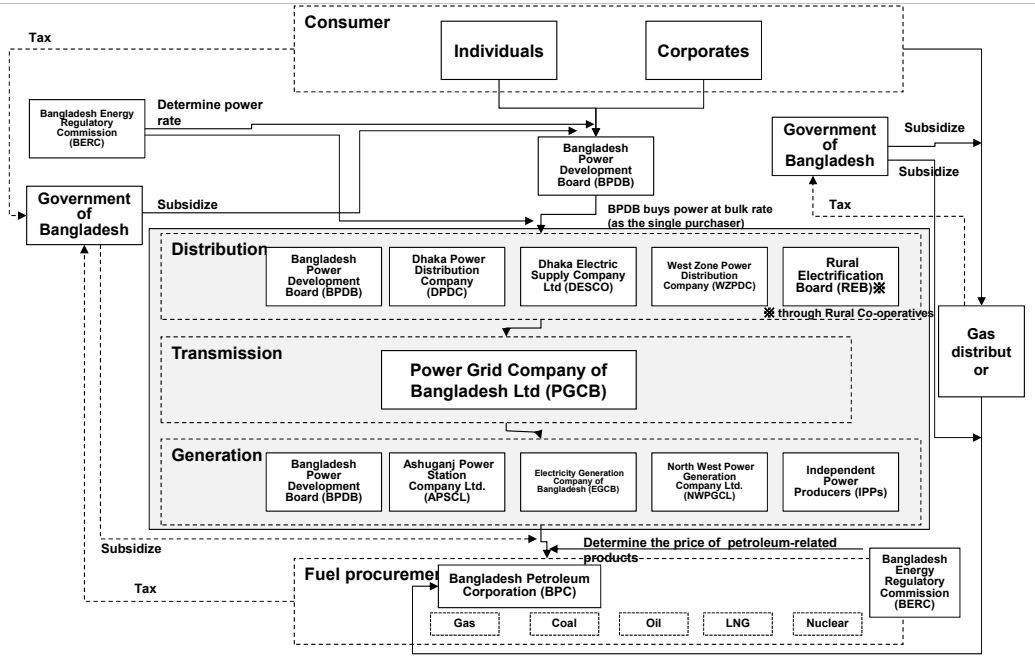
Target of Frequency control

5. Economic and Financial Approach

Overview of Analysis

1. Accurately understanding cash flow in power sector and gas sector (See 4-3 and 4-4)
2. Estimating expenditure from the Government of Bangladesh to the entities based of published materials
3. Simulating impact on public finance of the Government
4. Calculating macroeconomic impact of the master plan

Cash Flow in Power Sector (OPEX)



Cash Flow in Power Sector (CAPEX)

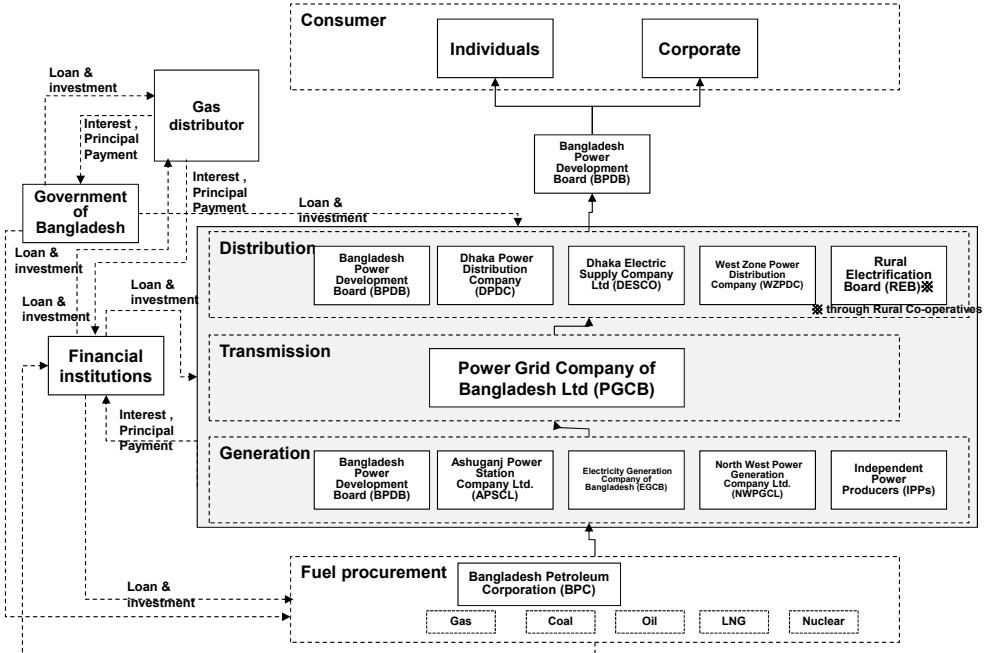
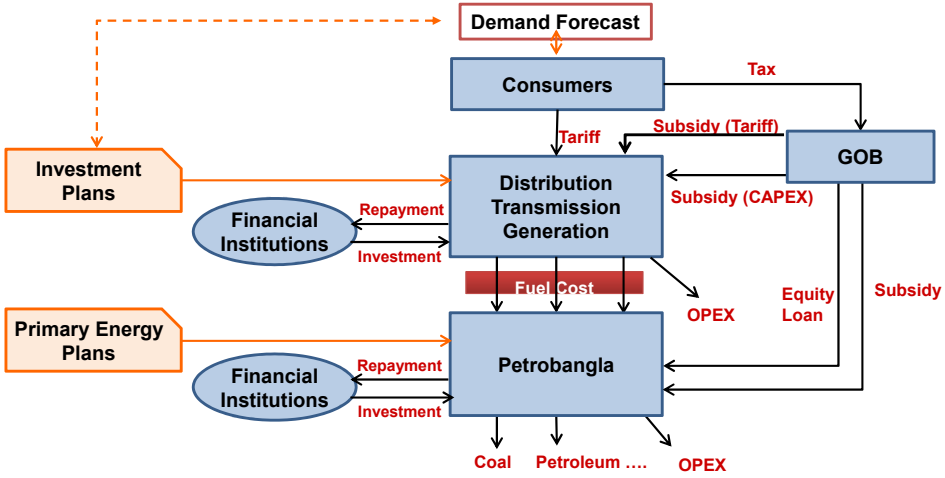


Image of Analytical Model

1. Structuring analytical model (See the below image)
2. Analyzing the output of the model using indicators: accumulated debt, amount of subsidy and so on.



Key Points in 3rd Mission

- Explaining the direction of our economic and financial analysis
- Figuring out schemes of subsidy provided by the Government of Bangladesh
- Collecting basic information for making out analytical model
  - Interest rate
  - Track record of tariff, primary energy cost and so on
  - Subsidy from GOB for electricity price, fuel procurement (consumer to gas distributor, power generator/gas distributor to BPC)
  - Tax (consumer/gas distributor/BPC to GOB)
  - Conditions of concessional loan by WB and ADB

  and so on

23.3 3rd Seminar (3rd Steering Committee)

- Date: 15 December 2015
- Venue: Board Room of BPDB at Buddyut Bhaban, Dhaka
- Discussion Point:
  - ✓ Project Outline
  - ✓ Primary Energy
  - ✓ Power Demand Forecast and Power Development Plan
  - ✓ Power Quality
  - ✓ Operation and Maintenance (O&M)





- Participants

Participants are shown below table.

No.	Name	Designation	Organization
1	Md. Sazzad Ahmed	Associate Project Analyst	ADB
2	Bidyut Kumar Saha	Senior Financial Sector Specialist	ADB
3	Ali Kausar M. Firoz	Project Officer Energy	ADB
4	Dr. Sherine Ibrahim	Senior Project Management Specialist	ADB
5	Subhrajit Datta Roy	Associate Director, P&C	ADB
6	Monsur A. Aziz	Reporter	Amader Orthoneety
7	Sazzadur Rahman	Executive Director (E)	APSCL
8	Mr. C.S Roy	Senior Maintenance Engr.	BBS
9	Bikash Dewan	Chief Engineer, P&D	BPDB
10	Md. Raihan Nobi Khan	Deputy Director – 3, Executive Engineer	BPDB
11	Bellal Hassan	Executive Engineer, System Planning	BPDB
12	Md. Abdullah Al Mamun	Assstant Engineer	BPDB
13	Engr. Md. Monower Zahid Khan	Assistant Engineer	BPDB
14	Engr. Ratan Kumar Paul	Director, System Planning	BPDB
15	Iqbal Hasan	Assistant Engineer	BPDB
16	Saiful Hasan	Director, Public Relation	BPDB
17	Md. Nazrul Islam	Director, RER&D	BPDB
18	Sayeed Ahmed	Additional Chief Engr.	BPDB

No.	Name	Designation	Organization
19	Momotaz Pervin	Aiistant Director, Public Relation	BPDB
20	Nurul Islam Bhuya	Chief Engr., Planning & Operation	BREB
21	A.K. Mainul Haque	Project Manager	Bright Green Energy Foundation
22	ANM Obaidullah	Superintending Engineer, Planning	CPGCBL
23	Md. Abul Quasem	Managing Director	CPGCBL
24	A.K.M. Mostofa Kamal	Executive Directo (Proc)	DESCO
25	Ferdous Hossain	Reporter	Dhaka Protidin
26	Santi Ram Roy	Executive Director, Engr.	EGCB
27	A. M. Monsurul Alam	Executive Director (Finance)	EGCB
28	Dr. Kazi M Humayun Kabir	Environmental Management Specialist	EGCBL
29	Ibrahim Ahmad Safi	Superintending Engineer, P&D	EGCBL Ltd
30	Mohammad Yamin Choudhury	Joint Secretary	ERD
31	Md. Mustafizue Rahman	Representative	GTZ / GIZ
32	Faisal Mahmud	Associate Professor	IUB, Independent University of Bangladesh
33	Kazi Zebunnessa	Joint Secretary	Ministry of Energy & Mineral Resources
34	Arfin Ara Begum	Joint Secretary, FD	Ministry of Finance
35	Md. Abdus Sobur Chowdhury	Deputy Secretary	Ministry of Industries
36	Kazi Sakhawat Hossain	Joint Secretary	Ministry of Water Resources
37	Abu Ahmed Siddique	Deputy Secretary	MOCAT
38	Md. Muslahuddin	Deputy Chief	MOL
39	Khurshedul Alam	Managing Director	NWPGCL
40	Md. Shah Alam		PDB
41	Arun Kumar Saha	Chief Engineer (P&D)	PGCB
42	M. Amzad Hossain	Director (Com)	Power Cell
43	CFK Musaddek Ahmed	Director, Private Power	Power Cell
44	Md. Abdur Rauf Miah	Director	Power Cell
45	S.M. Tarikul Islam	Director (Deputy Secretary)	Prime Minister Office
46	Satya Ranjan Debnath	Executive Director Engineering	RPCL
47	Md. Ehsan-E-Elahi	Joint Secretary	RTHD
48	Motiruzzaman Mitu	Reporter	Thereport24.com
49	Md. Majibur Rahman	DGM, Planning	Titas Gas
50	Engr. Rana. A. Hydari	DGM, Operation	Titas Gas

(Alphabetical order)

■ Presentation materials

Presentation materials are as next pages.

PSMP2015
3rd Steering Committee

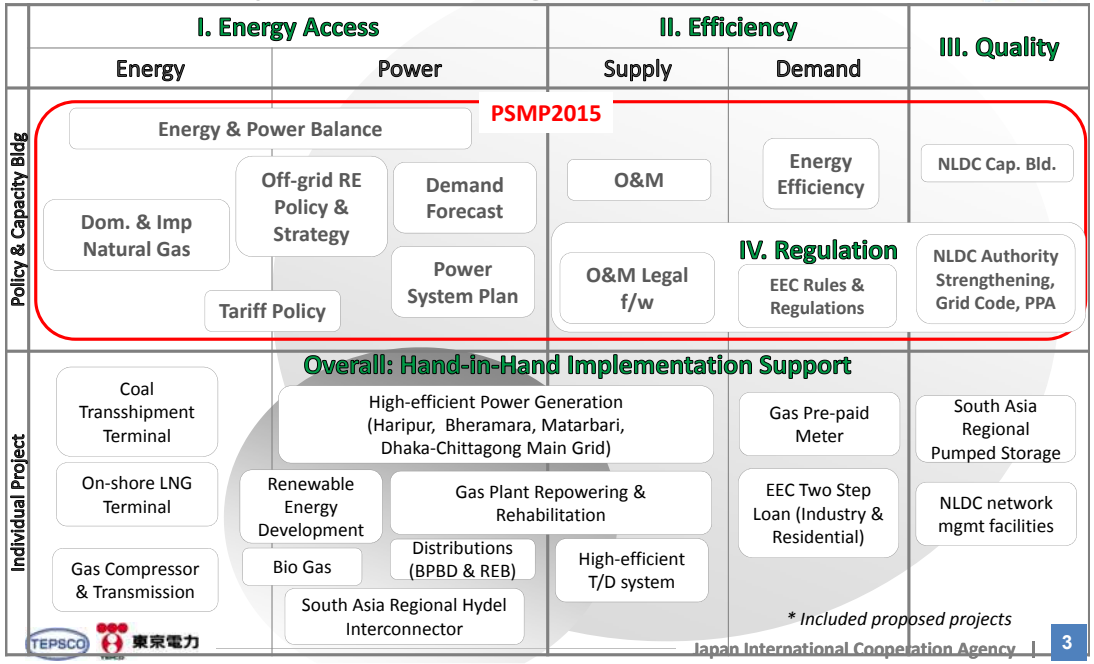
JICA PSMP2015 Team
15th December, 2015

Tokyo Electric Power Services Co., Ltd.
Tokyo Electric Power Company

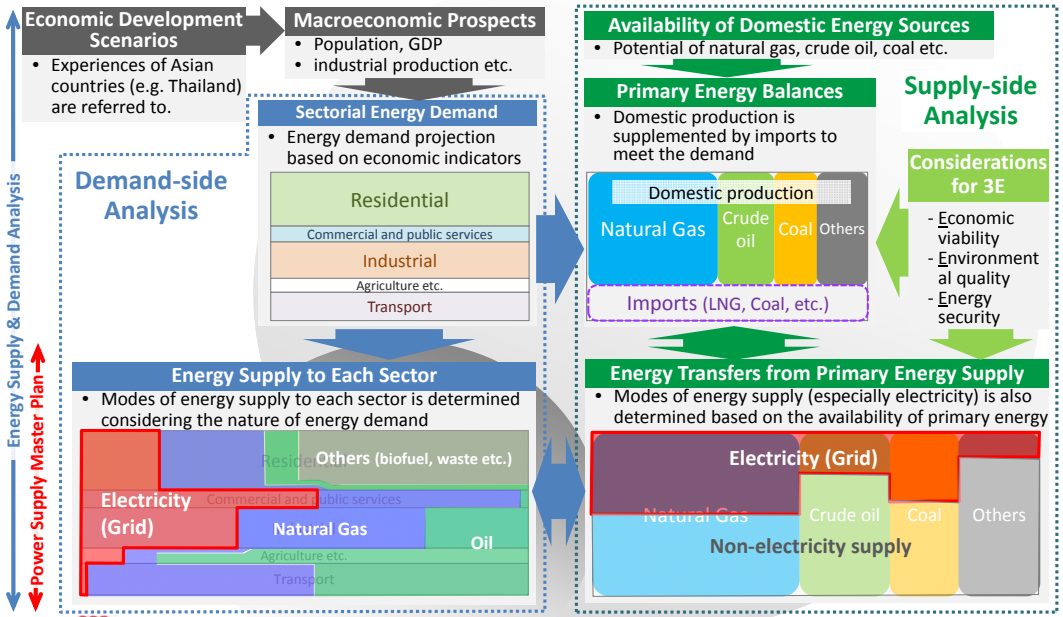
Agenda

1. Energy Balance
   - Primary Energy Balance
   - Domestic Natural Gas
   - Import LNG
   - Coal (Domestic & Import)
2. Power Balance
   - Demand Forecast
   - Power System Plan
   - Operation and Maintenance (O&M)
   - Power Quality
3. Energy and Power Tariff Strategy
   - Tariff Policy
   - Impact on National Economy

PSMP2015: Comprehensive and Integrated Plan



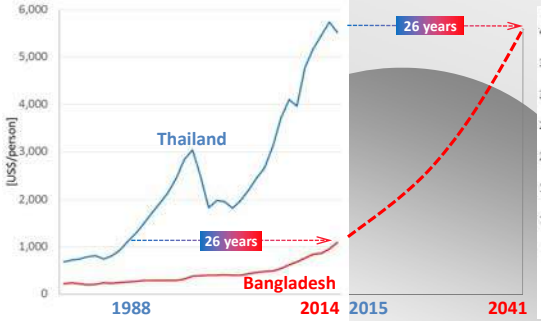
PSMP2015 Project Flow (Energy & Power Balance)



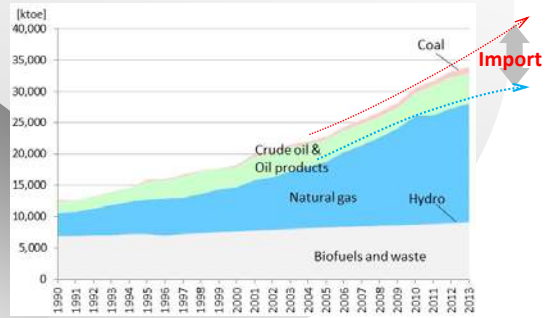
1. Energy Balance

Primary Energy Balance up to 2041

- Energy demand is expected to growing rapidly in Bangladesh, which has a potential to achieve economic development like what Thailand has done
- Bangladesh used to be rich in domestic natural gas production, but will soon become a big importer of LNG and coal to meet the demand
- Insufficient availability of statistic data for demand analysis is another challenge for promoting sound development of the energy industry



GDP per Capita of Bangladesh and Thailand



Trend of Primary Energy Supply in Bangladesh

Domestic Natural Gas: On-site Survey

Onshore Exploration and Supply

- **Aging Existing Gas Fields**

Fact Finding Heavily relying on existing gas production fields but the production is declining

- **Fast Truck Program to be reviewed**

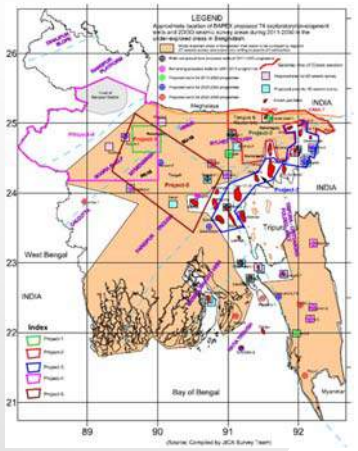
Fact Finding GoB signed a contract with Gazprom to drill 10 wells in September 2012 on turn key basis. The project completed, however, 2 wells failed and performance of some others are unsatisfactory. Further contract with Gazprom to drill 5 wells are underway.

Proposals Risk of failure should be minimized.

- **Best Industrial Practice through competitive bid**

Fact Finding BGFCL is introducing Best Industrial Practice through competitive bidding. Bid result shows that this can be attainable at a significantly low cost.

Proposals Best Industrial Practice can be replicated in other SGCs.



Drilling cost

Proposals Drilling using best industrial practice thorough competitive bid is essential

BGFCL	Competitive bid	USD 14.5 million /well
GAZPROM	Non-competitive basis	USD 20～21 million /well

Domestic Natural Gas: On-site Survey

Discussions and Proposals

- **Introduction of PSC to Onshore Exploration for risk mitigation**

  Introduce Product Sharing Contract (PSC) with IOCs partnered with BAPEX/BGFCL/SGFL to minimize exploration.

- **Exploitation of Confirmed Potentials**

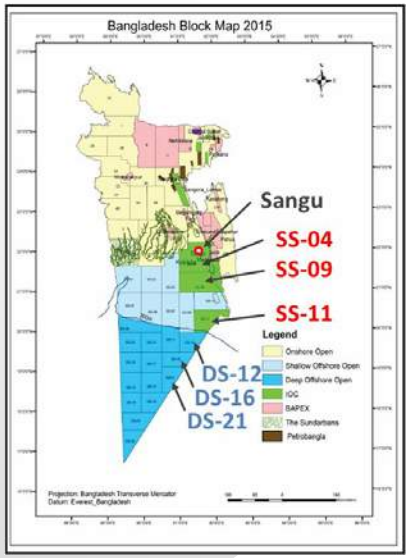
  Resume Chatak Gas Field Development (Condensate recovery to be maximized).

- **Offshore Exploration**

  Revise Model PCS to attract IOCs.

- **Role of BAPEX to be re-defined**

  Review the role of BAPEX and transform the organization to match IOC levels, and allow BAPEX to acquire energy assets overseas.



LNG Development Study

Fact Findings

- A huge gap between domestic natural gas (NG) supply capacity and the growing NG demand
- Less expectation of domestic NG exploration mainly in Sylhet in the future
- LNG import can be one of the significant measures to compensate this gap.

Discussions and Proposals

(1) LNG Connection to the Existing Gas pipeline

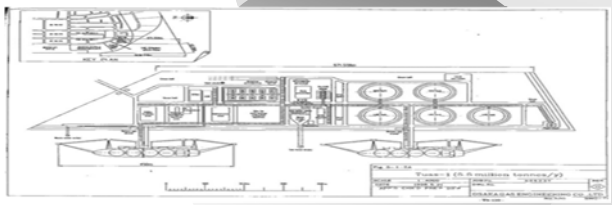
- Check the physical property difference between domestic NG and imported LNG (calorie, impurities, sp.gr,etc.)
- NG send out condition from the terminal in compliance with the existing pipeline gas at tie-in point
- Operation and management policy of national pipeline network in case of terminal emergency and/or planned shutdown

LNG Development Study

Discussions and Proposals

(2) LNG Terminal Layout Examination

a. Annual LNG operation capacity & gas production rate
b. LNG Tank storage capacity
c. Type selection of vaporizer
d. Gas send out pressure from the terminal
e. Necessity of BOG re-liquefaction system
f. Necessity of heat value adjustment by LPG or air
g. Necessity of organization system (for safety)
h. Spare unit arrangement of main equipment
i. Future expansion plan（road map to expansion）



Required land space: around 60 ha (600,000m²)
@5 million tons/p.a. (MTPA)



Osaka Gas Senboku 2 terminal (5MTPA: 5 million ton LNG per annum)

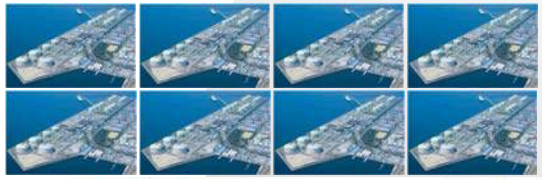


Above ground LNG storage tank in Senboku 2 terminal (180 thousand kl ×4 units are needed in 5 MTPA terminal)

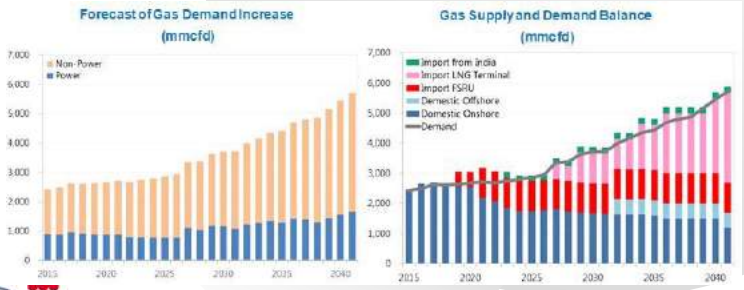
LNG Development Study

Discussions and Proposals

- Huge investment is required for LNG constructions.
- Approximately 4,000 mmcfd is required for Import LNG, which is;
- A standard size of 500mmcfd X 8 LNG fuel Base is required.



⇨ Challenging issue



Coal: Volatile import price & Open Cut Mining Pilot

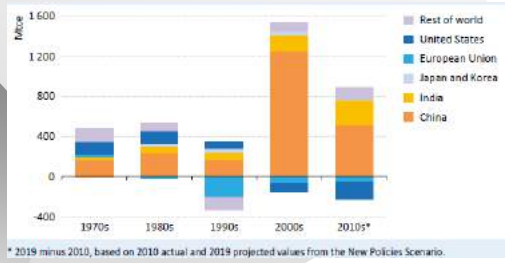
Fact Findings

- For Bangladesh, domestic coal development becomes important in future, due to the increasing competition for coals and Bangladesh has good quality coal deposit.
- There are two mining methods for coal development of Under Ground (U/G) and Open Cut (O/C).

Discussions and Proposals

- U/G mining: being established at Barapukuria Coal mine. Nurturing Bangladeshi engineers to be able to manage a coal mine by themselves is the key.
- O/C mining: essential technology in Bangladesh to get resources at high mining ratio in future. At first, the understanding of residents and the clearing the technical problem are the most important. Development of small scale O/C mining in Barapukuria might be possible.

Change in coal demand by key region and decade



Source: IEA World Energy Outlook 2015

2. Power Balance

Power Demand Model

Power M/P has to keep the consistency among the Strategies, Plans and Policies

- Country population & Regional population
- Economic strategies & GDP prediction
- Industrial & commercial development plan
- Recorded power demand
- Recorded power shedding
- Power potential demand
- International energy market and prices
- Gas & coal supply plan
- Renewable energy development plan
- Power tariff schedule
- Energy efficiency & conservation plan

Power & energy demand forecasting model

- Power development plan
- Energy (gas & coal) development plan

Power Demand Model

Generation

		2008	2009	2010	2011	2012	2013	2014
Max peak generation	MW	4,130	4,162	4,606	4,890	6,066	6,434	7,356
Max load shedding	MW	1,544	1,488	1,973	1,842	1,584	1,675	985
Computed peak generation	MW	5,674	5,650	6,579	6,732	7,650	8,109	8,341

Peak demand

		2008	2009	2010	2011	2012	2013	2014
Recorded net peak load	MW	3,924	3,954	4,376	4,646	5,823	6,177	7,062
Max load shedding	MW	1,438	1,385	1,883	1,765	1,502	1,588	978
Computed peak demand	MW	5,362	5,339	6,258	6,411	7,326	7,764	8,039

Sources: BPDB annual report

(1) Potential demand = Recorded data + Shedding

(2) Regarding BPDB, Shedding are eliminated up to 2020.

Forecasted data

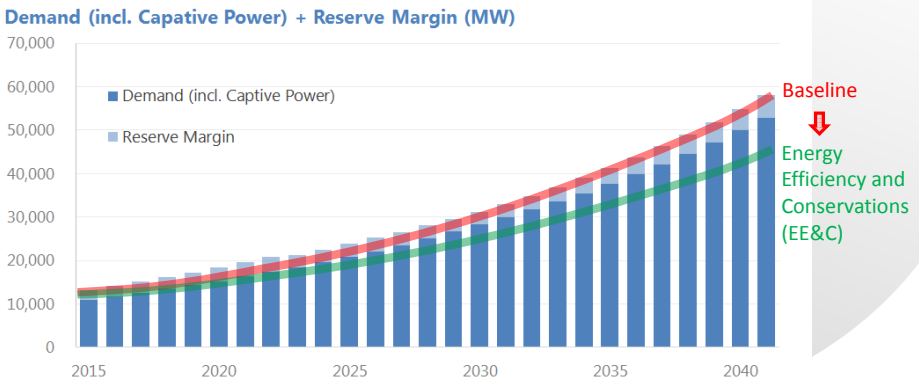
Power Demand Model

Assumptions:

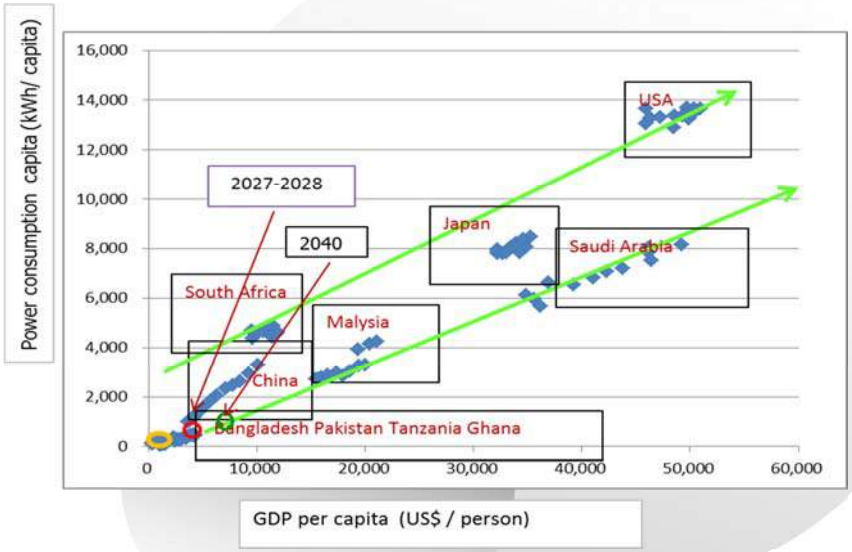
- GDP growth rate: 6.5% for 2030/15, and 6.0% for 2040/30.
- Reserve Margin (RM) kept down to 10% by 2030

Projections:

- Required supply will be at 57,000MW including RM
- Energy Efficiency and Conservations (EE&C) is challenging and important issue for Nation



Per capita Power Consumption



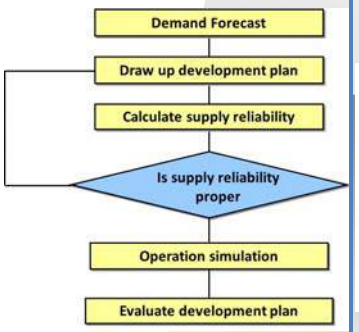
Source : World bank data base

3E for Optimum PDP Scenario

Discussions : Maximization of 3E (Economic, Energy Security, and Environment) will be considered to prepare optimum PDP options.

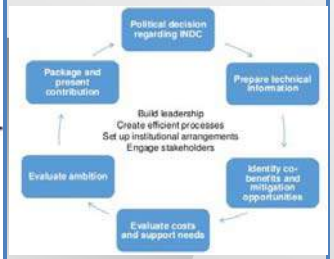
Economic

Minimization of Supply Cost



Environmental

Environmental policy study will focus on GHG emission reduction strategy



Energy Security

Minimization of procurement fuel supply risks

First Step:
Specify the considerable risks in Bangladesh energy situation

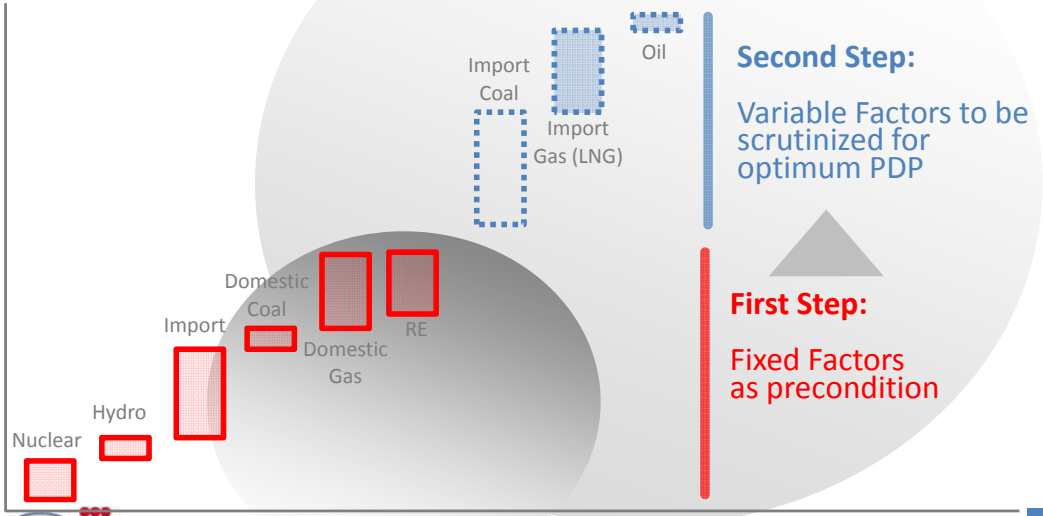
Second Step:
Choose a suitable index to express the degree of each risk

Third Step:
Integration of indices to one "energy security index"

Fixed and Variable Factors for PDP

Assumptions:

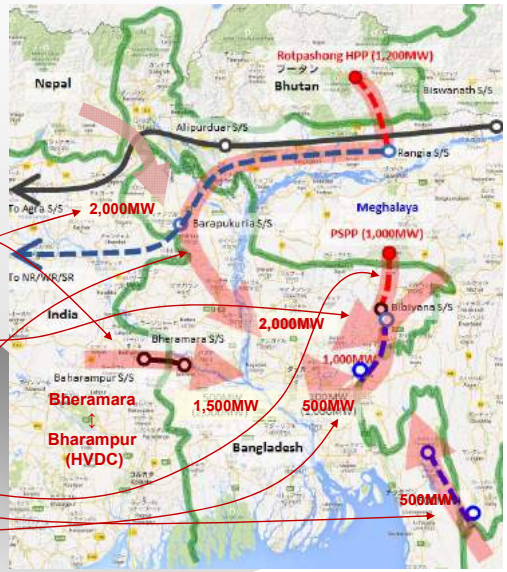
- Fixed Factor: Nuclear, Power Import, Dom Coal, Dom Gas and Renewable Energy
- Variable Factor: Imp Coal, Imp Gas and Oil



Power Import (Mainly Hydropower)

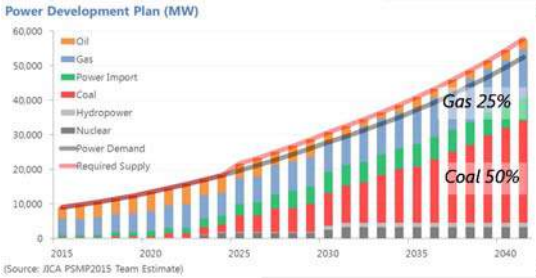
Power import from neighboring countries will become one of major sources of energy mix: ranging 15-20% of total power supply.

Project		MW	COD
Bheramara-Bharampur HVDC (Power		2,000	
Phase 1	Ex	500	2013
Phase 2	New	500	2017
Phase 3	New	1,000	2025
Hydropower from Nepal		2,000	
Phase 1	New	1,000	2025
Phase 2	New	1,000	2030
Comilla - Tripura HVDC		500	
Phase 1 (100MW)	New	100	2015
Phase 2 (400MW)	New	400	2020
Rangia/Rowta - Barapukuria		2,000	
Hydropower from Arunachal P	New	1,000	2023
Power from Bhutan	New	1,000	2030
Bibiyana - Meghalaya (PSPP)	New	1,000	2030
Cox's Bazar - Myanmar	New	500	2040
Bongaigaon or Rawta - Jamarpur HVD		1,000	2030
Total		8,500	

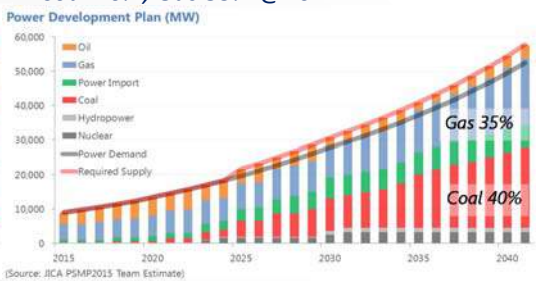


PDP Scenarios (to be determined)

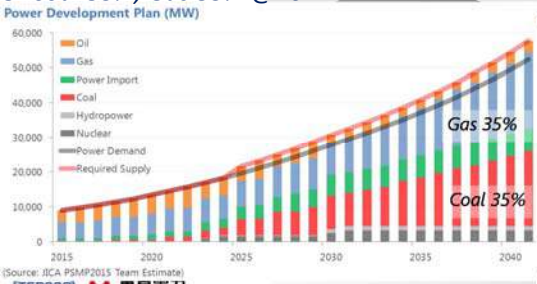
1: Coal 50%, Gas 25% @2041



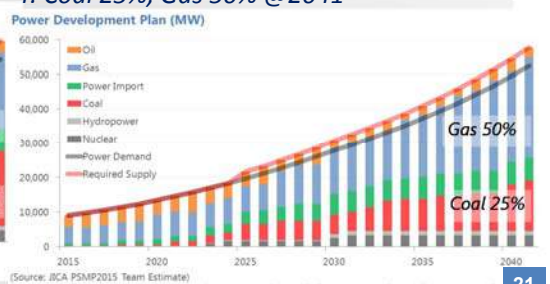
2: Coal 40%, Gas 35% @2041



3: Coal 35%, Gas 35% @2041



4: Coal 25%, Gas 50% @2041

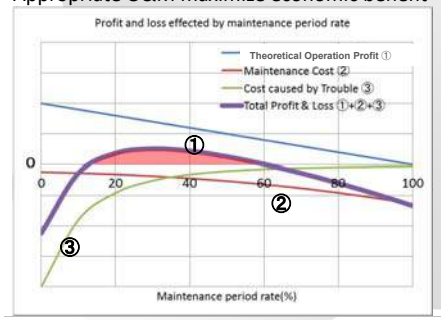


Legal Framework required to implement desirable O&M

Fact Findings /Discussions and Proposals

	Items	Authorities (BERC/BPEB?)	GenCos/BPDP
1	Periodic inspection	To decide the inspection-intervals and inspection-items	To comply with it.
2	Safety regulations	To order that GenCos/BPDP establish their own safety regulations	To comply in their daily operations
3	Responsible engineer	To order that GenCos/BPDP appoint their own responsible engineers	To comply with the instructions form him
4	Safety audit	To decide items and interval of safety audit	To implement periodically
5	National technical standards	To make national technical standards	To comply with it

Appropriate O&M maximize economic benefit

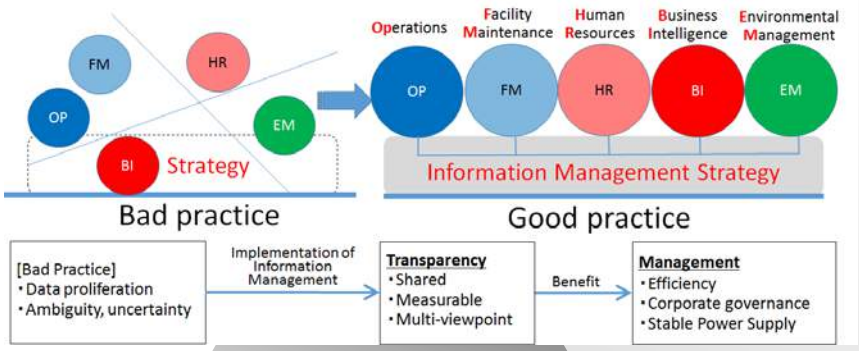


**Maintenance Period Rate (%) = Maintenance days/All days
MPR 0% = No maintenance, Operation always if no trouble
MPR 1000% = Maintenance always, No operation

Various measures can be taken for O&M implementation

Discussions and Proposals

<Information management system>



<Rehabilitation>

Power generation remodeling: appropriate size to be studied & determined

<Human resource development>

Training curriculum, instructor development and training facility are required.

Power Quality

Fact Findings

Each utility has a strong initiative and accurate understanding to improve power:

1. Significant deficiency of power source including spinning reserve.
2. No application of automatic control such as LFC, free-governor operation. Instruction by telephone communication only.
3. Inadequate coordination of daily generation scheduling between NLDC and GenCos.
4. NLDC has less regulatory authority to make a balance between demand and supply.

Challenges in NLDC proves Bangladesh has enormous power system quality improvement potential.



Frequency chart of Free Governor mode operation test with Khulna gas turbine generator (158MW)

Power Quality/Frequency Control : Higher Value-Added Economy

Discussions and Proposals

- There are high potential needs of frequency quality, in particular, from business sectors, in order to realize a higher value-added economy and more sophisticated industrial structure
- Frequency fluctuations could cause negative impacts as follows:

Industries	Effects by frequency fluctuations
Chemical fiber manufacturing	The change of winding speed could lead thread breakage and bad quality of thickness of the thread.
Paper	The change of winding speed could lead paper breakage and bad quality of thickness of the paper.
Oil	Bad pressure control for decomposition and desulfurization could lead to failure of impurity removal.
Iron and Steel Aluminum	Bad rolling process could cause uneven of thickness of products.
Motor vehicle	The change of weld time for automotive body panels could lead to bad effect for weld strength and quality of products appearance.

Power Quality

Discussions and Proposals

1. Improvement of Grid Code or other rules

- Amendment of various rules in relation to demand-supply planning or frequency control.
- Amendment of the Grid Code by PGCB and reinforcement of NLDC's instructions and GenCos/BPDB participation in frequency controls.

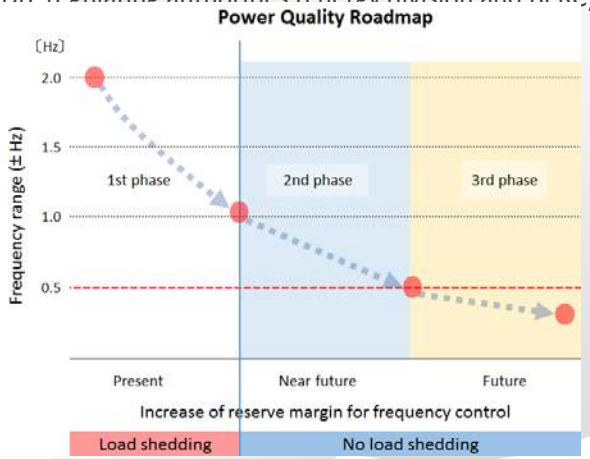
Area	Target range of frequency	Criteria
Bangladesh	50Hz ± 1.0Hz	Instantly
Eastern region in Japan	50Hz ± 0.2Hz	Instantly
Western region in Japan	60Hz ± 0.2Hz	Instantly
North America	Eastern region : 0.018Hz Western region : 0.0228Hz Texas (ERCOT) : 0.020Hz Quebec : 0.0212Hz	Annual standard deviation
Europe	50Hz ± 0.04Hz, over 90% 50Hz ± 0.06Hz, over 99%	The ratio of stay within the standard

Power Quality

Discussions and Proposals

2. Draft plan for frequency quality improvement

- Propose the development of future plan for securement of spinning reserve (free governor mode, LFC) and roadmap for frequency quality improvement for PGCB (NLDC) and BPDB, regulating authorities (Energy division and BERC).

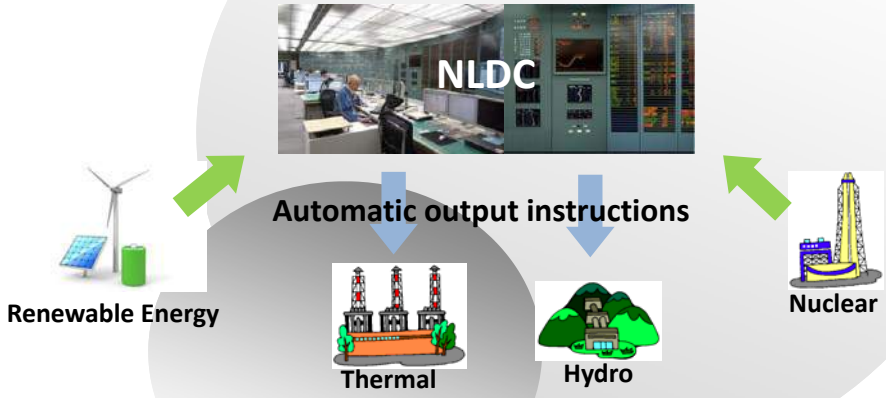


Power Quality

Discussions and Proposals

3. SCADA* system renewal plan for National Load Dispatching Center (NLDC)

- Confirming needs for introducing new functions or adding data to NLDC's SCADA system, in order to realize Automatic output instructions for power stations.



SCADA* : Supervisory Control And Data Acquisition

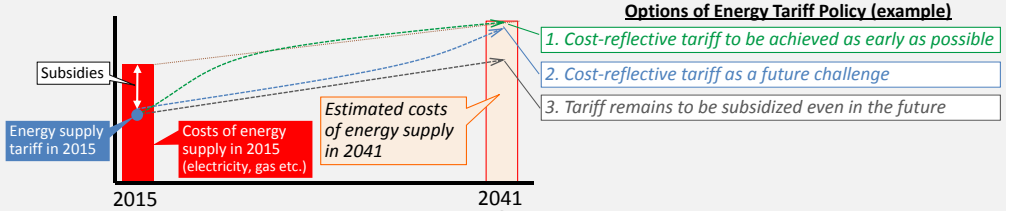
3. Energy and Power Tariff Strategy

Energy and Power Tariff Strategy

Energy Supply Tariff Analysis

Projection of Costs of Energy Supply and Tariff Policy

- The energy tariff in Bangladesh needs to be adjusted to be cost-reflective with the progress of economic development



Impact of Energy Tariff Increase on National Economy

- For avoiding a negative effect of rapid tariff increase on national economy in Bangladesh, policy tools for mitigation may be justified
- However, priority of distributing the limited financial resources (subsidies) among sectors also needs to be considered
- Policy options of energy tariff are analyzed using GTAP model

তোমাকে ধন্যবাদ

People's Republic of Bangladesh
Survey on Power System Master Plan 2015

December , 2015

Tokyo Electric Power Services Co., Ltd.
Tokyo Electric Power Company Co., Inc.

Agenda

1. Project Outline
2. Primary Energy
   2.1 Primary Energy Balance
   2.2 Domestic Natural Gas
   2.3 Import Liquefied Natural Gas (LNG)
   2.4 Environment and Social
3. Power Demand Forecast and Power Development Plan
4. Power Quality
5. Operation and Maintenance (O&M)

1. Project Outline

Key Issues in Energy Balance Analysis in Bangladesh

Energy Demand

- In Bangladesh, where the energy demand is expected to grow rapidly, the energy supply infrastructure needs to be developed so that the supply shortage won't impair the development of national economy.
- Forecasting the long-term economic development should consider a non-linear structural changes of the national economy in the future. Scenario planning analysis referring to the experiences in Asian countries is recommended.

Primary Energy Supply

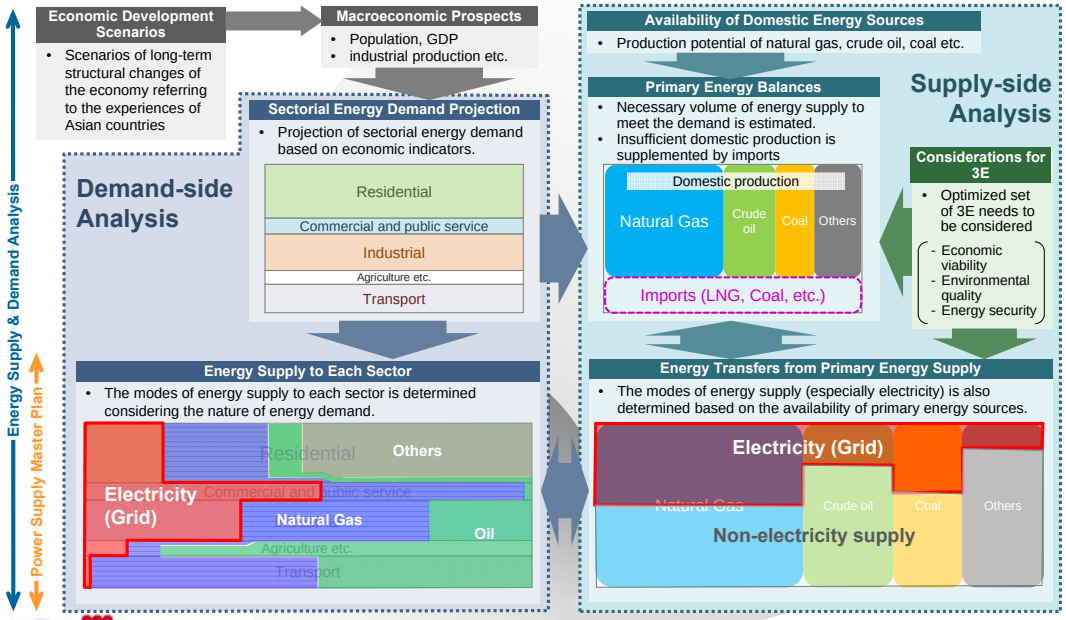
- Energy supply in Bangladesh has been heavily dependent on the domestic production of the primary energy sources, especially natural gas.
- Though the domestic production is expected to start depreciating and the energy import will gain importance, the optimized utilization of domestic production remains to be the core of energy supply.
- In addition, consideration for environmental issues and energy security will be a factor to confine the availability of energy sources

Modes of Energy Supply to End Consumption

- From demand-side, necessary capacity of electricity supply should consider not only the increasing energy demand but also the electrification of energy demand (shift to electricity supply from other modes of supply) though the extent of electrification varies among sectors.
- From supply-side, the capacity of electricity supply is affected by the available sources for electricity generation (including the geographical conditions of energy supply infrastructure).

→ Composition of the modes of energy supply (especially electricity supply) will be determined both by demand-side and by supply-side.

Flow of Energy Balances Analysis

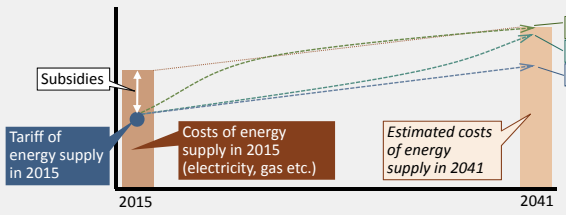


Energy Supply Tariff Analysis

Energy Supply Tariff Analysis

Projection of Costs of Energy Supply and Tariff Policy

- Necessary CAPEX for forming the infrastructure of energy supply (electricity, natural gas etc.) is formulated from the previous sections, then the costs of energy supply up to 2041 are estimated.
- The energy tariff in Bangladesh, which is generally set lower than the actual costs of supply with subsidies, needs to be adjusted to be cost-reflective with the progress of economic development.



Impact of Energy Tariff Increase on National Economy

- It needs to be noted that raising energy tariff may cause a negative effect on national economy in Bangladesh, such as the competitiveness of the industrial sector. If a seriously negative effect is expected, policy tools for mitigation (e.g. subsidies) may be justified.
- The impact of energy tariff increase on the national economy is quantitatively analyzed using GTAP (Global Trade Analysis Project) model.

2. Primary Energy

2-1 Primary Energy Balance

(1)Future Scenario of Economic Development

(2)Prospects of Energy Supply and Demand

(3)Study on Energy Security

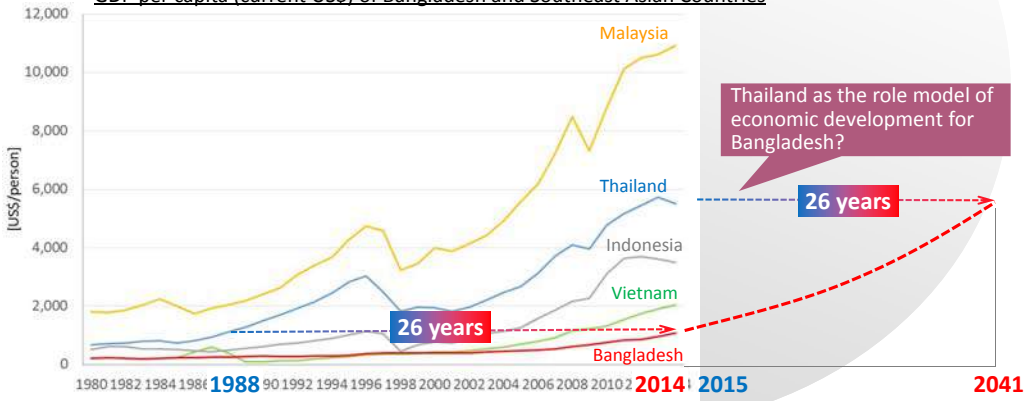
(4)Considerations for Environmental Issues

(1) Future Scenario of Economic Development

Prospects of Long-term Economic Development

- GDP per capita of Bangladesh as of 2014 was 1,093 USD/person, almost equivalent of that of Thailand 26 years before (1988).
- Bangladesh will be able to reach at least the level of Thailand at present by 2041, 26 years from now (5,500 USD/person), if the country's economic growth continues at the same pace as that of ASEAN countries in the past.

GDP per capita (current US$) of Bangladesh and Southeast Asian Countries



Source: Prepared by the Study Team based on World Bank database, GDP: current

Future Scenario of Economic Development

- Thailand may give a good implication in studying future development of Bangladeshi economy, especially in the following points:
  - The industrial policy (which industry to be promoted) has changed considering the stage of economic development;
  - Even after industrialization, agriculture remains to play an important role. Agricultural production shifted to more value-added products to maintain international competitiveness;
- Appropriate policy measures need to be provided for clearing the challenges and bringing the country to a group of "developed countries" by 2041.

Key Challenges for the Future Development of Bangladeshi Economy

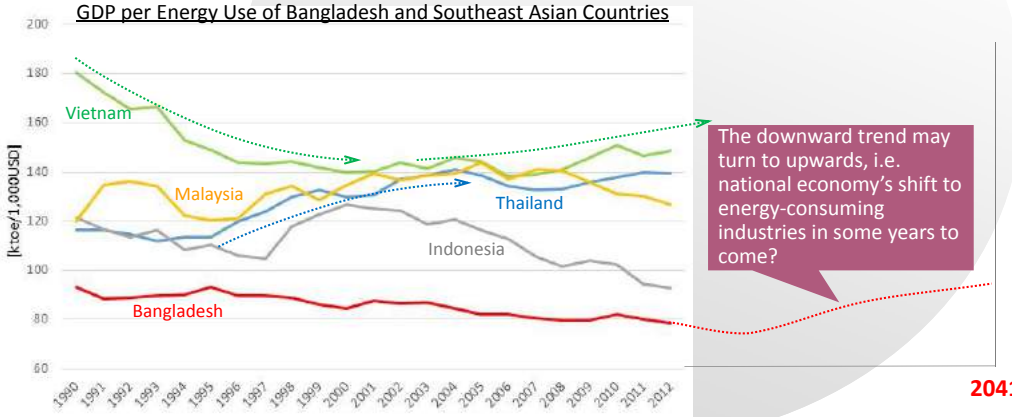
Industries	Key challenges for Future Development
Agriculture	● Productivity improvement ● Improvement of farmers' income
Food and beverage manufacturing	● Improvement of quality ● Export of products
Garment	● Evolution from consignment manufacturing to manufacturing by original design and own brand
Other second industries	● Catch up of technologies for manufacturing ● Export of products ● Capacity development of human resources

(2) Prospects of Energy Supply and Demand

Economic Development and Energy Consumption

- At the initial stage of economic development, GDP growth outperforms that of energy consumption (e.g. Vietnam in 1990s), but it may turn to upwards with the progress of industrialization (Thailand since 1990s, Vietnam since 2000s)
  - In the long run, the trend may go downwards again with the shift to services industry and the advancement of energy efficiency

GDP per Energy Use of Bangladesh and Southeast Asian Countries

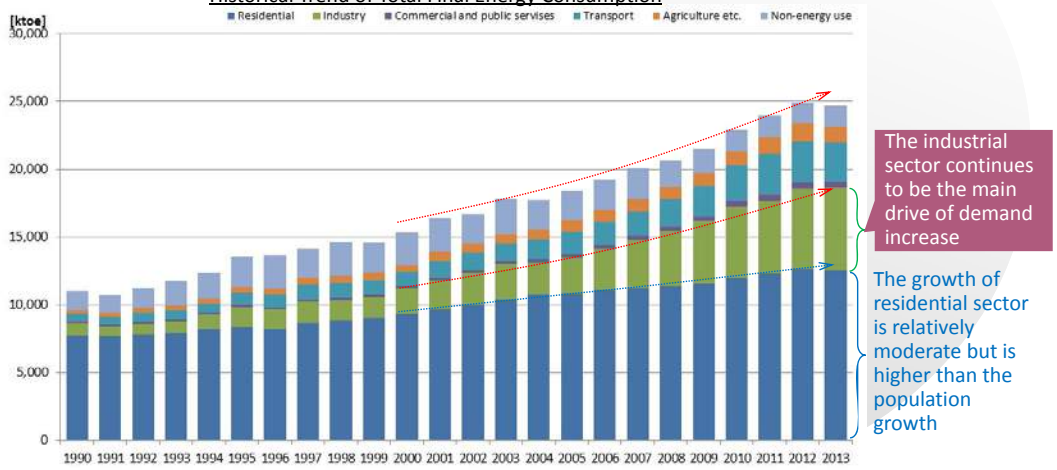


Source: Prepared by the Study Team based on World Bank database and IEA statistics, GDP: constant 2011 PPP

Historical Trend of Energy Demand

- Whereas the residential sector accounts for the largest share in the total energy consumption, the rapid growth of the industrial sector (6.3 times in 23 years=8.3% p.a.) has been the main drive for rapid growth of energy consumption.

Historical Trend of Total Final Energy Consumption



The industrial sector continues to be the main drive of demand increase

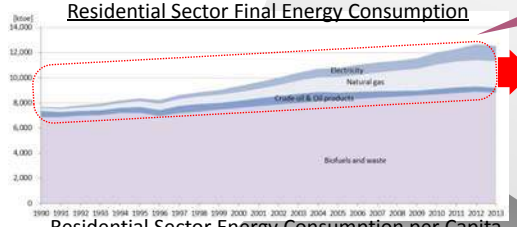
The growth of residential sector is relatively moderate but is higher than the population growth

Source: IEA statistics

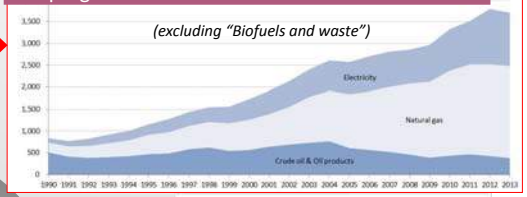
Residential Sector Energy Demand

- Shift from traditional energy source (biofuels etc.) to electricity and gas has helped to mitigate the growth of the total energy (rationalization of energy consumption).
- In the meanwhile, the creeping growth of the energy consumption per capita implies that the sector's energy demand growth may be accelerated with the progress of household electrification.

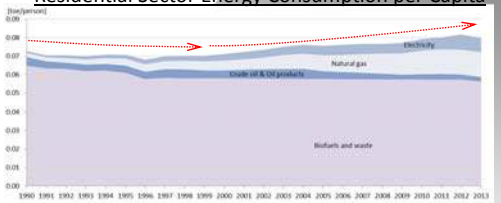
Residential Sector Final Energy Consumption

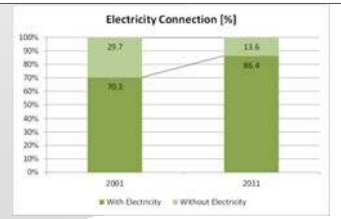


Energy demand growth may become steeper with the progress of household electrification?



Residential Sector Energy Consumption per Capita





Source: Study Team based on World Bank database and IEA statistics

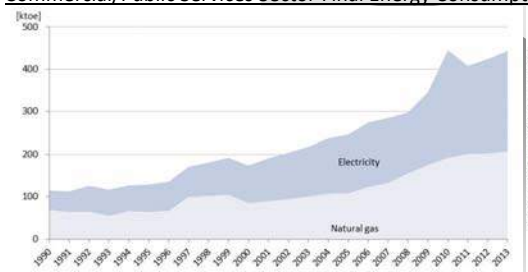
Source: BBS "Population & Housing Census-2011"

Commercial/Public Services Sector Energy Demand

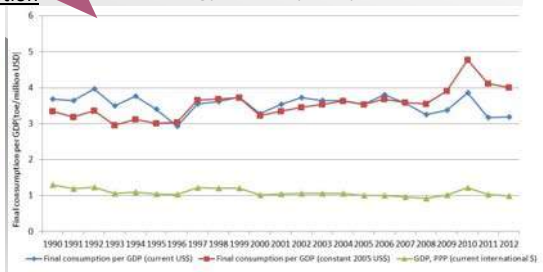
- The growth of energy consumption is relatively modest compared to that of the industrial sector. The share of electricity supply and gas supply is roughly 50:50.
- A correlation between the sector's energy demand and national GDP, especially PPP-based GDP.
- Provision of more information will help to deepen the analysis on the other factors affecting the energy demand of the sector.

More information will help identify other factors than GDP that may affect the sector's energy demand

Commercial/Public Services Sector Final Energy Consumption



Final Energy Consumption per GDP



Source: IEA statistics

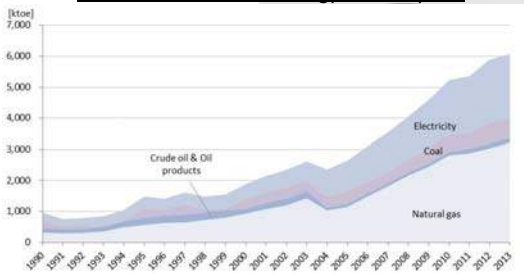
Source: Prepared by the Study Team based on World Bank database

Industrial Sector Energy Demand

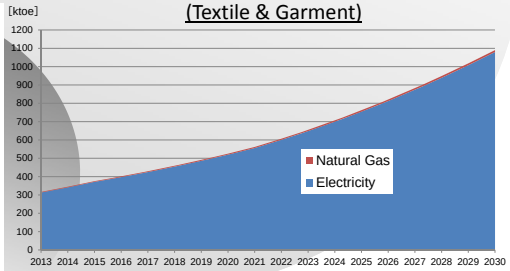
- Energy consumption has been growing rapidly, especially electricity and gas.
- The profile of energy consumption is supposed to be different among subsectors, and there are some existing studies to analyze the sector's energy demand, including JICA's "Energy Conservation Master Plan" that tried a demand projection for each of major subsectors (textile & garment, steel, cement etc.)
- However, these past studies apparently rely a lot on estimates because of data unavailability.

Because of data insufficiency, Discussion with stakeholders on the "likeliness" of the estimates is needed to compliment the data unavailability.

Industrial Sector Final Energy Consumption



An Example of Subsector Demand Forecast (Textile & Garment)



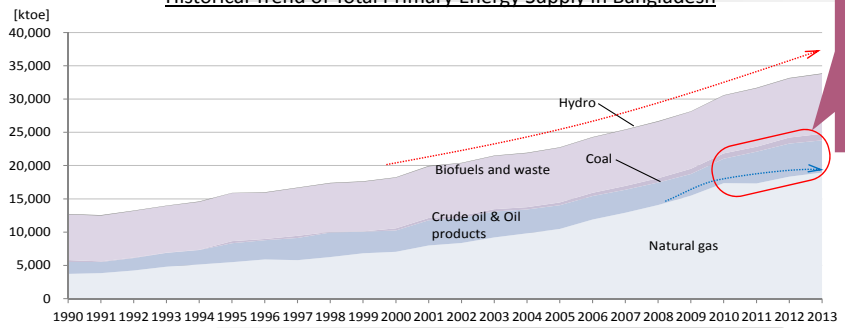
Source: IEA statistics

Source: Prepared by the Study Team based on JICA's "Energy Conservation Master Plan"

Prospects of Primary Energy Supply

- Domestic production of natural gas, which has been the main source of commercial energy supply, is expected to come to saturation.
- In order to meet the still growing energy demand, other sources of energy supply need to be secured. Expanding the usage of coal (including import) is considered a preferred option on a longer-term basis.

Historical Trend of Total Primary Energy Supply in Bangladesh



The recent insufficiency of natural gas supply was tentatively covered by oil, but expanding the usage of coal should be considered as an preferred option

Source: IEA statistics

(3) Study on Energy Security

Study on Energy Security: Overview

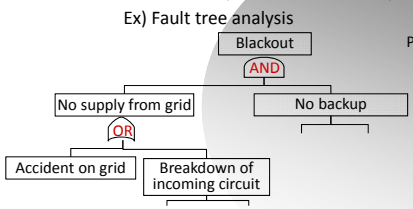
- As the Bangladeshi economy continues to grow to become modernized, the necessity for stable energy supply is expected to gain importance.
- Definition of energy security varies depending on the concern of stakeholders and cover wide range of concepts, e.g. diversity of energy supply sources, self-sufficiency, resilience of energy distribution system against various risks.

Energy Security Assessment

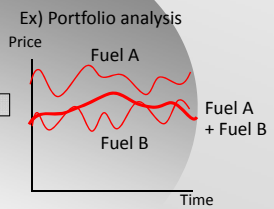
Risk Assessment Methodology
- Established theme in reliability engineering and decision-making theory
- Risks are definitely consisted of :
  - probability of realization
  - impact of the consequence

Specified Risks to Energy Security
- Covers a broad range of issues and no unified approaches
- Significant risks are different by countries and stakeholders

Ex) Fault tree analysis



Ex) Portfolio analysis



Past Studies on Energy Security

- There are several past studies to quantify “energy security” as an index.
- Since diversification of supplier and energy sources are know as an important and simple way to reduce supply risk, some past studies adopted the methods based on “Herfindhal-Hirschman Index”(HHI).
- Other studies employs different approaches to express other various aspects on energy security.

Past Studies on Quantification of Energy Security

Literature	Approach
IEA “Energy Security and Climate Policy”, 2007	Focusing on diversification of resource supply, an index of market concentration is established. This index is a kind of weighted Herfindahl-Hirschman Index. Concentration of each fuel is defined as the sum of squares of the supplier country’s share weighted by country risk. They are summed up after weighted by each energy share on primary energy supply.
METI (Japan) “2010 Annual Report on Energy (Energy white paper 2010)”, 2010	It defines energy security as being able to secure energy in the “quantity” necessary for people’s live, economic and social activities, and national defence etc. at affordable” price”. National energy security is evaluated using 8 indices across energy supply chain, including primary energy self-sufficiency, diversification of countries from which energy is imported, diversification of energy source and reduction of dependency on choke points. Herfindahl-Hirschman Index is employed to evaluate diversification.

Herfindhal-Hirschman Index (HHI) is the number obtained by taking the sum of the squares of the market share.

Past Studies on Energy Security

Past Studies on Quantification of Energy Security (continued)

Literature	Approach
IMF working paper "Measuring Energy Security: Trends in the Diversification of Oil and Natural Gas Supplies ", 2011	Primary energy supplier diversification is evaluated using squared sum of shares of energy suppliers, weighted with country risk of each supplier, distance to each supplier, and import share of evaluated country (smaller import share means more flexibility in supply).
METI (Japan) "Toward the Stable Assurance of Fuel Resources - Energy Risk Index (Security Index) -", 2015	Energy supply stability is evaluated focusing supply chain from supplier countries to Japan. Suppliers' country risk, sea-lane risk, and effect of diversification of suppliers and sources considered in harmonized way.
American Chamber of Commerce (ACC), "Index of US Energy Security Risk", annually updated	US's national energy security is evaluated using 37 different indices including geopolitical factor (ex. production of fossil fuel, import of US), economic factor (ex. energy price, energy consumption per GDP), reliability factor (ex. Electricity reserve rate), environmental factor (CO2 emission, R&D investment to renewable energy)
IEA "Measuring Short-term Energy Security" , 2011	Each energy source is evaluated, considering the "risk" related data and the "resilience" related data. Countries are experientially ranked using these statistics data. No evaluation is done for energy sources mix.

Past Studies on Energy Security

American Chamber of Commerce

- A quantity of different metrics relating energy security are employed
- It scores each metric and integrates them using experimental weights

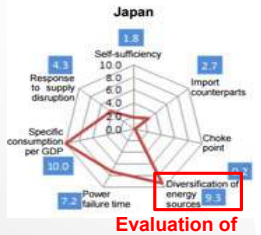


Source: American Chamber of Commerce (ACC), "Index of US Energy Security Risk 2014", 2014

METI (Japan), 2010

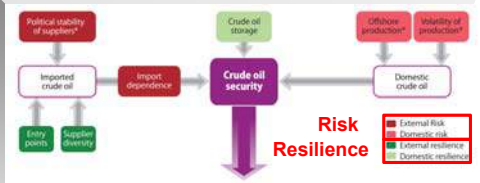
- It employs 8 indices and shows them using a radar chart
- Herfindahl-Hirschman Index is used to evaluate index relating to diversification

Source: METI (Japan), "2010 Annual Report on Energy (Energy white paper 2010)", 2010



IEA, 2011

- Risk and resilience are clearly distinguished
- It evaluates both the degree of remain risk and the intensity of resilience



Source: IEA "Measuring Short-term Energy Security" , 2011

Past Studies on Energy Security (continued)

- Studies on energy security in Bangladesh focus on relatively primary long-term energy supply.
- They commonly mention the importance stable energy supply expand to achieve the economic growth target.

Past Studies on Energy Security in Bangladesh

Literature	Approach

UNNAYAN ONNESHAN, "Energy Security: Trends and Challenges - Bangladesh Economic Update", 2014	It discusses current energy security situation using related data.
	• Power
	  • Availability (Consumption per capita, electricity access, load shedding)
	  • Reliability (Ownership, use of fuel)
	  • Affordability (Tariff and subsidy, system loss, cost)
	• Other energy
	  • Reserve, production, import
	  • Price, import cost

T. Ishtiaque (Bangladesh University) et al., "Energy Sector Development and Energy Security in Bangladesh", 2013	Energy sector development to 2050 is discussed. It points out that long-term energy policy is crucial to sustainable development of Bangladesh. As for energy security, it mentions the importance of cooperation with other countries to ensure energy supply, especially hydropower from Bhutan and Nepal.
ANM Obaidullah, Energy Security & Climate Change: Challenge for Bangladesh, Energy & Power	Uninterrupted energy supply is essential for stable economic growth in Bangladesh. It focuses on primary energy mix to ensure such energy supply. It consists coal is the most stable commodity in Bangladesh in spite of high CO2 emission. LNG, nuclear and renewables are other prospective commodities.

Key Issues in Considering Energy Security in Bangladesh

- The first step to evaluate energy security is to specify the considerable risks in Bangladesh energy situation.
- In Bangladesh, national risks relevant to long-term energy supply quantity need to be considered with priority rather than other risks (e.g. short-term interrupt of supply due to accident or hike of oil price in international market).

Steps to analyze energy security

First Step:
- Specify the conceivable risks in Bangladesh energy situation

Second Step:
- Choose a suitable index to express the degree of each risk

Third Step:
- Integration of indices to one "energy security index"

Example of Conceivable Risk on Energy Security Bangladesh

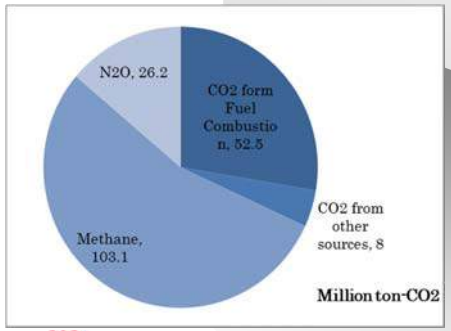
Impact to whom	Impact of when	Impact to what	Risk in Bangladesh
Nation (and passed along to consumer)	Short-term	Quantity	• Political and economic incidents of energy export countries • Accident on domestic energy supply facilities
		Price	• In addition to above, global energy market volatility
	Long-term	Quantity	• Rapid increase of domestic energy demand • Decrease of domestic energy sources (coal, gas)
		Price	• In addition to above, international energy demand increase which puts a pressure to international market price
Consumer	Short-term	Quantity	• Accident on domestic energy supply chain
		Price	• Same as above
	Long-term	Quantity	• Insufficient investment for energy supply chain
		Price	• Highly regulated domestic energy market

(4) Considerations for Environmental Issues

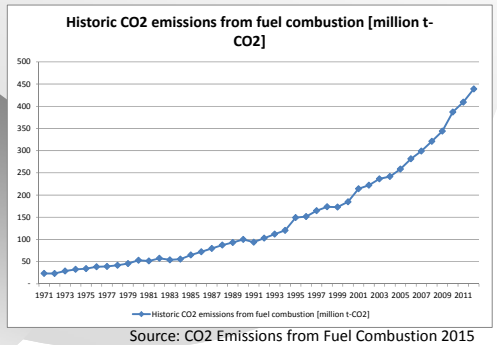
Environmental Policy: Current Status of GHG Emission

- As seen in the pie-chart on the left, it is estimated that CO2 emissions from fuel combustion accounts for less than one third of total green house gas(GHG) emissions in IEA publication.
- Accordingly, power sector has not necessary been the first priority for GHG emissions reduction in Bangladesh. Nevertheless, As seen in the chart on the right, CO2 emissions from fuel combustion(including power sector)has been increasing and it will be large portion of GHG emissions in Bangladesh.

Estimated GHG emissions by gases in Bangladesh



CO2 emissions from fuel combustion in Bangladesh



Source: CO2 Emissions from Fuel Combustion 2015

Bangladesh's Involvement in UNFCCC

- At COP19 Meeting (Bali Island, 2012), Countries have agreed to publicly outline what post-2020 climate actions they intend to take under a new international agreement. The action is called Intended Nationally Determined Contributions (INDCs).
- Bangladesh government submitted INDC: Intended Nationally Determined Contributions to UNFCCC secretariat in September 2015. Other countries also submitted INDC and all the submitted INDCs cover around 90% of total CO2 emissions in the world.
- Particularly, Bangladesh stated on power sector's action in INDC as measures assumed conditional contribution.

Proposed Commitments of Bangladesh Government

Mitigation contribution

- Unconditional contribution (Contribution assuming no additional international support)
  - Reduce GHG emissions in the power, transport, and industry sectors by 12 MtCO2e by 2030 or 5% below BAU emissions for those sectors
- Conditional contribution (Contribution assuming additional international support)
  - Reduce its GHG emissions in the power, transport, and industry sectors by 36 MtCO2e by 2030or 15% below BAU emissions for those sectors

Existing mitigation actions(Measures assumed in Unconditional contribution)

- Power
  - A target to deliver 5% of energy from renewable sources by 2015, and 10% by 2020 (2008Renewable Energy Policy)
  - Construction of Combined Cycle Power Plant (CCPP) by the Government of Bangladesh and utilities companies

Additional mitigation actions in power, industry and transport (Measures assumed in Conditional contribution)

- Power
  - Ensure all new coal generation uses super-critical technology (100% of new coal based power plants use super-critical technology by 2030)
  - Increased penetration of wind power（400 MW of wind generating capacity by 2030)
  - Implement grid-connected solar plant to diversify the existing electricity generation mix(1000 MW of utility-scale solar power plant)

Commitments of Other Asian Countries

- Among the other Asian countries that submitted INDC, India especially expresses proactive commitments to address the GHG emission in power sector.
- It is noted that India shows an expectation on the next-generation clean-coal technologies such as IGCC and IFGC and nuclear power.

Summary of INDC Submitted by India

Target of Reducing GHG Emission	Technologies to be Promoted
▪ Reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level. • Achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF). • Create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030 ▪ India declared a voluntary goal of reducing the emissions intensity of its GDP by 20–25%, over 2005 levels, by 2020, despite having no binding mitigation obligations as per the Convention	▪ Clean Coal Technologies (CCT) • Pulverized Combustion Ultra Super Critical (PC USC) • Pressurised Circulating Fluidised Bed Combustion, • Super Critical, Combine Cycle (PCFBC SC CC) • Integrated Gasifier Combined Cycle (IGCC) • Solid Oxide Fuel Cell (SOFC) • Integrated Gasifier Fuel Cell (IGFC) • Underground Coal gasification (UCG) ▪ Nuclear Power • Pressurized water reactor • Integral pressurized water reactor • Advanced Heavy Water Reactor (AHWR) • Fast breeder reactor (FBR) • Accelerated-driven systems in advanced nuclear fuel cycles

Steps Ahead of This Study

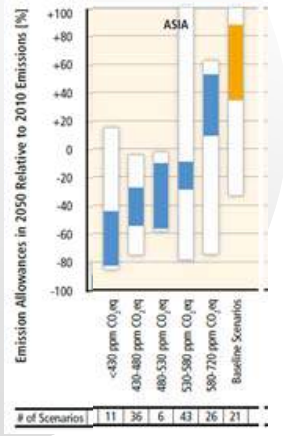
- Following the agreements of COP21 (Paris, December 2015) on GHG emission towards 2030, this study will discuss the possible direction of UNFCCC beyond 2040, such as the timetable and the institutional setup of negotiations.
- Then, also referring to the 5th Assessment Report (AR5) of IPCC, this study discusses what responsibilities Bangladesh will have to assume to deal with GHG by 2041.
  - AR5 stipulates that, for achieving 450ppm scenario, Asian countries will have to reduce CO2 emission by at maximum 60% compared to 2010.
- This study will discuss the possible measures that Bangladesh can take, both from technical and policy aspects, taking into account the proposed measures in INDC up to 2030.

Opening Session of COP21 in Paris



Source: IISD

Allowance of CO2 Emission for Asian Countries stipulated in AR5



Source: IPCC AR5

Other Environmental Considerations

- In Bangladesh, reduction of GHG emission from other sectors than energy supply also needs to be dealt with priority.
- Recently more attention has been paid to short-lived climate pollutants such as black carbon and tropospheric ozone, which have relatively short lifetime in the atmosphere but have strong greenhouse effect
- An international initiative called CCAC (Climate and Clean Coalition) summarizes the main issues concerning short-lived climate pollutants as follows. This study will also discuss this, especially focusing on those related to energy supply.
  - Cook stoves: black carbon
  - Brick kilns: black carbon
  - Vehicular emission: black carbon
  - Open burning: black carbon
  - Rice parboiling systems: black carbon
  - Paddy rice cultivation: methane
  - Municipal waste deposits: methane
  - Livestock (manure and enteric fermentation): methane





Source:
http://www.unep.org/ccac/Portals/50162/COP20/docs/11Dec_Agriculture_side_event/Raisul_Alam_Mondal_Bangladesh_Presentation_CCAC_COP20_11_Dec_Agriculture.pdf

CCAC CLIMATE AND CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

2. Primary Energy

2-2 Domestic Natural Gas

(1) Current Status of Existing Gas Fields
(2) Production Forecasts
(3) Cost Estimation of Seismic Survey and Well Drilling
(4) Future Gas Development

(1) Current Status of Existing Gas Fields

Bangladesh Gas Production : Actual < PSMP 2010 Forecast

Unit: mmscfd

Sl. No.	Gas Field	Average Daily Production							
		Actual					PSMP2010 Forecasts		
		2010	2011	2012	2013	2014	2010	2014: Case1	2014: Case 2
1	Titas	404	445	450	490	515	408	578	560
2	Habiganj	235	260	227	225	225	240	260	260
3	Bakhrabad	35	33	32	41	41	36	51	51
4	Kailashtila	91	86	89	84	74	87	97	97
5	Rashidpur	49	49	47	47	61	49	84	85
6	Sylhet/Haripur	3	10	9	9	8	7	30	30
7	Meghna	0	10	10	11	10	0	5	5
8	Narshingdi	33	30	30	28	28	35	25	25
9	Beanibazar	15	9	11	10	10	15	15	15
10	Fenchuganj	25	23	36	37	39	24	65	60
11	Saldanadi	8	18	16	15	12	8	8	8
12	Shahbazpur	6	0	7	7	8	8	10	10
13	Semutang	0	14	8	6	5	0	15	15
14	Sundalpur	0	0	10	10	4	0	60	60
15	Srikail	0	0	0	42	39	0	60	60
16	Sangu	37	14	23	0	0	40	0	0
17	Jalalabad	163	165	232	249	246	130	250	200
18	Moulavi Bazar	58	42	94	77	63	60	160	80
19	Bibiyana	658	753	792	822	1,007	716	900	850
20	Bangura	105	102	86	111	110	120	120	120
21	Begumganj	0	0	0	0	0	0	0	0
22	Kutubdia	0	0	0	0	0	0	0	0
23	Chattak	0	0	0	0	0	0	0	0
24	Kamta	0	0	0	0	0	0	0	0
25	Feni	2	0	0	0	0	2	2	2
	Total	**1,926**	**2,062**	**2,210**	**2,323**	**2,435**	**1,995**	**2,765**	**2,563**

Note: A production rate of 60 mmscfd for Sundalpur and Srikal by the PSMP2010 forecasts means that the sum of production from Sundalpur and Srikail should be equal to 60 mmscfd in this case.

Source: Prepared based on Petrobangla Annual Reports 2010 to 2014 and PSMP2010 report (JICA, 2011)

Bangladesh Gas Production : Actual < PSMP 2010 Forecast

- Only Bibiyana gas field has shown a steady increase in production since 2010.
- The Jalalabad gas field showed a significant increase in production in 2012.
- Production from Sangu gas field was suspended from Oct. 1, 2013.
- Counter measures against excessive water production (e.g. Titas-21 well) is important for the existing gas fields.
- Successes of new development wells are important to increase production in the future.
- Reserve additions by installing wellhead compressors in mature fields will result in the extension of the field life.

Counter measures for production issues

Maintaining Production Levels	Production Argumentation
Major issues: ● Excessive water production ● Sand production	Major Issues: ● Gas recovery is not maximized
Counter Measures: ● Successful drilling and completion operations ● Successful well workover operations	Counter Measures: ● Well-head gas compressor installation (on-going) ● Horizontal Drilling and Completion technology introduction (optional)
Required: ● Operational Experience and Skills	Required: ●
How to Obtain: ● Strategic alliance with foreigners/IOCs	How to Obtain: ● GDF utilization

Installation of Wellhead Compressors

- The installation of wellhead gas compressors is planned for eight (8) gas fields.

Gas Field	Predicted Year of Installation	Remarks
Titas	Around 2016	BGFCL has undertaken a project to install wellhead compressor at this field with JICA finance.
Narshingdi	Around 2017	BGFCL has undertaken a project to install wellhead compressor at this field with JICA finance.
Meghna	Around 2027	Compressor will not be required in the near future.
Kailashtilla	Around 2023	Compressor will not be required in the near future.
Sylhet	Around 2017	This field is supplying gas to JGTDSL network at about 550 psig. Commercial viability of compression should be examined.
Fenchuganj	Around 2017	
Semutang	Around 2016	Commercial viability of compression should be examined.
Srikail	Around 2015	Preparatory works to undertake a project by BAPEX is underway.

Source: Prepared based on Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

Measures for Maintaining Prod. Levels

Major production problems:
- Excessive water production
- Sand production

Measures:
- Successful drilling and completion operations
- Successful well workover operations

Required

Operational Experience and Skills

Measures for Production Augmentation

Technical Challenges for maximizing gas recovery

In addition to conventional development drilling:

Installation of Wellhead Gas Compressors

In mature gas fields

Extension of Field Life

One of other possible options:

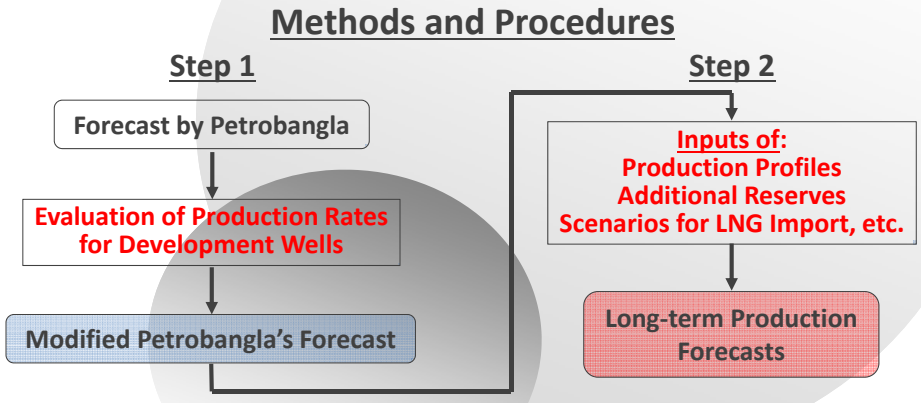
Introduction of Horizontal Drilling and Completion Technology

Note: A feasibility study may be required.

(2) Production Forecasts

Production Forecasts takes 2 steps

- **Step 1: Production forecast for existing gas fields for the period of 2015-2019 (based on that by Petrobangla)**
- **Step 2: Production forecast for the period of 2015-2041**



Production Forecast : Petrobangla

- The production rates in most of the gas fields are considered to be somewhat overestimated.
- A peak production occurs in the second half of the year 2016.

Unit: mmscfd

Company	Fields	2015		2016		2017		2018		2019	
		Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec
1. BGFCL	Titas	525	520	520	590	580	570	510	510	460	460
	Bakrabad	40	38	36	34	30	26	23	23	30	30
	Habiganj	224	224	224	224	220	218	215	215	200	200
	Narsingdi	28	28	28	28	26	25	24	24	23	23
	Meghna	10	10	10	10	10	10	9	9	9	9
	Sub-total	**827**	**820**	**818**	**886**	**866**	**849**	**781**	**781**	**722**	**722**
2. SGFL	Sylhet	8	8	7	17	16	15	15	14	14	13
	Kailashtila	72	85	110	125	125	120	120	115	115	110
	Rashidpur	60	59	58	57	56	65	85	83	80	80
	Beani Bazar	9	9	9	9	8	8	8	8	8	8
	Sub-total	**149**	**161**	**184**	**208**	**205**	**208**	**228**	**220**	**217**	**211**
3. BAPEX	Saldanadi	10	18	18	15	14	13	12	12	12	12
	Fenchuganj	35	34	32	30	30	29	28	28	28	28
	Shahbazpur	45	45	45	45	45	45	50	50	50	50
	Semutang	4	3	2	2	10	15	15	15	15	15
	Sundalpur	3	3	2	8	8	8	8	8	8	8
	Srikail	38	36	55	55	50	50	50	50	45	45
	Rupganj	0	8	8	8	8	8	7	7	7	7
	Begumganj	8	10	10	10	8	23	21	18	14	10
	Sub-total	**143**	**157**	**172**	**173**	**173**	**191**	**191**	**188**	**179**	**175**
Sub-total (1+2+3)		**1,119**	**1,138**	**1,174**	**1,267**	**1,244**	**1,248**	**1,200**	**1,189**	**1,118**	**1,108**
4. Chevron	Jalalabad	250	250	250	250	220	220	220	220	220	220
	Maulavibazar	60	60	55	55	50	50	50	50	50	50
	Bibiyana	1,050	1,150	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200
5. Tullow	Bangora	115	115	114	114	85	85	72	72	60	60
Sub-total (4+5)		**1,475**	**1,575**	**1,619**	**1,619**	**1,555**	**1,555**	**1,542**	**1,542**	**1,530**	**1,530**
6.	Feni				10	20	20	20	18	15	13
7.	Chhatak				20	40	40	40	35	35	30
Ground Total (1+2+3+4+5+6+7)		**2,594**	**2,713**	**2,793**	**2,916**	**2,859**	**2,863**	**2,802**	**2,784**	**2,698**	**2,681**

Source: Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

Production Forecast: PSMP2015 (1)

- A production forecast was prepared by modifying the Petrobangla 's forecast because of the following reasons:
  - The delay in the time of well completion will occur in the period of 2015-2019 with high probability.
  - The daily production rates for new development wells are considered to be somewhat overestimated.
- Evaluation of the daily production rates estimated by Petrobangla based on the comparison between plan and actual results for the times of well completion, and the daily production rates:
  - Times of well completion: At least **one year behind schedule** for recently drilled wells
    - → Assumed to be **one year behind schedule in the period of 2015-2019 (5 years)**
    - → **Expressed as decrease in production rate: Production decreases by 20%**
  - Daily production rates for new development wells: **About 70%** of those estimated by Petrobangla
    - → Assumed to be **70%** of the initial estimates by Petrobangla
- A peak production occurs in the second half of the year 2016 (the same as Petrobangla's forecast).

Production Forecast: PSMP2015 (2)

Unit: mmscfd

Company	Field	2015		2016		2017		2018		2019		Remarks
		Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	
1. BGFCL	Titas	525	520	520	566	556	546	489	489	441	441	Production start-up: Jul-Dec 2016—Well nos. 23, 24, 25 and 26
	Bakrabad	40	38	36	34	30	26	23	23	30	30	
	Habiganj	224	224	224	224	220	218	215	215	200	200	
	Narsingdi	28	28	28	28	26	25	24	24	23	23	
	Meghna	10	10	10	10	10	10	9	9	9	9	
	Sub-total	**827**	**820**	**818**	**862**	**842**	**825**	**760**	**760**	**703**	**703**	
2. SGFL	Sylhet	8	8	7	13	12	11	11	10	10	9	Production start-up:Jul-Dec 2016—Well no. 9
	Kailashtila	72	78	92	100	100	96	96	92	92	88	Production start-up: Jul-Dec 2015—Well no. 1&5, Jan-Jun 2016—Well no. 9, Jul-Dec 2016—Well no. 7
	Rashidpur	60	59	58	57	56	61	72	70	67	67	Production start-up: Jul-Dec 2017–Well no. 9, Jan-Jun 2018–Well nos. 10 & 11
	Beani Bazar	9	9	9	9	8	8	8	8	8	8	
	Sub-total	**149**	**154**	**166**	**179**	**176**	**176**	**187**	**180**	**177**	**172**	
3. BAPEX	Saldanadi	10	16	16	13	12	11	10	10	10	10	Prpduction start-up: Jul-Dec 2015—Well no. 4
	Fenchuganj	35	34	32	30	30	29	28	28	28	28	
	Shahbazpur	10	29	29	29	29	29	29	29	29	29	Production start-up: Jul-Dec 2015—Well no. 4
	Semutang	4	3	2	2	6	10	10	10	10	10	Production start-up: Jan-Jun 2017—Well no. 7, Jul-Dec 2017—Well no. 8
	Sundalpur	3	3	2	4	4	4	4	4	4	4	Production start-up: Jul-Dec 2016—Well no.2
	Srikail	38	36	46	46	41	41	41	41	36	36	Production start-up: Jan-Jun 2016—Well no. 4
	Rupganj	0	8	8	8	8	8	7	7	7	7	
	Begumganj	4	12	12	12	10	18	16	16	12	9	Jan-Jun 2015: Actual production, Production start-up: Jul-Dec 2015—Well no. 3, Jul-Dec 2017—Well no. 4
	Sub-total	**104**	**141**	**147**	**144**	**140**	**150**	**145**	**145**	**136**	**133**	
Sub-total (1+2+3)		**1,080**	**1,115**	**1,131**	**1,185**	**1,158**	**1,151**	**1,092**	**1,085**	**1,016**	**1,008**	
4. Chevron	Jalalabad	250	250	250	250	220	220	220	220	220	220	
	Maulavibazar	50	50	50	50	45	45	45	45	45	45	Jan-Jun 2015: Actual production
	Bibiyana	1,100	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	Jan-Jun 2015: Actual production
5. Tullow	Bangora	110	110	109	109	81	81	69	69	58	58	Jan-Jun 2015: Actual production
Sub-total (4+5)		**1,510**	**1,610**	**1,609**	**1,609**	**1,546**	**1,546**	**1,534**	**1,534**	**1,523**	**1,523**	
6.	Feni				6	12	12	12	11	9	8	Resumption of production: Jul-Dec 2016—Well no. 6, Jan-Jun 2017—Well no. 7
7.	Chhatak				11	22	22	22	19	19	16	Resumption of production: Jul-Dec 2016—Well no. 3, Jan-Jun 2017—Well no. 4
Ground Total (1+2+3+4+5+6+7)		**2,590**	**2,725**	**2,740**	**2,811**	**2,738**	**2,731**	**2,660**	**2,649**	**2,567**	**2,555**	

Note: **Production rates in yellow cells were modified** from those shown in Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

Source: Petrobangla's "Draft Five Year Gas Supply Strategy" (2015) and PSMP2015 survey team

Long-term Production Forecasts

- Long-term production forecasts cover the period of 2015-2041
- The major factors affecting production forecasts:
  - Production forecasts for the period of 2015-2019
  - Production decline rates for each gas field
  - Production from new discoveries
  - Installation of wellhead gas compressors for maximizing recovery from existing gas fields
  - LNG import plan

(3) Cost Estimation of Seismic Survey and Well Drilling

Cost Estimation of Seismic Survey

Cost for 2D and 3D seismic surveys are estimated as follows:

- **2D seismic survey: 5.1 thousand USD per line-km**
- **3D seismic survey: 12.0 to 18.5 thousand USD per sq. km**

As of October 2015

Field/Area	Length (line-km)	Area (sq km)	Survey Period	Estimated Survey Cost		Cost Analysis		Remarks
				M BDT	M USD	Cost per line-km K USD	Cost per sq km K USD	
Dhaka, Manikganj, Shariatpur, Faridpur, Gopalganj, Madaripur, Khulna, Netrokona, Kishoreganj, Sunamganj, Habiganj, Sylhet, Maulavibazar and Bhola	1,800	—	Dec. 2012 (?) - (Underway)	711.3	9.15	5.1	—	
Titas	—	335	2010 - 2012 (Details unknown)	784.5 (for 2 fields)	10.09 (for 2 fields)	—	18.5	• Appraisal of Gas Field (3D Seismic) (Titas, Bakhrabad, Sylhet, Kailashtila and Rashidpur) Project (Revised)
Bakhrabad	—	210						
Rashidpur	—	325		859.5 (for 3 fields)	11.05 (for 3 fields)	—	15.7	
Kailashtila	—	190						
Sylhet	—	190						
Sunetra	—	260	May 2013 (?) - (Underway)	1,825.0 (for 6 fields/area, 1,950 sq km in total)	23.47 (for 6 fields/area, 1,950 sq km in total)	—	12.0	
Shahbazpur	—	600						
Sundalpur-Begumganj	—	440						
Srikail	—	150						
Narshingdi	—	250?						
Habiganj	—	250?						

Note: The BDT to USD exchange rate on January 1, 2015 (1 BDT = US$ 0.01286) is used.

Source: Prepared based on Petrobangla Annual Report 2012 and BAPEX Annual Reports 2013 and 2014

Cost Estimation of Well Drilling (1)

Costs for two model wells are estimated:

- **Model well with a total depth of 3,000 m: 9.5 million USD** (based on the cost for well Fenchuganj-5)
- **Model well with a total depth of 4,500 m: 10.9 million USD** (based on the costs for wells Mubarakpur-1 and Sunetra-1)

As of October 2015

Well Name	Expl./ Appr./ Dev.	Well Type	Well Depth (m)		Operation Period	Estimated Well Drilling Cost		Remarks
			Proposed	Actual		M BDT	M USD	
Titas-27	Dev.	Directional	(N/A)	3,138	Nov. 19, 2013 - Apr. 11, 2014	1,070.0	13.8	
Mubarakpur-1	Expl.	Vertical?	4,500 (+)	(Underway)	Aug. 22, 2014 - (Underway)	892.6	11.5	• Mubarakpur Oil/Gas Exploration Well Drilling Project
Sundalpur-1	Expl.	Vertical?	(N/A)	3,327	Dec. 21, 2010 - Mar. 11, 2011	736.5	9.5	• Discovery well
Kapasia-1	Expl.	Vertical?	(N/A)	3,301	Feb. 6, 2012 - Apr. 13, 2012	701.7	9.0	• Kapasia Oil/Gas Exploration Well Drilling (Revised) • Dry
Srikail-2	Appr.	Vertical?	(N/A)	3,214	May 5, 2012 - June 29, 2012	811.2	10.4	• Srikail Oil/Gas Exploration Well Drilling Project (Well #2) • Discovery well
Fenchuganj-5	Dev.	Vertical	3,100	3,137	Sept. 27, 2013 - (?)	760	9.8	• A part of Salda # 3, 4 & Fenchuganj # 4, 5 Gas Fields Development Project • Dry
Sunetra-1	Expl.	Vetical	4,500	4,683	Aug. 10, 2012 - Mar. 18, 2013	802.5	10.3	• Sunetra Oil/Gas Exploration Well Drilling Project • Dry
Rashidpur-8	Dev.	Vertical	2,902	2,990	(?) - Aug. 27, 2014	1,705.0	21.9	• Drilling was undertaken by Gazprom.
Rupganj-1	Expl.	Vertical	3,700	3,615	May 19, 2013 - (?)	970.0	12.5	• Discovery well
Sundalpur-2	Dev.	Vertical?	3,250	—	—	754.5	9.7	• Well has not been drilled yet.

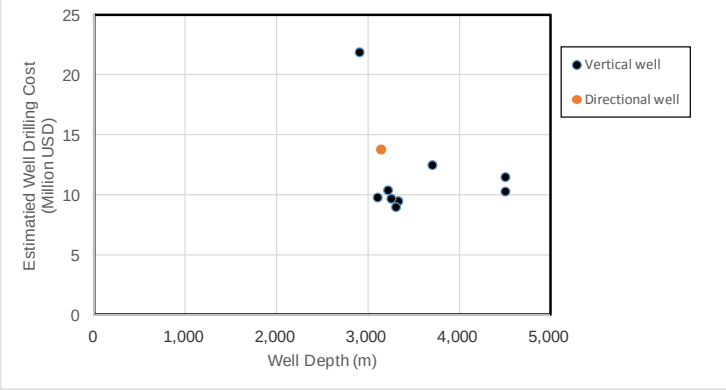
Note: The BDT to USD exchange rate on January 1, 2015 (1 BDT = 0.01286 USD) is used.

Source: Prepared based on Petrobangla Annual Reports 2012 and 2013, etc.

Cost Estimation of Well Drilling (2)

- **No apparent relationship between estimated well drilling costs and well depths** is found due to:
  - A small amount of data set
  - Relatively narrow range of well depths

(In general, it is empirically known that a well drilling cost can be described as an exponential function of depth.)



Source: Prepared based on the data sets in the table on p. 28.

(4) Future Gas Development

Offshore Exploration Activities

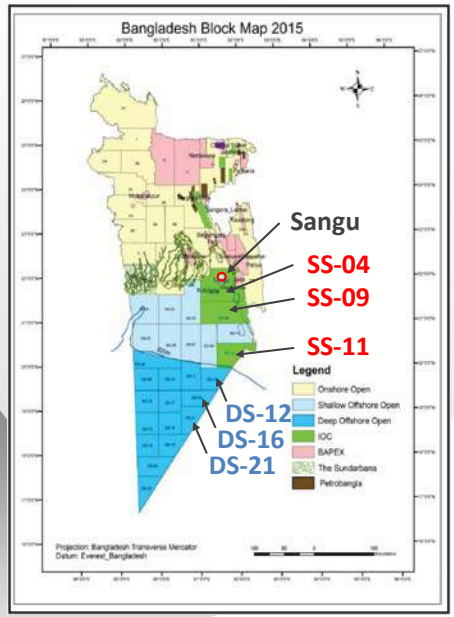
Offshore Bidding Round 2012

Shallow Water Blocks:

- **JV of ONGC Videsh, Oil India and BAPEX:**
  Blocks SS-04 and SS09
- **JV of Santos, KrisEnergy and BAPEX:**
  Block SS-11

Deepwater Blocks:

- **JV of ConocoPhillips and Statoil:**
  Blocks DS-12, DS-16 and DS-21
  (PSCs have not been signed yet.)



Source: Prepared based on Petrobangla Annual Reprot 2014

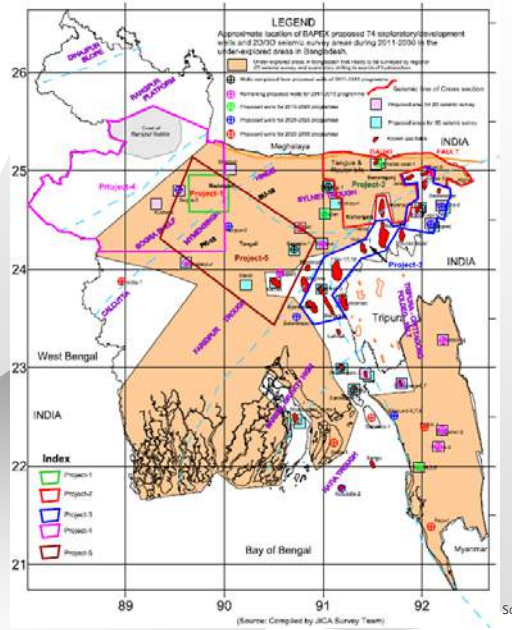
Proposed New Exploration Projects

The following new exploration projects which have not been planned by Petrobangla are proposed (JICA, 2014):

- **Project 1 (exploration in under-explored areas):** 2D seismic survey and exploration drilling in the Madargandj and Sariakandi areas
- **Project 2 (exploration in difficult areas):** 2D seismic survey over the marshy-swampy areas of the Sunamganj-Kishorganj and surrounding areas and deep drilling
- **Project 3 (exploration in deep structures in existing gas fields):** Deep drilling in the Bakhrabad gas field area
- **Project 4 (exploration for unconventional gas resources):** High resolution 2D seismic survey to identify all the Gondwana coal basins and drilling to confirm the presence of coal deposits and their CBM potential over the Bogra Shelf and Rangpur Platform areas
- **Project 5 (exploration in under-explored areas):** 2D seismic survey over the Bogra-Lalmai low amplitude broad structure and exploratory deep drilling

(*See p. 34*)

Location of Proposed Projects



Source: Fig. 9.4-1 from JICA (2014)

Sizes and Prod. Capacity of New Fields

Estimation Methods and Procedures

Estimation of Sizes (GIIPs) of New Gas Fields

Sizes (GIIPs) of Existing Gas Fields

Histogram analysis

Sizes (GIIPs) of New Gas Fields

Assuming ***Recovery Factor***

Sizes (Recoverable Reserves) of New Gas Fields

Estimation of Production Capacity of New Gas Fields

Current Production Capacity of Existing Gas Fields

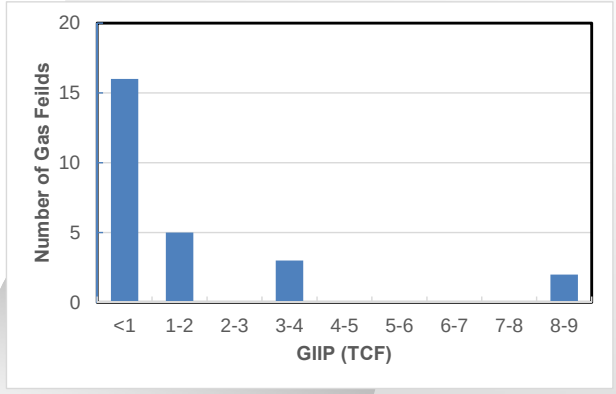
Relationship between production capacity and remaining reserves (2P)

Production Capacity of New Gas Fields

Note: Production capacity also depends on the number of producing wells and flow rate per well.

Sizes of Existing Gas Fields

- **GIIPs** of most of newly discovered gas fields are estimated to be **smaller than 1 TCF**.
  → **Recoverable reserves**: smaller than 0.7 TCF (assuming average recovery factor is about 70%) (*see also p. 37*).



Source: Prepared based on Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

Recovery Factors of Existing Gas Fields

- An average recovery factor is estimated to be **roughly 70%**.

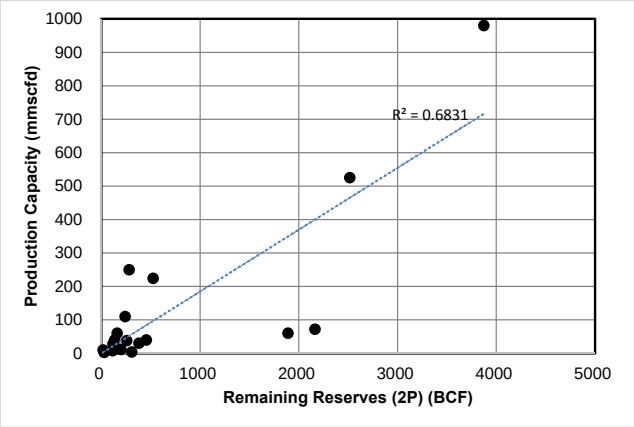
Gas Field	GIIP (BCF)	Proved + Probable (2P) Reserves (BCF)	Recovery Factor (%)
Titas	8,148.9	6,367.0	78.1
Habiganj	3,684.0	2,633.0	71.5
Bakrabad	1,701.0	1,231.5	72.4
Kailashtila	3,610.0	2,760.0	76.5
Rashidpur	3,650.0	2,433.0	66.7
Sylhet/Haripur	370.0	318.9	86.2
Meghna	122.1	69.9	57.2
Narshingdi	369.0	276.8	75.0
Beani Bazar	230.7	203.0	88.0
Fenchuganj	553.0	381.0	68.9
Shaldanadi	379.9	279.0	73.4
Shahbazpur	677.0	390.0	57.6
Semutang	653.8	317.7	48.6
Jalalabad	1,491.0	1,184.0	79.4
Moulavi Bazar	1,053.0	428.0	40.6
Bibiyana	8,350.0	5,754.0	68.9
Bangura	1,198.0	522.0	43.6
Sundulpur Shahbazpur	62.2	35.1	56.4
Srikail	240.0	161.0	67.1
Begumganj	100.0	70.0	70.0
Kutubdia	65.0	45.5	70.0
Rupganj	48.0	33.6	70.0
Chhatak	1,039.0	474.0	45.6
Kamta	71.8	50.3	70.1
Feni	185.2	125.0	67.5
Sangu	899.6	577.8	64.2
		Average	66.7

→ **70%**

Source: Prepared based on Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

Prod. Capacity of Existing Gas Fields

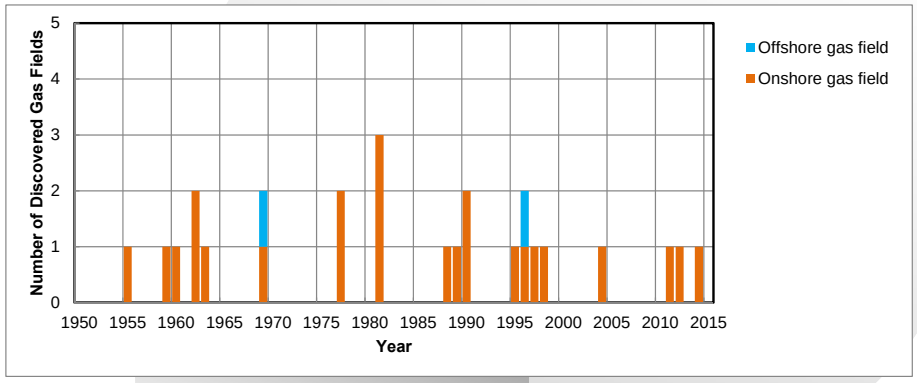
- Production capacity of new gas fields can be roughly estimated by using the relationship between the current production capacity and remaining 2P reserves .



Source: Prepared based on Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

Frequency of Gas Field Discoveries

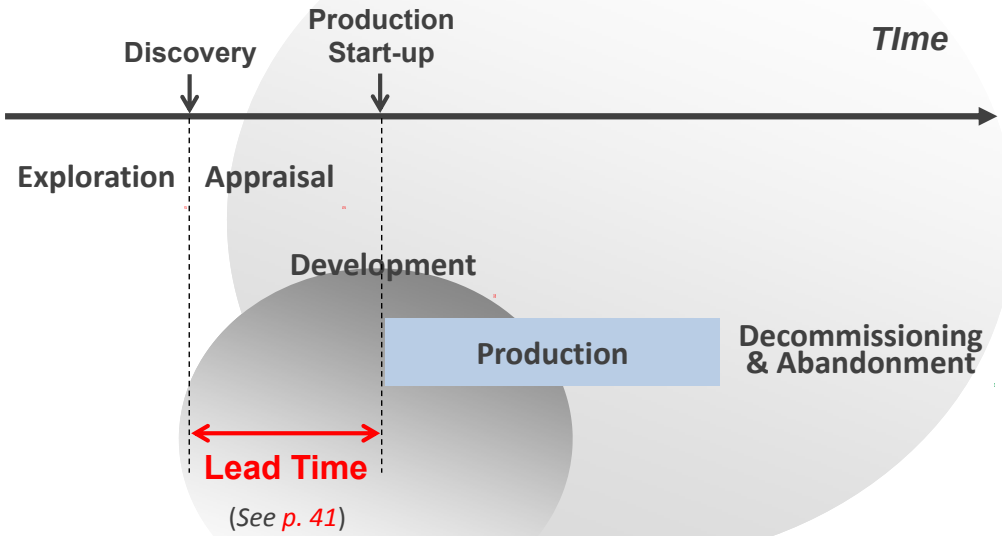
- The rate of discovery for 1950 to 2014 with 26 gas fields resulted in **0.4 fields per year** (or **2 fields per 5 years**) in average.



Source: Prepared based on Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

Lead Time to Production Start-up (1)

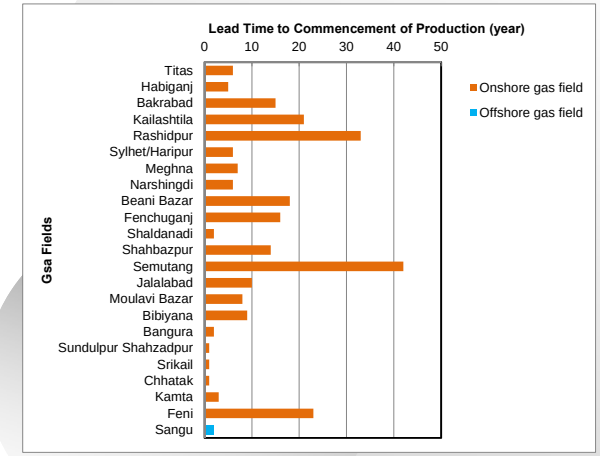
In Bangladesh



(*See p. 41*)

Lead Time to Production Start-up (2)

- The average lead time is about 10 years.
- The average lead time will be shortened in the future because the lead times for 14 out of a total of 23 fields show less than 10 years.



Source: Prepared based on data from Petrobangla's "Draft Five Year Gas Supply Strategy" (2015), etc.

Possible Future Assistance from Japan

Future Assistance from Japan will be focused on two categories:

- **Participation in Exploration and Development Projects**
  - Seismic survey
  - Well drilling
  - Geological and geophysical (G&G) study
  - Reservoir engineering
  - Engineering study on infrastructure

- **Technical Capacity Building**
  - Geology & geophysics for oil and gas exploration and development
  - Basin evaluation and geochemistry
  - Drilling in overpressure zone
  - Production and O&M
  - Seismic survey in marine and difficult areas
  - Horizontal well drilling and completion technology

Natural Gas Exploration and Supply

1. Onshore Exploration and Supply

1.1 Aging Existing Gas Fields

Heavily relying on existing gas production fields but the production is declining

1.2 Fast Truck Program to be reviewed

GoB signed a contract with Gazprom to drill 10 wells in September 2012 on turn key basis. The project completed, however, 2 wells failed and performance of some others are unsatisfactory. Further contract with Gazprom to drill 6 wells are underway. Risk of failure to be minimized this time.

1.3 Introduction of Industrial Best Industrial Practice through competitive bid

BGFCL is introducing Best Industrial Practice through competitive bidding. Bid result shows that this can be attainable at a significantly low cost.

1.4 Introduction of PSC to Onshore Exploration for risk mitigation

Introduce PSC with IOCs and domestic Gas Field Companies for future exploration acreage to minimize the risk involved in the exploration.

Natural Gas Exploration and Supply

1.5 Exploitation of Confirmed Potentials

Chhatak Gas Field Development to be resumed (Condensate recovery to be maximized).

2. Offshore Exploration
   - Model PCS to be revised to attract IOCs .

3. Role of BAPEX to be re-defined
   - Role of BAPEX to be reviewed and transformed to match the level of IOCs, and allows BAPEX to acquire energy assets overseas.

2. Primary Energy

2-3 Import Liquefied Natural Gas (LNG)

(1) LNG Connection to the Existing Gas pipeline

(2) LNG Terminal Layout Examination

(1) LNG Connection to the Existing Gas pipeline

LNG Development Study

1. Background of the study

- A huge gap between domestic NG supply capacity and the growing NG demand
- Less expectation of domestic NG exploration mainly in Sylhet in the future
- LNG import will be one of the significant measure to compensate this gap.
- LNG regasification plant to produce NG from LNG should be cost effective, safety & reliable in operation, and environmental friendly.
- Well experienced consultant should advise technically from FS to commissioning.

LNG Development Study

2. Scope of work & Methodology

- Meteorologic /hydrographic condition ⇒(Interview to other team of power plant study)
- Allowed LNG vessel (shipment) capacity⇒ (Check the chart nearby and interview to port authority)
- Soil condition⇒ (Site survey & interview to other team of power plant study)
- Environmental regulation ⇒(interview to local gas distribution Co.(KGDCL) and Petrobangla)
- Check the physical property difference between domestic NG and imported LNG (calorie, impurities, etc.)⇒(Interview to Petrobangla)

(continued)

LNG Development Study

2. Scope of work & Methodology

- NG send out condition from the terminal in compliance with the existing pipeline gas at tie-in point ⇒(Interview to KGDCL)

- Operation and management policy of national pipeline network in case of terminal emergency and/or planned shutdown⇒ (Interview to Petrobangla & national gas transmission Co.(GTCL))

- Study of new distribution pipe line from the terminal to power plant and/or fertilizer, etc. ⇒ （Interview to KGDCL)

LNG Development Study

3. Other study topics

- Near to candidate onshore LNG receiving terminal site in Moheshkhali Island, offshore FSRU (floating storage and regasification units) of 500 mmcfd is likely to be applied in advance. Thus we have to study how FSRU and LNG terminal should be optimally utilized.

- Recently among ASEAN countries, due to the healthy economic growth, the construction of LNG receiving terminal is booming like in Singapore, Indonesia, and Thailand.

  Therefore we would like to study other countries' situation how they had come up with LNG terminal construction, which will be useful information for FS in Bangladesh.

(2) LNG Terminal Layout Examination

Onshore LNG receiving terminal plan

At pre-fs stage, for the budgetary and land space study, the following technical issues should be specified and agreed.

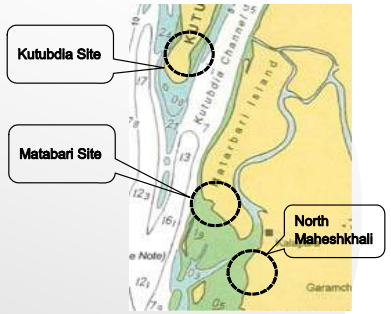
(1) Annual LNG operation capacity & gas production rate
(2) LNG Tank storage capacity
(3) Type selection of vaporizer
(3) Gas send out pressure from the terminal
(4) Necessity of BOG re-liquefaction system
(5) Necessity of heat value adjustment by LPG or air
(6) Necessity of odorization system
(7) Spare unit arrangement of main equipment
(8) Future expansion plan (road map to expansion)



Site selection study

Candidate site of LNG receiving terminal

Case	Candidate site and condition		Remark
Case1-1	Matabari Site	Jointly owned port	Jointly own port by coal power station and LNG receiving terminal
Case1-2		Individual port (without breakwater)	Construct LNG jetty in front of the ocean without breakwater
Case1-3		Individual port (with breakwater)	Construct LNG jetty and breakwater in front of the ocean
Case2	North Maheshkhali Site		Dredge shallow beach and construct channel and LNG jetty
Case3	Kutubdia Site		Dredge Kutubdia Channel and construct LNG jetty



Evaluation result of candidate

Case	Case1-1	Case1-2	Case1-3	Case2	Case3
Calmness	Excellent	Not so good	Excellent	Excellent	good
Comparison of Cost	Cost effective	Cost effective *Filling Soil Balance	Fairly expensive(Break water construction)	Expensive (Continuous dredging)	Expensive (Continuous dredging)
Evaluation result	◎	○	○	○	×

Remark: From civil point of view, the foundation of LNG facility yard should be raised by 10 m against the flood tide. Also the countermeasure should be studied for the large scale earthquake occurred in the boundary area between the plates in Bay of Bengal.

Challenges of future survey and study

For the future survey and study, the operation management procedure of LNG receiving terminal should be mainly focused. Namely the following issues should be planned to develop the total natural gas supply.

(1) Each responsibility of FSRU and onshore LNG receiving terminal
(2) Natural gas production platform by natural gas pipeline and LNG receiving terminal
(3) In case of the terminal shutdown due to power outage and natural disaster, pipeline backup to LNG receiving terminal
(4) Security measure of LNG receiving terminal

2. Primary Energy

2-4 Environment and Social

Environmental and Social Considerations

1 .Research on Environmental regulations and procedures
- Regulating agencies, required clearance and permit
- Emission standard or target

2 .Confirmation of the actual status of the development site
- Visit the operating coal mine and gas field and identify possible Environmental and Social impact

3 Draft Scoping possible impact
- Identify and evaluate magnitude, possibility, difficulty of the management of the possible impact

4 .Comparison of impact evaluations
- Compare Environmental and Social impact of coal development and gas field

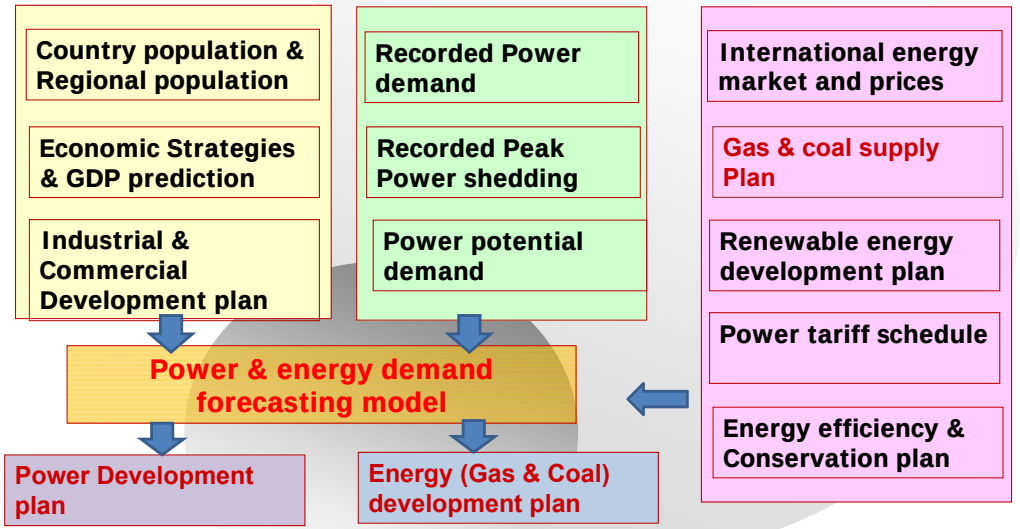
5 .Ways to development
- Identify the conditions to be cleared to the developments

3. Power Demand Forecast & Power Development Plan

(1) Power Demand Forecast

1. Power demand Model

Power M/P has to keep the consistency among the Strategies, Plans and Policies



2. GDP scenario

- *The Sixth and Seventh five year plans are implemented with political stability after 2015.*
- *The energy shortage (natural gas) will be resolved and the electricity import from neighboring countries is realized.*
- *The targeted economic growth rate with 8 % in Vision 21 is not realized, however, GDP growth rate with 7 % per year in five year plans (Sixth and Seventh) can be expected.*
- *Bangladesh GDP growth rate is in the range from 6% to 7 % per year.*
- *The following cases named Base case, High case and Low case are set as economic scenario.*

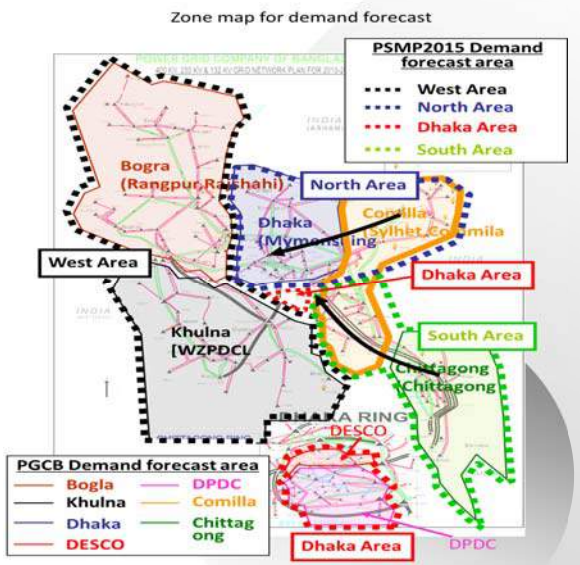
<GDP growth scenario> (%)

Case	Unit	2020/15	2025/20	2030/25	2035/30	2040/35	2040/15
Base	%	6.5	6.5	6.5	6.0	6.0	6.4
High	%	7.0	7.0	7.0	7.0	7.0	7.0
Low	%	6.0	6.0	6.0	5.0	5.0	5.7

Source: JICA Study team

3. Regional Forecasting

<Region definition>



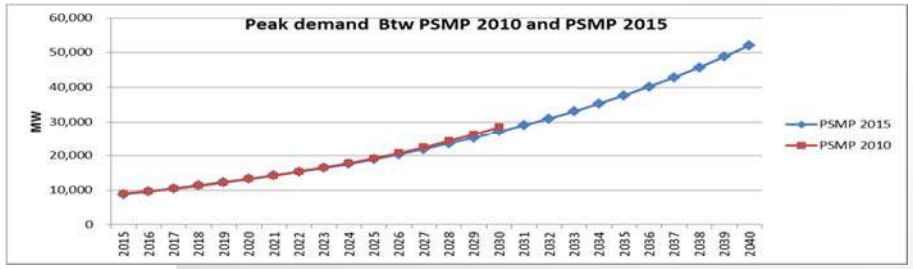
<Data collection>

Region	Distribution
Dhaka	DESCO
	DPDC
	Dhaka total
North	BPDB(Comilla)
	BPDB(Sylhet)
	REB(Syhet)
	BPDB(Mymenshing)
	North total
South	BPDB(Chittagong)
	REB(Chittagong)
	BPDB(Other)
	South total
West	BPDB(Rajshahi)
	BPDB(Rangpur)
	REB(Rangpur)
	REB(Rajshai)
	REB(Barisal)
	REB(Kulna)
	WZPDCL
	West total
Total	

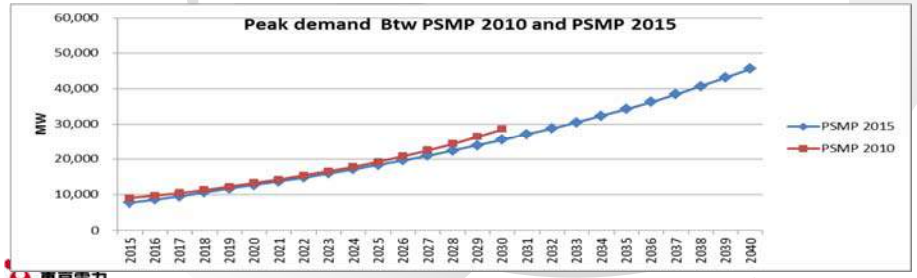
Source: Defined by JICA Study team

4. Power Demand Forecast

< Peak demand> (MW)



< Peak demand With EE&C >

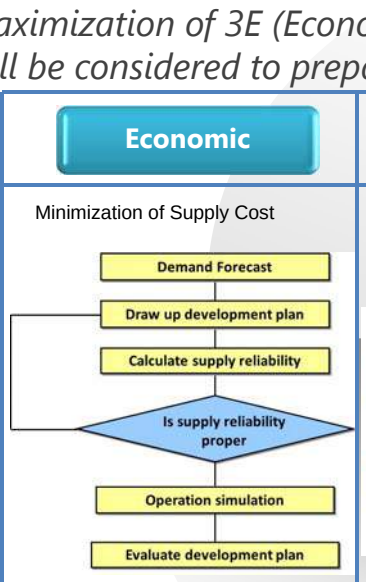


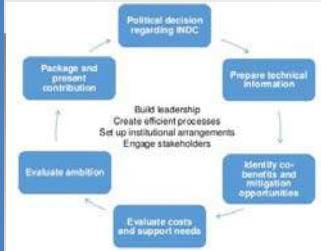
(2) Power Development Plan

3E for Optimum PDP Scenario

Maximization of 3E (Economic, Energy Security, and Environment) will be considered to prepare optimum PDP options.

Economic	Environmental	Energy Security
Minimization of Supply Cost	environmental policy study will focus on GHG emission reduction strategy	Minimization of procurement fuel supply





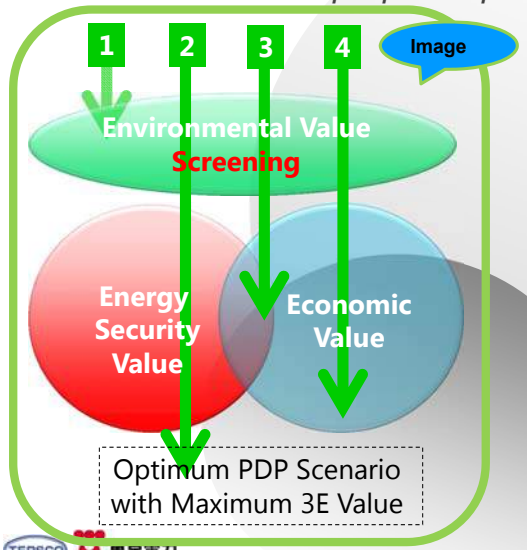
First Step:
Specify the considerable risks in Bangladesh energy situation

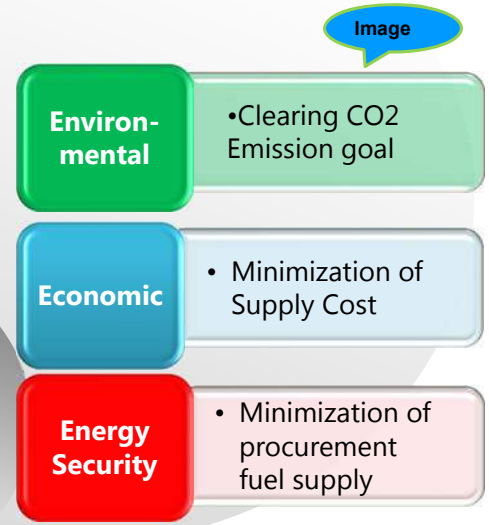
Second Step:
Choose a suitable index to express the degree of each risk

Third Step:
Integration of indices to one "energy security index"

3E for Optimum PDP Scenario

Maximization of 3E (Economic, Energy Security, and Environment) will be considered to prepare optimum PDP options.





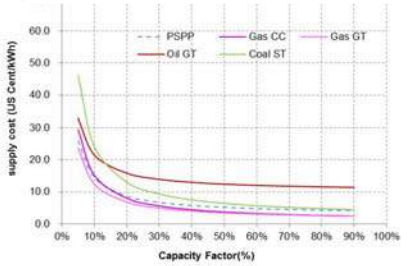
Summary 3E Values (Tentative)

How to numerically evaluate 3E value is key issue

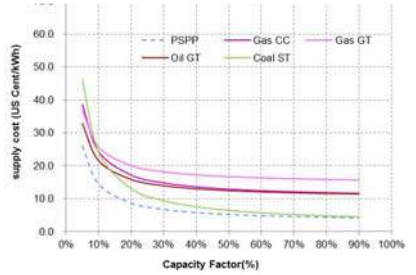
Scenario0	1	2	3	4
	Coal Max	PSMP2015	Mid	Gas Max
Coal	50%	40%	37.5%	25%
Gas	25%	35%	37.5%	50%
Oil	5%	5%	5%	5%
Others(Nuc, Re, CB) FIX	20%	20%	20%	20%
Total	100%	100%	100%	100%
Evaluation				
Environmental Value				
Economic Value (US Cent /kWh)	17.0	19.7	20.1	22.6
Energy Security				
Maximum 3E Value				

Economic Value

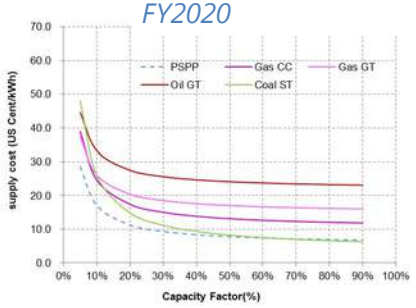
FY2015 (Gas=Domestic Price)



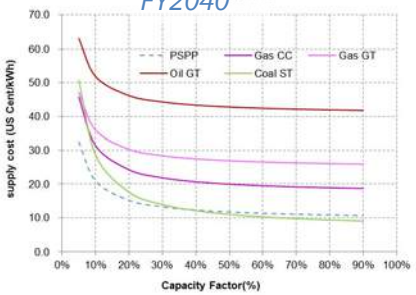
FY2015 (Gas=International Price)



FY2020



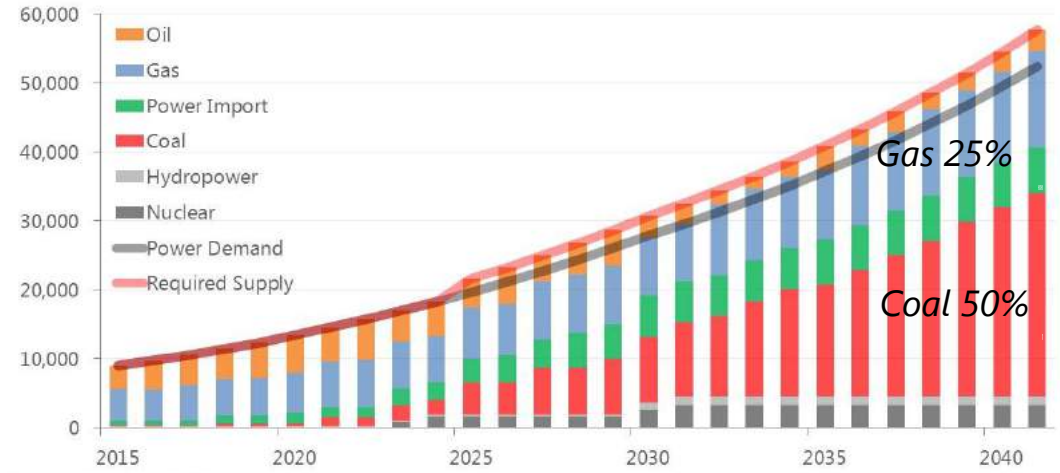
FY2040



Scenario 1: Coal Max

Coal 50%, Gas 25% @2040

Power Development Plan (MW)

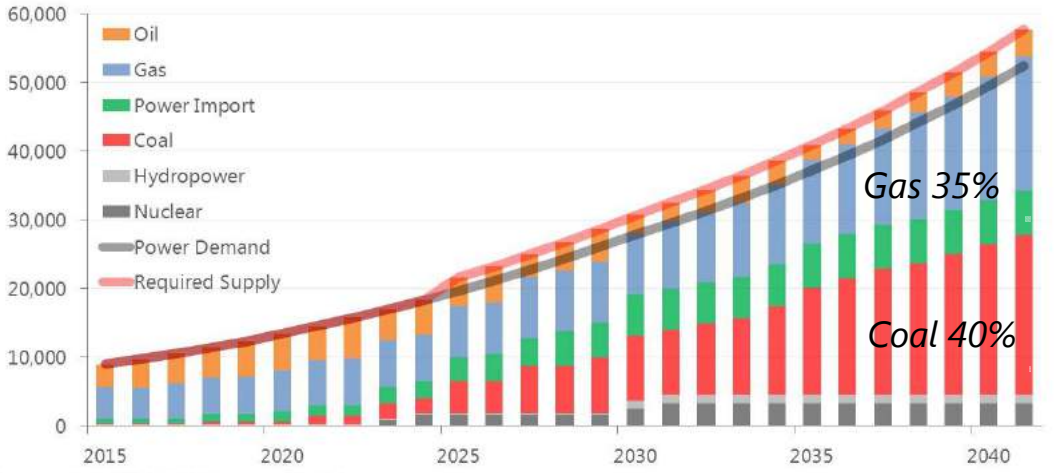


(Source: JICA PSMP2015 Team Estimate)

Scenario 2: PSMP2015 Optimum

Coal 40%, Gas 35% @2040

Power Development Plan (MW)

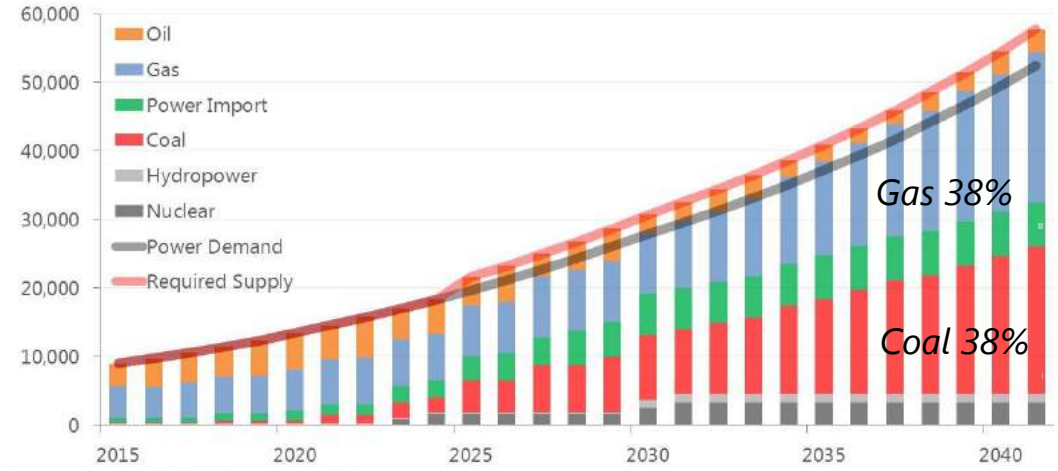


(Source: JICA PSMP2015 Team Estimate)

Scenario 3: Mid

Coal 37.5%, Gas 37.5% @2040

Power Development Plan (MW)

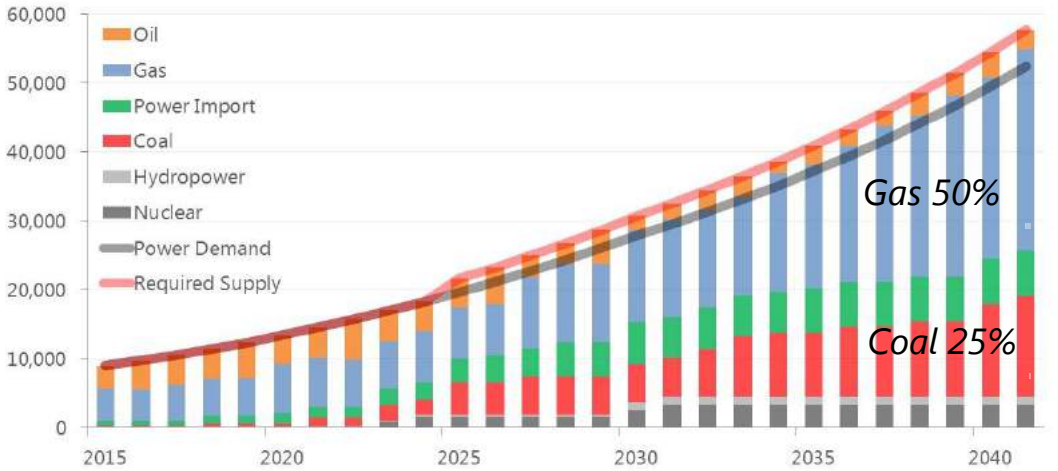


(Source: JICA PSMP2015 Team Estimate)

Scenario 4: Gas Max

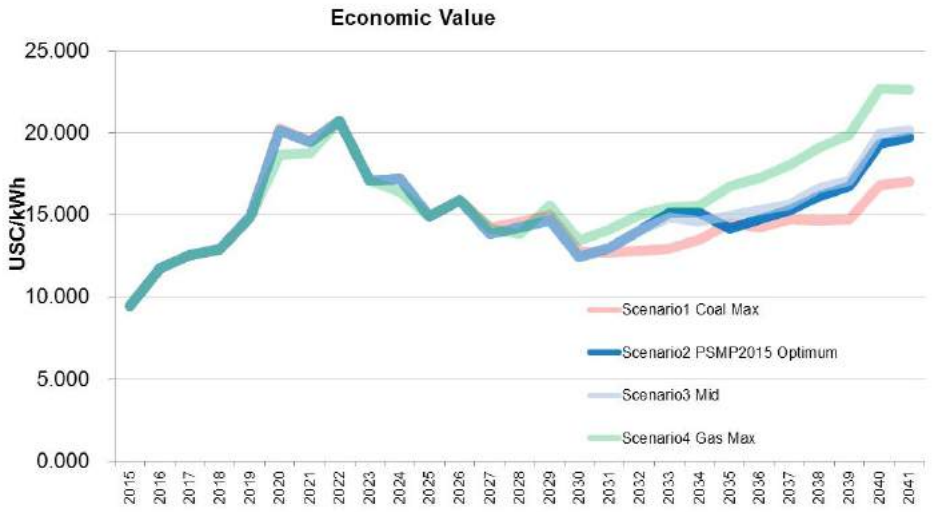
Coal 25%, Gas 50% @2040

Power Development Plan (MW)



(Source: JICA PSMP2015 Team Estimate)

Economic Value



4. Power Quality

1. Schedules of 1st visit

- Outline of 1st visit for "improvement of demand/supply operation of electric power and frequency quality" is shown below.

Place and target of visit

Date	Place	Major target
2015.9.13(sun)	PGCB	Opinion for improvement of power quality from viewpoint of transmission entity.
2015.9.14(mon)	PGCB(NLDC)	Organization chart of NLDC and outline of frequency control operation.
2015.9.15(tue)	BPDB	Opinion for frequency control from viewpoint of generation entity.
	BERC	Opinion for ancillary service from viewpoint of regulating authority.
2015.9.16(wed)	NLDC	Outline of demand-supply planning, frequency control and SCADA system in NLDC.
	Siddhirganj power station	Outline of generator control system, opinion for frequency control from viewpoint of power station.

2. Planning of Demand-supply Balancing

(1) Results of interview with NLDC

Variety of the Term of Planning

- A day plan and a day-ahead plan are formulated in NLDC. Weekly, monthly, yearly or longer term plans are not dealt with.

Demand Forecasting and Plans for Demand-supply balancing and Unit Commitment

- Demand forecasting is performed by NLDC.
- The day plan is formulated on an hourly basis from 16:00 to 15:00 of the next day.

Integration of the Generation Plans (Maintenance Outage Plans)

- Generation plans are not provided to NLDC until the day before.
- Coordination of the maintenance outage plans is performed by BPDB, and NLDC can't take part in the decision making process for the plans.

3. Demand-supply, Frequency Control

(1) Willingness of PGCB

- The installation of a nuclear power station is planned for 2025, but it will be difficult to keep generating operation stable with the existing quality of frequency. An improvement of frequency quality is eagerly desired.
- Before the unbundling of the electricity industry in 1996, frequency fluctuation was smaller than at present because about 50% of generators could offer reserves for frequency control, including generators in Kaptai hydro power station. However, since the unbundling, the number of generators which can offer the reserves has gradually decreased.

(2) Willingness of BPDB

- BPDB is also eager to enhance the frequency quality toward 50±0.5Hz by 2020 and 50±0.2Hz by 2025 as TEPCO proposed, in order to mitigate the damage to the generators.
- BPDB is considering that the burden of governor-free operation should be shared among as many generators as possible, in order to reduce the power fluctuation of each generator.

3. Demand-supply, Frequency Control

(3) Willingness of the Power Stations (The Results of Interview with the Siddhirganj Power Station)

- It may be possible to operate in AGC (Automatic Generation Control) mode with the necessary modifications and testing conducted by the manufacturer (GE), yet the generators are not currently set to respond to the LFC (Load-Frequency Control) signal from NLDC's system.
- They have a willingness to cooperate in the frequency control, if a system is developed that can make compensation for the opportunity loss of power selling.
- They have a strong desire to share detailed information about the situation of a power system among the stakeholders, because this operation should be performed under fair and transparent terms.

3. Demand-supply, Frequency Control

(4) Present work condition in NLDC

Operation in normal state (Supply = Demand)

- Power output instructions from NLDC to P/S are performed by telephone only.
- The generators operated in governor-free mode are decided by BPDB, not NLDC. NLDC cannot take part in the decision making and manage the total amount of primary reserve.
- There is no P/S receiving the LFC signal and operated in AGC mode, as of now.

Operation in abnormal state (Supply < Demand: deficiency of power source)

- Demand-supply balancing control is performed by load shedding.
- In the case of a sudden decrease of frequency due to the unplanned outage of a generator, inadequate load shedding, and so on, automatic switching control by SCADA system is performed to shed the load.
- In the case of further frequency decrease, despite the SCADA control, load shedding by UFR (Under Frequency Relay) is performed in the range of 48.90Hz to 48.50Hz.

Operation in abnormal state (Supply > Demand: Frequency rise)

- Operated in following manner and order:

① Re-charging of shedded distribution lines, ② Instruction for power output decrease

3. Demand-supply, Frequency Control

(5) Recognition of Challenges to Improving the Frequency Quality by NLDC

- Significant deficiency of power sources. A mismatch between supply and demand.
- No application of AGC (Automatic Generating Control).
- No application of LFC (Load Frequency Control) or governor-free operation.
- No automation of EMS, DSM. Manual operation only.
- Inadequate spinning reserve.
- Unstable output from generators. In particular, output of part of combined-cycle generators decreases in response to the decrease of frequency.

4. Current Issues (summary)

Each entity has a strong hope and accurate understanding for improving power quality in order to establish a stable operation, such as:

- Significant deficiency of power source including spinning reserve.
- No application of automatic control such as LFC, free-governor operation. By telephone only.
- Inadequate coordination (Coordination of the generation plans including reserves is performed by BPDB. NLDC can't take part in the decision making process).
- No rules and authorities for demand-supply control.

5. Improving frequency quality Actions

Independent Actions for improving the frequency quality in Bangladesh

(1) Challenges in BPDB

- At present, BPDB provides two generators for frequency control (Haripur p/s: 100MW×1 unit, Shahjibazar p/s 100MW×1 unit), but their outputs are uncontrollable due to some trouble in the fuel supply system. BPDB is currently negotiating with the gas company regarding a stable supply of appropriate quantity and pressure.

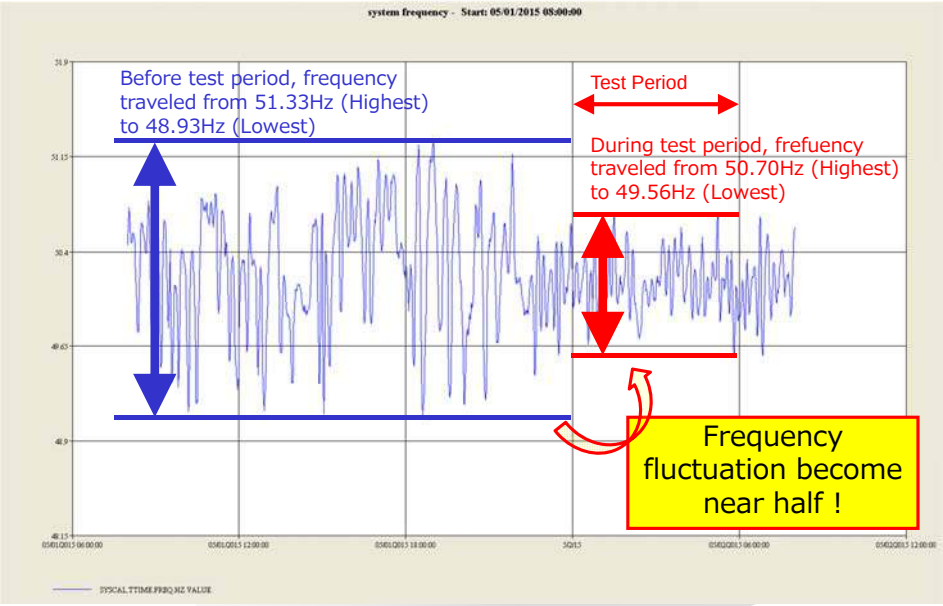
(2)Challenges in NLDC

NLDC is independently progressing with a selection process for generators for frequency control. Khulna P/S performed testing effectiveness of governor-free operation.

- The following is a brief summary of the test results:

Date	May 2nd, 2015 (SAT.) 0:00 – 6:00 AM (for 6 hours)
Site	Khulna Power Station (Rated output: 158MW×1 unit, Gas-Turbine, fuel: HSLO: High-sulfur light oil)
Conditions	Governor-free operation mode Change the output from 34.5% to 96.0% of rated output during the test period.
Total demand	5,870MW (at 0:00 AM) - 4,500MW (at 6:00 AM)
Effectiveness	Before/After the test: 51.33Hz - 48.93Hz (+2.66% -- -2.14%) During the test: 50.70Hz - 49.56Hz (+1.40Hz -- -0.88%)

5. Improving frequency quality Actions



6. Project Road map

(1) Proposal for Preparation of a Legal Framework, rules and improvement of work procedures

- Propose and support the preparation or amendment of various rules with reference to the rules in Japan (or Europe/America, if necessary) and TEPCO.
- Check progress of amendment of the Grid code by BPDB and suggest reinforcement of NLDC's orders and generator participation in frequency control.

(2) Draft plan for frequency quality improvement

- Evaluate the frequency quality improvement by introducing generators with frequency control functions.
- Propose the development of future plan for securement of spinning reserve (free governor mode, LFC) and roadmap for frequency quality improvement for PGCB (NLDC) and BPDB, regulating authorities (Energy division and BERC).

(3) SCADA system renewal plan for NLDC

- Confirming needs for introducing new functions or adding data to NLDC's SCADA system, in order to realize online output instruction orders for power stations.

5. Operation and Maintenance (O&M)

(1) Ascertaining actual conditions

(2) Issues and countermeasures

(3) Rehabilitation

(4) Information management

(5) Training

(6) Regal frame work

(1) Ascertaining actual conditions

1. Ascertaining actual conditions

Survey result

Item	Contents
Maintenance plan	Based on manual and experience
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb maintenance	Waiting for budget approval, bidding and shutdown permission
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff and manufacture
Safety for staff	Only have BPDB guideline

Item	Contents
Fuel analysis	No analysis
Efficiency management	Nobody cares
Environmental regulation	No regulation
Report for Head office	Handwritten monthly report
Equipment issues	Does not reach rated output
Staff issues	Shortage of human resources
Training system	OJT Only theoretical lectures

(2) Issues and countermeasures

2.Issues and countermeasure

Focused on four categories and countermeasure to optimize O&M

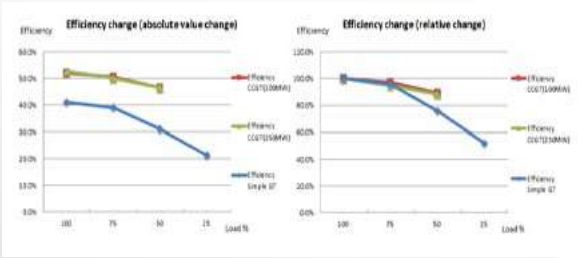
Equipment and maintenance plan	*Budget approval and shutdown permission are delayed because there is no mid-long term maintenance information *Cannot repair because of shortage of power generation *Do not care about power plant efficiency *Does not reach rated output	→	**Equipment and maintenance plan**	Rehabilitation	Steam turbine rehabilitation
					Combined cycle power generation remodeling
Staff	*No effective training curriculum *Lack of technical skill		**Staff / Budget / Information**	Utilize the information effectively	Information management strategy
Budget	*No mid-long term maintenance plan				
Information	*Lack of information strategy			Human resource development	Training center

(3) Rehabilitation

3.Rehabilitation

Merit of small size combined cycle power generation remodeling

Plant capacity	Hot start	Cold start	efficiency
400MW Class CCGT	1hour	6hours	50%
250MW Class CCGT	< 1hour	4hours	50%
100MW Class CCGT	0.5hour	2hours	50%
Simple GT	0.5hour		40%(new) 30%(old)



merit1 : short start time characteristics

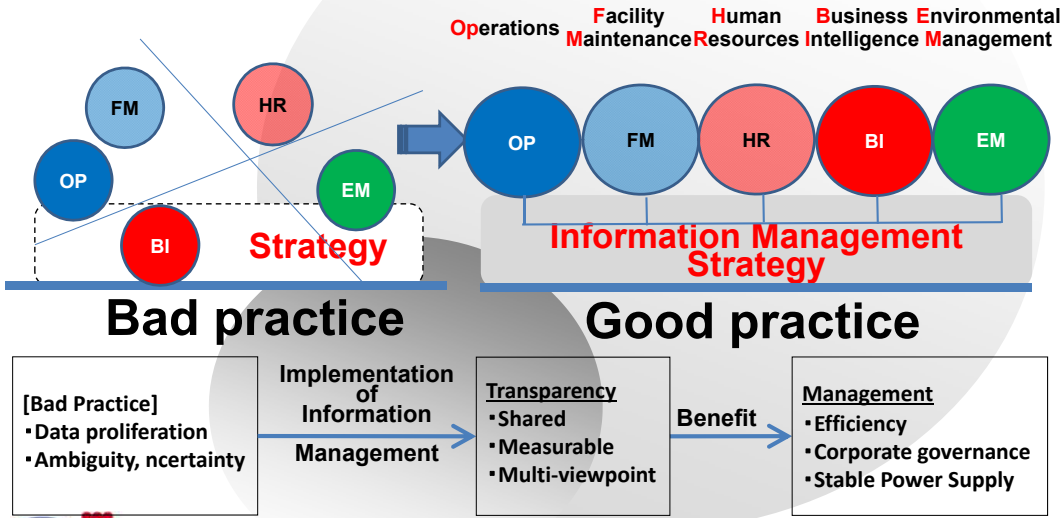
merit2 : High efficiency under low load operation

	Site name	Target unit	COD	capacity condition installed A	de-rated B	remarks C	New D	output increase D-C	Estimated Cost Mill dollar	Unit price mill dollar / MW	Efficiency after	Efficiency now	Manufacture support	Remaining plant life after rehabilitation (assumed plant life time 30years) years	year cost mill dollar / MW
Build and scrap (for CCGT)	Siddhirganj	Unit1	2004	210	150	110 (gas limitation)	150	40MW	200	5.0	50	33.8 (*1)	MHPS/Kawasaki	30	0.17
	Haripur	Unit1,2,3	1987	96	60	40(Unit 3 stopped)	100	60MW	150	2.5	50	21.2			0.08
	Tongi	Unit1	2005	105	105	105	150	45MW	200	4.4	50	25.9 (*2)			0.15

(4) Information management

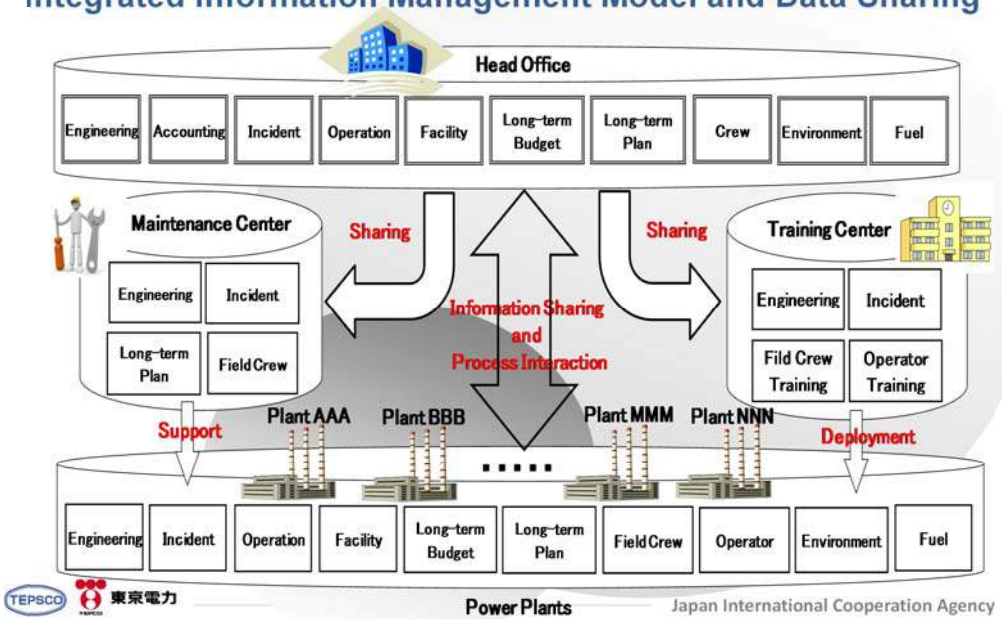
4.Information Management (1)

Strategic Approach to Integrated Information Management



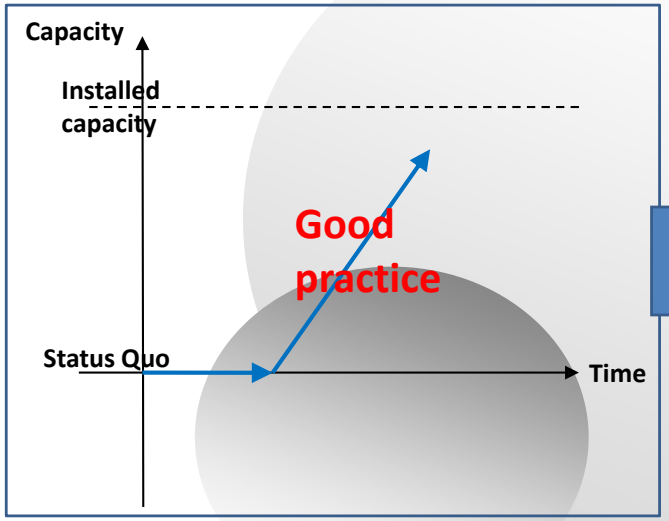
4.Information Management (2)

Integrated Information Management Model and Data Sharing



4.Information Management (3)

Operating at Constant Generation Level with High Quality



By applying proper maintenance, it is possible to bolster capacity.

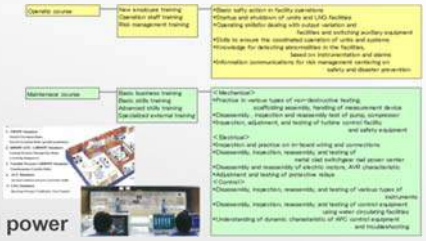
By practicing planned maintenance, it is possible to mitigate shut-down impact on the grid.

(5) Training

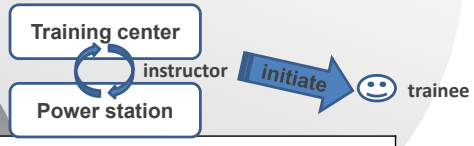
5.Training

Key item of human resource development

a. training curriculum
⇒ From a new face to a veteran, the maintenance of various curricula is necessary



b. Development of the instructor
⇒ rotation between the training center and power station
→ instructor getting site knowledge and feeding
→ back into the training content



c. Training facility

For operator	Operation simulator
For maintenance staff	Motor , pump , fan , instruments , Non Destructive Inspection/Test facilities, vibration analysis device …etc.,

(6) Regal frame work

6.Legal framework -1

O&M Problems and Solutions

① Problems
- MW Down (Output)
- η Down (Efficiency)
- Re Down (Reliability)

② Main Reasons
- Insufficient Maintenance
- Insufficient Inspection
- Insufficient η management

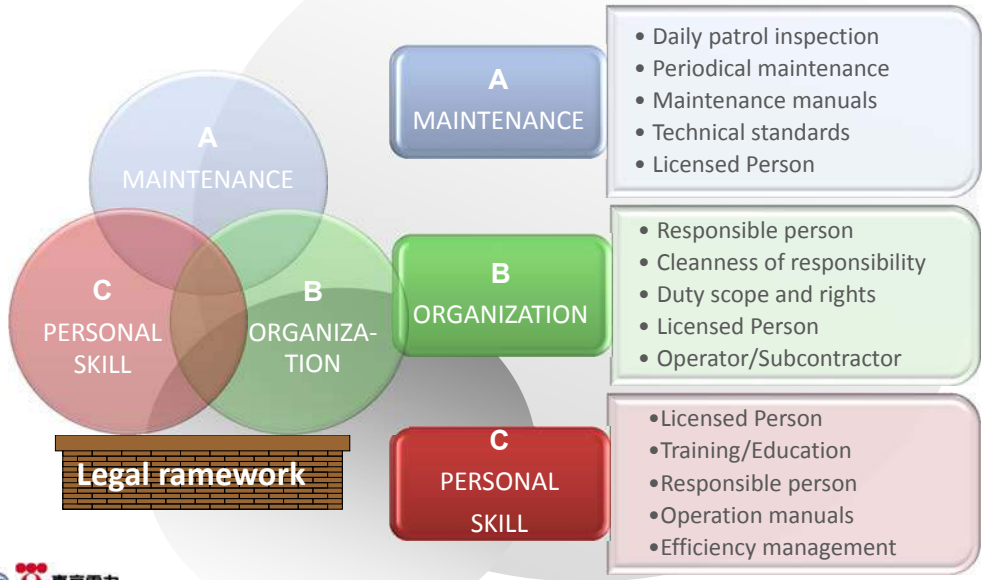
③ Why ?
- Lack of budget
- Lack of technical skill
- Lack of time
- It is not easy to stop for maintenance due to power shortage.

④ O/M Solutions
- Operating efficiently
  - Efficiency management
  - Reduction of maintenance period
- Personal skill-up
  - Training, Education
- Efficient maintenance
  - CBM, Daily maintenance, Patrol inspection

⑤ Legal Framework Solutions
- To build the mechanism for O/M legal solutions
  - Formation of organization
  - Clarification of responsibility
  - Sustainability, PDCA
  - Incentives and penalty

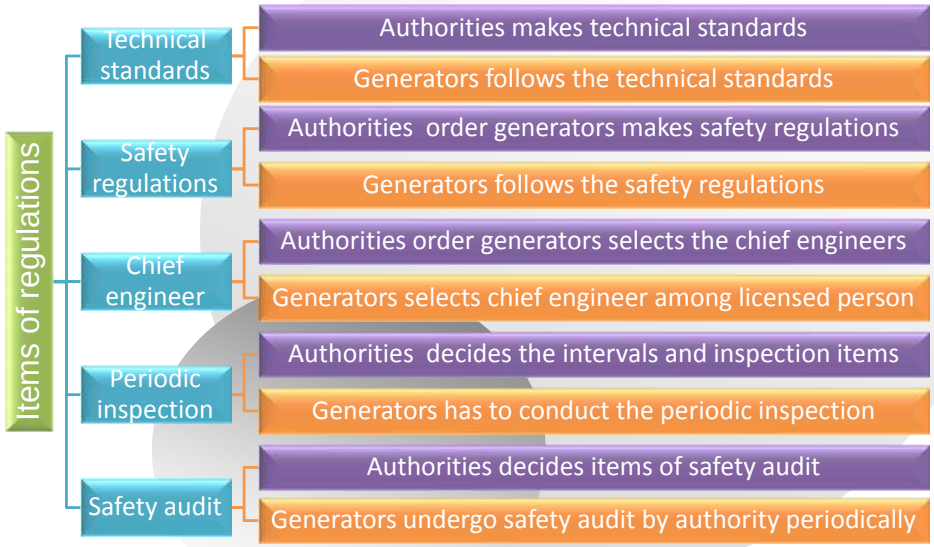
6.Legal framework -2

Legal framework should support key factors of O&M



6.Legal framework -3

Recommended items of regulations for Bangladesh



23.4 Pre- High Level Discussion Meeting (Tokyo)

- Date: 5 Apr 2016
- Venue: TEPCO Headquarter (Tokyo)
- Discussion Point:
  - ✓ Economic Development
  - ✓ Primary Energy Balance
  - ✓ Power Balance
  - ✓ Cost and Tariff Balance



- Participants

Participants are shown below table.

No.	NAME	Designation	Organization
1	Mr. Md. Kowsar Ali	Joint secretary	Power Division
2	Ms. Kazi Zebunnessa Begum	Jioint Secretary	Enrgy&Mineral Division
3	Mr. A. K. M. Monowar Hossain Akhand	Director (Joint Secretary)	BERC
4	Mr. Mohammad Nazmul Abedin	Deputy Secretary	Power Division
5	Mr. Md. Shahidul Islam	Deputy Secretary	Energy & Mineral Resources Division
6	Mr.Shafiuddin Md.Farhad Omar	Deputy General Manager	Transmission – Chittagong, GTCL
7	Mr. Md. Lutfar Rahman	General Manager	Petrobangla
8	Mr. Md. Khalekuzzaman	Executive Engineer	PGCB
9	Mr. Faozul Islam Shaker	Sub-Division Engineer	BPDB
10	Mr. Abdullah-Al-Mohit	Assistant Director	Power Cell

(Alphabetical order)

23.5 High Level Discussion (Dhaka)

- Date: 7 April 2016
- Venue: Bijoy Hall, Bidyut Bhaban, Power Division, MoPEMR
- Discussion Point:
  - ✓ PSMP 2010/2016 comparison
  - ✓ Macroeconomic Projection & Industrial Policy
  - ✓ Energy Balance Strategy
  - ✓ Energy Efficiency Target Setting & Supply-Demand Balance
  - ✓ Power Balance Strategy
  - ✓ A Project Outline and Road Map





- Participants

Participants are shown below table.

No.	Name	Designation	Organization
1	A.M.M. Sazzadur Rahman	Managing Director	APSCL
2	Kamal Ahmed	Dhaka city correspondent	Bangladesh Beter
3	Monjur Ahamed	Special Correspondent	BD News
4	Md. Altaf Hossain	Secretary	BEPRC
5	Sayeed Ahamed	Chief Engineer, Private Generation	BPDB
6	Md. Mofijul Islam	Deputy Secretary, Company Affairs	BPDB
7	Golam Kibria	Director, IPP Cell-1	BPDB
8	Bellal Hossan	Executive Engineer	BPDB
9	Ashutosh Roy	Chief Staff Officer (CSO) to Chairman	BPDB
10	Munshi Bashir Ahmed	Director, Project Planning	BPDB
11	Moniruzzaman	Deputy Secretary (Generation)	BPDB
12	Saiful Hasan Choudhuri	Director, Public Relations	BPDB
13	Md. Mahbubur Rahman	Director IPP Cell-3	BPDB
14	A.H.M. Kamal	Chief Engineer, Generation	BPDB
15	Md. Shamsul Hassan Miah	Chairman	BPDB
16	Khaled Mahmood	Member, Generation	BPDB
17	Minhaj Uddin Ahmed	Member, Company Affairs	BPDB

No.	Name	Designation	Organization
18	Md. Asadullah	Consultant	BPDB-RPCL(Powergen Ltd.)
19	Mahbub Kabir	Superintending Engineer	BPDB-RPCL(Powergen Ltd.)
20	Sunil Chandra Day	Member (P&D)	BREB
21	Md. Mizanur Rahman Khan	Member Engineering, (P&O)	BREB
22	Engr. Jagodish Chandra Mondol	Executive Director (Engg)	DESCO
23	Birg Gen Shohid Sarwar (Rtd.)	Managing Director	DESCO
24	Engr. Md. Hafizul Islam Bhuiyan	Chief Engineer (P&D)	DESCO
25	Aminur Rahman Rasel	Senior Reporter	Dhaka Tribune
26	Brig Gen. Md. Nazrul Hasan (Rtd.)	Managing Director	DPDC
27	A.M. Monsurul Alam	Executive Director	EGCB
28	Ibrahim Ahmed Shafi	Superintending Engineer	EGCB
29	ATM Zahirul Islam Majumdar	Managing Director	EGCB
30	Md. Mehdi Masud	Manager (FP)	GTCL
31	Hasan	Reporter	INB Barta
32	M. Ahsanul Jabbar	Addl. Secretary, Energy Division	Ministry of Energy & Mineral Resources
33	Mr. Nazimuddin Chowdhury	Secretary, Energy Division	Ministry of Energy & Mineral Resources
34	Mr. Nasrul Hamid	State Minister	MoPEMR
35	Tahmina Yeasmin	Deputy Secretary, Power Division	MoPEMR
36	Mr. Anwar Hossain	Additional Secretary	MoST
37	Harendra Mondal	Executive Director (Engg.)	NWPGCL
38	Dr. Tawfiq-E-Elahi Chowdhury	Adviser to PM	PEMR
39	Nasimul Aleem	Manager	Petrobangla
40	Arun Kumar Saha	Chief Engineer (P&D)	PGCB
41	Chowdhury Alamgir Hossain	Executive Director (P&D)	PGCB
42	Md. Nuruzzaman	Superintending Engineer, Planning	PGCB
43	Masum-Al-Beruni	Managing Director	PGCB
44	Shaikh Sharif Uddin	Deputy Chief	Planning Commission
45	Md. Saiful Alam Hamidi	Chief, Industry & Energy Division	Planning Commission
46	Md. Abdur Rouf Miah	Director	Power Cell
47	Md. Amzad Hossain	Director	Power Cell
48	Mohammad Hossain	Director General	Power Cell
49	SK Md. Abdul Ahad	Joint Chief	Power Division
50	Dr. Ahmed Kaikaus	Additional Secretary	Power Division
51	Md. Zillur Rahman	Senior Assistant Secretary	Power Division
52	Mr. Monwar Islam	Secretary	Power Division
53	Mr. Md. Rakib Hossain	Additional Secretary	Power Division
54	Abdul Halim	Joint Secretary	Power Division

No.	Name	Designation	Organization
55	A.K.M Humayun Kabir	Joint Secretary	Power Division
56	M. Bazlur Rahman	Joint Secretary	Power Division
57	Mohammad Alauddin	Joint Secretary	Power Division
58	Md. Abdus Sabur	Managing Director	RPCL
59	Muntasir	Staff Reporter	Somoi Kantha
60	Sojal Ahamed	Staff Reporter	Somoy News 24.com
61	Siddique Zobaur	Member	SREDA
62	Md. Anwarul Islam Sikder, ndc	Chairman	SREDA
63	Md. Shafique Uddin	Managing Director	WZPDCL

(Alphabetical order)

■ Presentation materials

Presentation materials are as next pages.

PSMP2015
High-Level Discussion
SUMMARY PART

JICA PSMP2015 Team
April 2016

Tokyo Electric Power Services Co., Ltd.
Tokyo Electric Power Company

Objectives and Project Outline

High-level Discussion Objectives

- To share PSMP2015 Survey Team's assumptions, especially the Economic Development Scenarios.
- PSMP2015 Survey Team has come up with various [Discussion and Proposals]. These are the basis for Policy Recommendations.
- Without consent from High Level, the Survey Team is not possible to go further to derive appropriate Policy Recommendations.

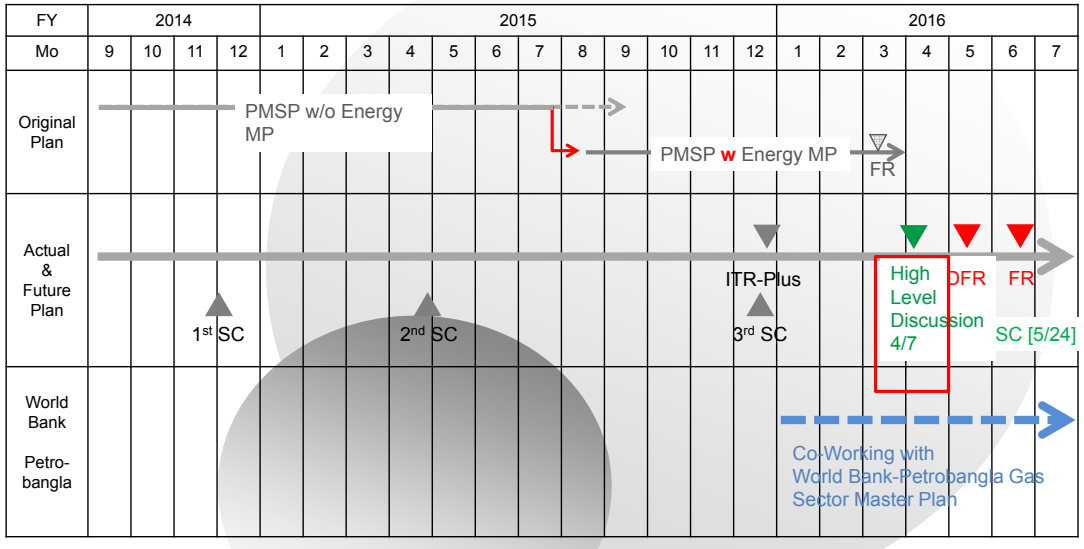
TO SHARE AND DISCUSS THE ASSUMPTIONS and PROPOSALS, WE JOIN THE HIGH LEVEL DISCUSSION

Necessity for High Level Discussion

- "Common" GDP growth forecast needs to be applied for primary energy demand forecasts and other national-level infrastructure strategies should follow.
  - But no such figure is yet established.
- How the growing needs of primary fuel will be met in the next two decades? This question must be answered as soon as possible
  - Specifically domestically produced coal, natural gas, and condensate – domestic fuel should come first, import later and.
- How to determine Optimum Primary Energy Balance and Power Development Plan, considering 3E(Economic, Environment, and Energy Security. O&M and Quality of Power requires new legal systems. Power Quantity and Power Quality.
  - Without high-level commitment, such new system never works

TO ADDRESS THESE ISSUES, PSMP2015 is required

Implementation Schedule



PSMP2015 Key Discussion Points

A Road Map

B PSMP2010 Review

C Global Policy Trends
- SDGs
- COPs

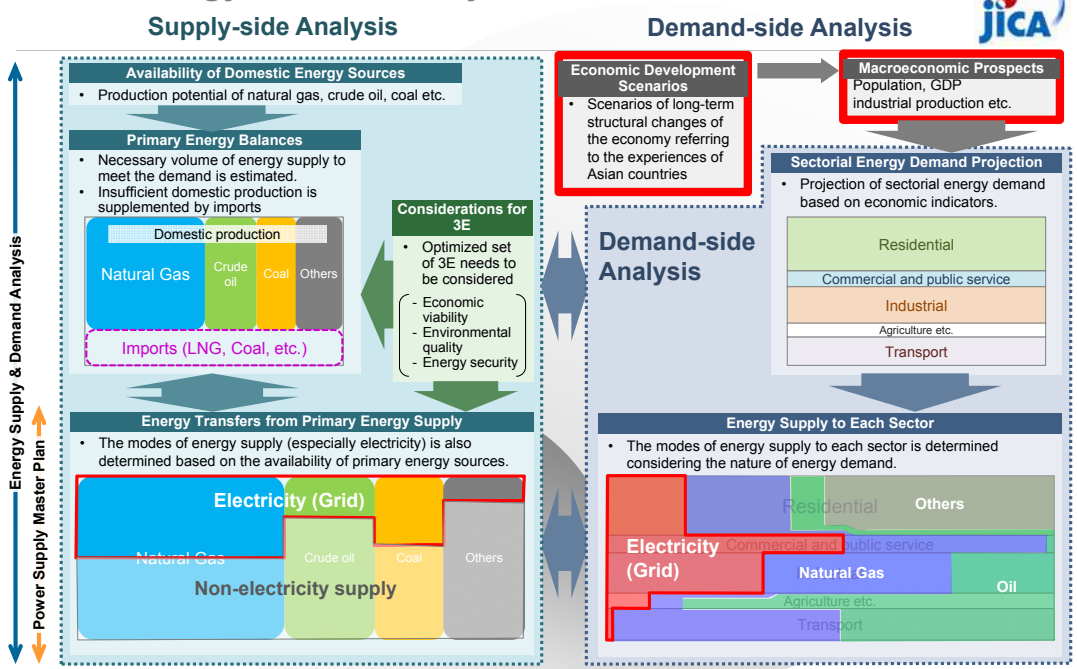
D Economic Development
- GDP Projection
- Economic Growth Scenario
- Policy for Industrial Development

E Energy Balance Strategy
- Projection of Energy Consumption in Bangladesh
- Industrial Sector Energy Demand
- Policy Measures for Promoting Industrial Development
- Transport Sector Energy Demand
- Prospects of Transport Sector in Bangladesh
- Civilian Sector Energy Demand (Residential & Commercial)
- Agricultural Sector Energy Demand
- Energy Supply & Demand Balances
- Gas Supply (Domestic & Import LNG)
- Coal Supply (Domestic & Import)
- Oil and LPG Supply

F Power Balance Strategy
- Demand Forecast and Power System Plan
- 3E (Economy, Energy Security, and Environment)
- Power Quality
- Nuclear and Cross Border
- Universal Access to Modern Energy and Renewable Energy
- Operation and Maintenance (O&M) and Legal Framework

G Energy and Power Tariff Strategy
- Tariff Policy
- Impact on National Economy

Flow of Energy Balances Analysis



Key Issues in Energy Balance Analysis in Bangladesh

Energy Demand

- In Bangladesh, where the energy demand is expected to grow rapidly, the energy supply infrastructure needs to be developed so that the supply shortage won't impair the development of national economy.
- Forecasting the long-term economic development should consider a non-linear structural changes of the national economy in the future. Scenario planning analysis referring to the experiences in Asian countries is recommended.

Primary Energy Supply

- Energy supply in Bangladesh has been heavily dependent on the domestic production of the primary energy sources, especially natural gas.
- Though the domestic production is expected to start depreciating and the energy import will gain importance, the optimized utilization of domestic production remains to be the core of energy supply.
- In addition, consideration for environmental issues and energy security will be a factor to confine the availability of energy sources

Modes of Energy Supply to End Consumption

- From demand-side, necessary capacity of electricity supply should consider not only the increasing energy demand but also the electrification of energy demand (shift to electricity supply from other modes of supply) though the extent of electrification varies among sectors.
- From supply-side, the capacity of electricity supply is affected by the available sources for electricity generation (including the geographical conditions of energy supply infrastructure).

→ Composition of the modes of energy supply (especially electricity supply) will be determined both by demand-side and by supply-side.

PSMP2010 Review
&
PSMP2010/2015 Comparison

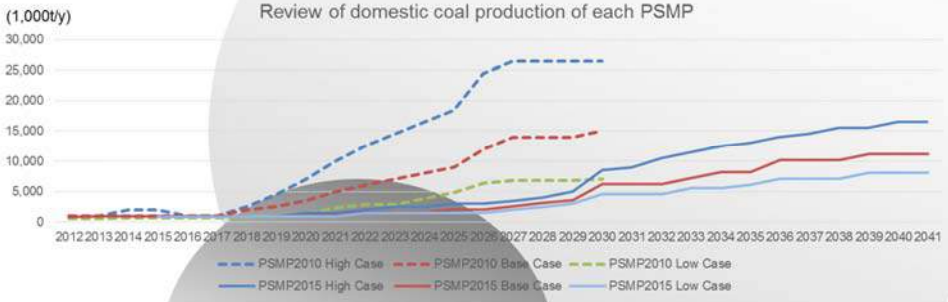
Comparison of 2010/2015

		PSMP2010 Outline	PSMP2015 Outline	PSMP2015 Discussions Perspectives
GDP		3 Scenario *Government Policy Scenario *6% Growth Scenario *7% Growth Scenario (In case of Government Policy Scenario Below)	PSMP2015 Scenario based on Macroeconomic Analysis	Economic Development
Power Demand	2020	17,304 MW	12,949 MW	
	2030	33,708 MW	27,434 MW	
	2041	-	52,034 MW	
Power Supply (Installed Capacity)	2020	23,809 MW	12,949 MW	
	2030	38,685 MW	30,178 MW	
	2041	-	57,238 MW	Energy Balance Strategy -Domestic Gas to be developed? -Domestic Coal to be developed? Power Balance Strategy -3E analysis Economic Development -Impact on Economy
Diversification	Gas	25%	15%-55%	
	Coal	30%	15%-55% (Domestic: 1% or above)	
	Oil	5%	5%	
	Others(Nuclear, Import, Hydro)	20%	25%	
Features		*Proposal of Prioritized Projects (Matarbari PP) *Financing	*Integrated Discussion on Energy, Power, and Economy *Power Quality	

Coal Review

National Coal Development Policy

[Fact Finding]



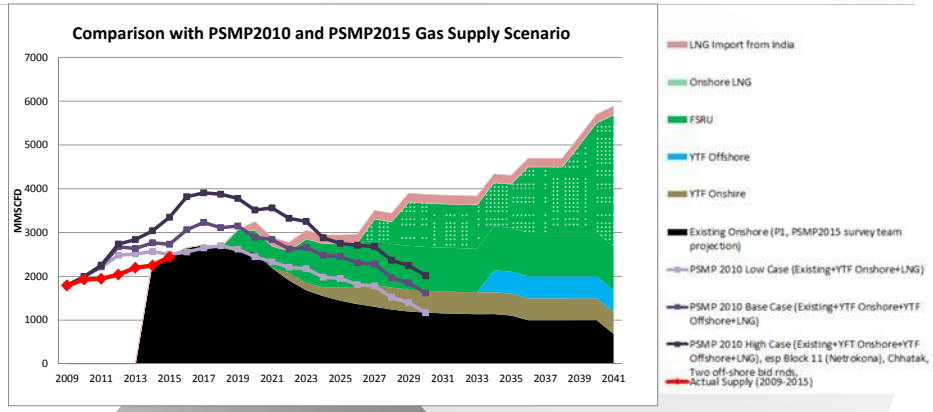
The reasons that lowered amount of production of PSMP2015 in comparison with PSMP2010 are following the fact that;

(1) Coal Policy was almost ready for public and domestic coal development was strongly recommended by the Government in PSMP2010.

(2) Domestic coal development is in a difficult social situation in PSMP2015, and urge for importing.

Gas Review

[Fact Finding]



- Gas Supply Projection in PSMP2010 was reviewed against Actual Gas Production Record from 2009 to 2015.
- PSMP2010 employed HCU resource projection. This was more optimistic resource count than what PSMP2015 employs (RPS Energy & Petrobangla). Detail of the difference is as follows:

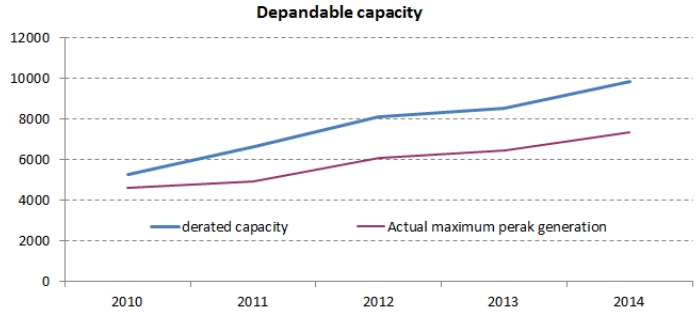
Study	P95	P90	Mean	P50	P10	P05
HCU/NPD	15	19	42	42	64	71
USGS -Petrobangla	9	-	32	31	-	66

- PSMP2010 assumed more optimistic timeline of YTF resource development. (both onshore and offshore)

Power Development Plan (Dependable capacity)

Go to Additional N0.13

Dependable Capacity for existing generations
[Fact Finding]



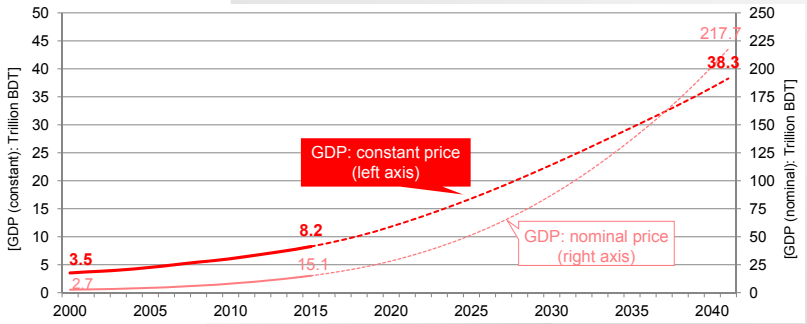
Items	2009	2010	2011	2012	2013	2014
Actual maximum perak generation	4,162	4,606	4,890	6,066	6,434	7,356
Derated capacity	5,166	5,271	6,639	8,100	8,537	9,821
Depandable capacity ratio (max/capacity)	81%	87%	74%	75%	75%	75%
Recent 5 year average						77%

Macroeconomic Projection and Industrial Policy

Comparison with International Organizations' Projections

- GoB's economic growth target (7.4% p.a. growth from 2016 to 2020) appears to be overstretching. However, this study's GDP projection refers to this target up to 2020, assuming that all the necessary policy measures to achieve this target (to be presented in the following slides) will be optimally in place.
- Based on the assumptions shown in following slides, this study estimates that the real GDP (constant at 2005 price) as of 2041 will reach 38 trillion BDT, about 4.6 times of the current level. The average growth rate from 2016 to 2041 is 6.1% p.a.

GDP Projection Up to 2041



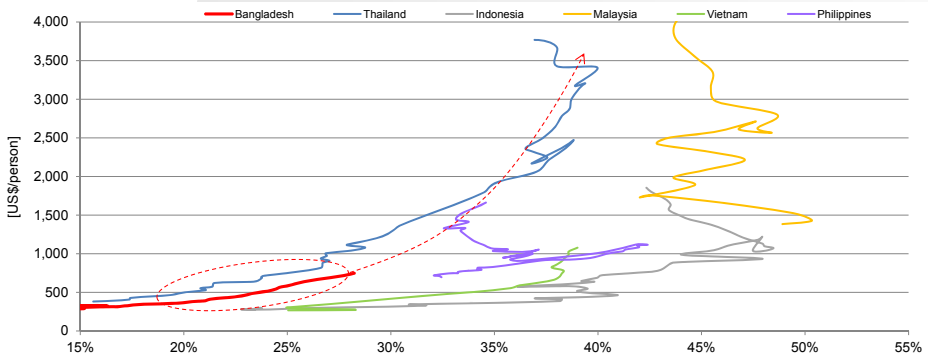
Average growth rate (real GDP)	
2011-2015	6.3%
2016-2020	7.4%
2021-2025	7.4%
2026-2030	6.3%
2031-2035	5.3%
2036-2041	4.4%
2016-2041	6.1%

Source: Prepared by the Study Team

Economic Development Scenario for Bangladesh

- The following figure plots the relation between the share of industrial sector in GDP (horizontal axis) and the GDP per capita of Bangladesh and five ASEAN countries since 1960.
- As a general trend, the industrial sector's share in GDP increases up to a certain level along with the growth of GDP per capita.
- Bangladesh's GDP capita started increasing rapidly when the industrial sector's share exceeded 20%. Recently the trend curve has been taking a similar track to what Thailand experienced before.

Industrial Sector's Share in GDP and GDP per Capita (real GDP) of Bangladesh and ASEAN Countries (1960-2014)

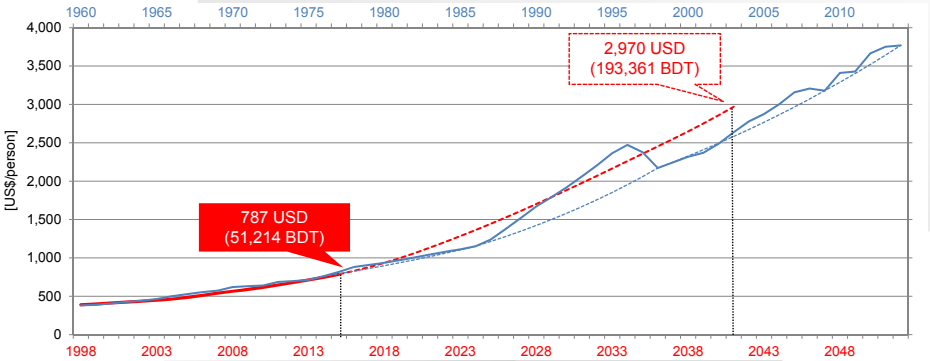


Source: Prepared by the Study Team using World Bank database

Economic Development Scenario for Bangladesh (continued)

- This study assumes that Bangladesh's economic development follows the track of Thailand's and is expected to grow rapider. The expected growth rate of GDP per capita from 2014 to 2041 is 5.2% p.a., about 10% higher that of Thailand from 1976 to 2003 (4.7% p.a.), taking into account the "follower's advantage".
- Bangladesh's GDP per capita (real) as of 2041 is expected to reach about 3,000 USD.

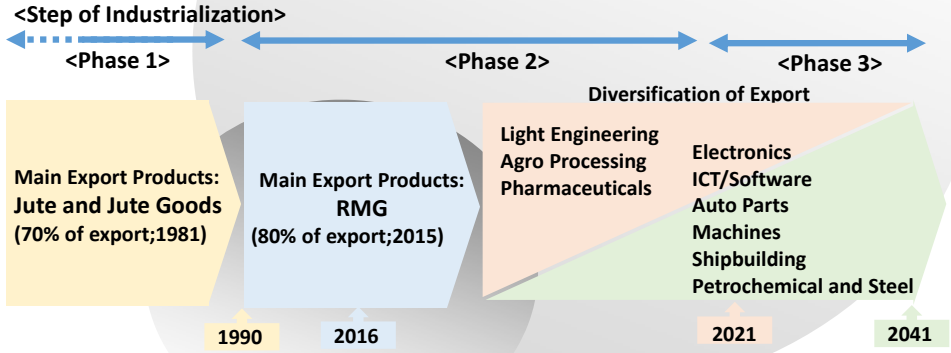
Historical Trend (and Estimation) of GDP per Capita (real GDP) of Bangladesh (red) and Thailand (blue)



Source: Prepared by the Study Team. All the numbers in this figure are expressed at 2005 price.

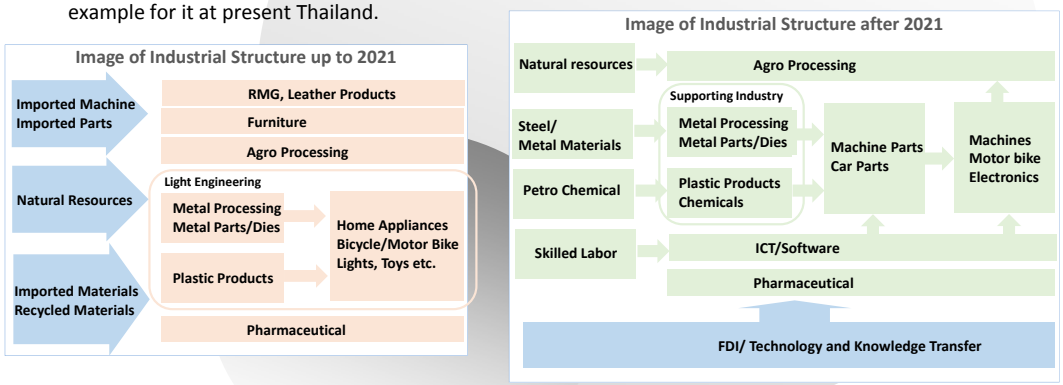
Future Image of Industrial Development in Bangladesh

- Jute and Jute goods were main export products at 1981 in Bangladesh.
- It is said that Bangladesh proceeded from Phase1 (import substitution) to Phase2 (export-oriented: labor intensive) around 1990 and now Bangladesh is in the Phase2 whereas Thailand proceeded from Phase1 to Phase2 at 1971 and entered into Phase 3 (technology and capital intensive) at middle of 1980s.
- Until 2021, although the Bangladesh economy will remain to depend much on traditional industries, RMG (ready-made garment), Jute and Leather etc., the new industries will expand gradually and the export products will be diversified during the same period and from 2021 the tendency will be accelerated.



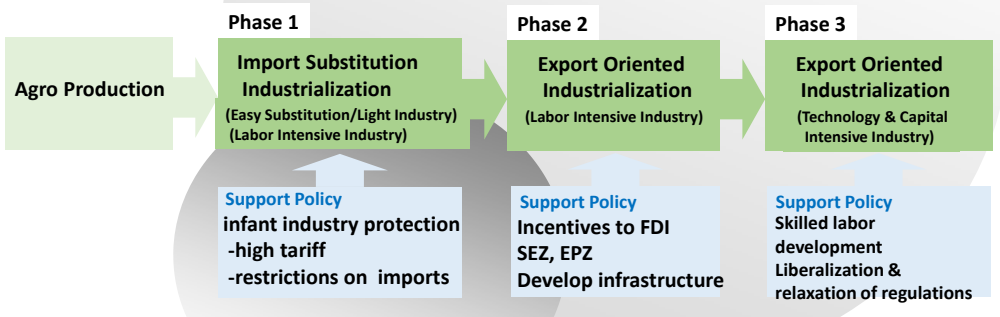
Future Image of Industrial Structure in Bangladesh

- Until 2021, Bangladesh Industry will depend on natural resources, imported materials and imported parts & machines and will diversify gradually including Light Engineering and Pharmaceutical.
- After 2021 towards 2041, Bangladesh Industry will be able to provide row materials and machines for itself and will be a high value added industry by introducing FDIs and taking advanced technologies and knowledges.
- Agro industry is always important because it can absorb huge labor force and can secure food supply. Furthermore Agro industry can be high value added industry by agro processing. We can see a good example for it at present Thailand.



Measures Needed for Industrialization in Bangladesh

- For Import Substitution Industrialization, policies for infant industry protection should be needed (ex. High tariff, restriction on imports).
- For Export Oriented Industrialization, policies on provision of incentives to FDI, construction of Industrial zone like SEZ for foreign enterprises and development of various infrastructures like port ,road, railway, power supply must be needed.
- In the stage of Phase3, in addition to the above mentioned policies in Phase2, skilled labor development and liberalization & relaxation of regulations are needed for realizing the industrialization among international competition.



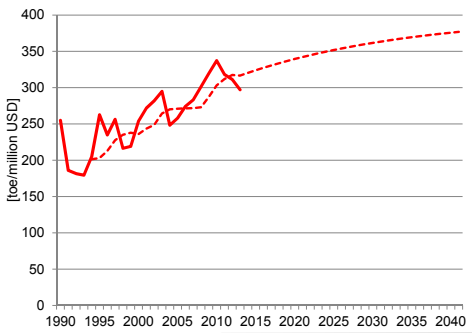
Energy Balance Strategy

(1) Projection of Energy Consumption (BAU Case)

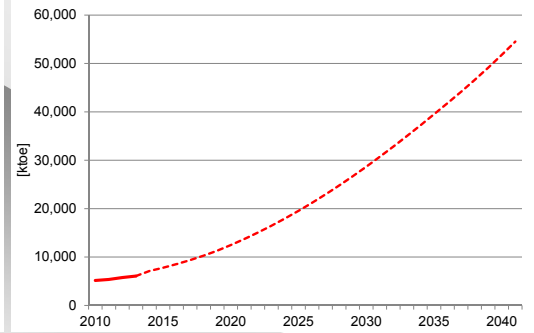
Projection of Industrial Sector Energy Consumption

- In Bangladesh, the industrial sector's energy intensity, i.e. energy consumption divided by the sectorial valued added (= GDP), has seen a gradually increasing trend (industrial sector's GDP elasticity > 1), whereas this ratio is relatively constant in Thailand, Malaysia (about 400).
  - In Bangladesh, the economic development is still at an early stage and that a shift from labour-intensive industries to energy-consuming industries is still in process.
- This study projects that this trend is expected to continue and the energy consumption of the industrial sector will be about 54,500 ktoe, about nine times increase from 2013.

Energy Consumption per Sectorial Value Added (projection)



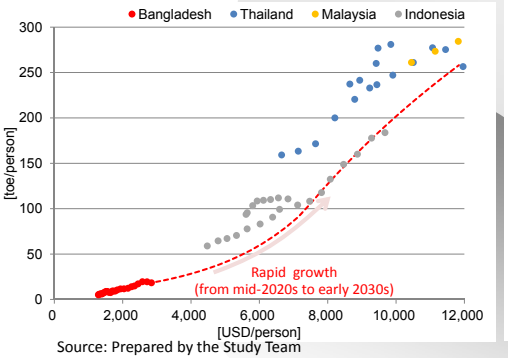
Sectorial Energy Consumption (projection)



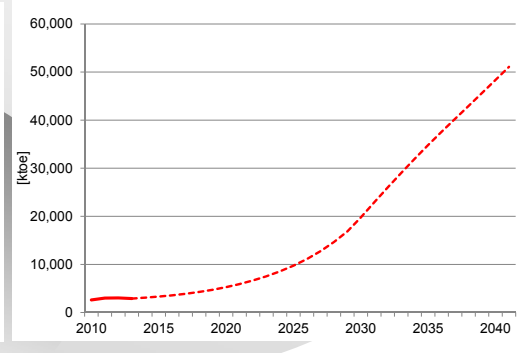
Projection of Transport Sector Energy Consumption

- Referring to the historical trend of Indonesia and Thailand that the transport sector's energy consumption per capital starts growing steeply when GDP capita (PPP) reached around 5,000-6,000 USD and the growth becomes moderate when it exceeds 8,000 USD, this study considers that the car ownership increases rapidly during that period.
- Bangladesh is expected to follow this track, i.e. the transport sector energy consumption, driven by car ownership, will increase rapidly from mid-2020s to early 2030s.
- The sector's energy consumption will reach around 51,000 ktoe in 2041.

Sectorial Energy Consumption per Capita (projection)



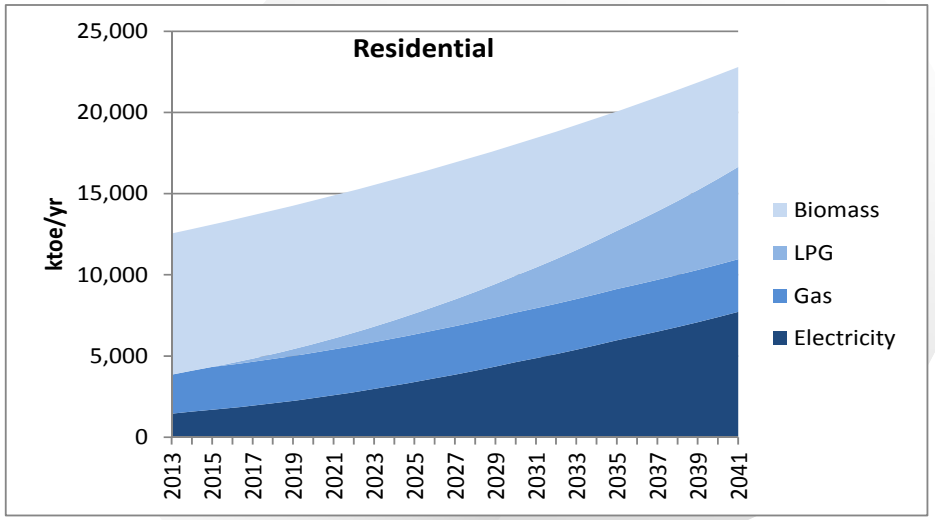
Sectorial Energy Consumption (projection)



Source: Prepared by the Study Team

Residential Sector Energy Consumption (Modes of Energy Supply)

- Conventional modes of energy supply (biofuels, e.g. firewood) will be substituted by electricity and gas (mainly LPG, assuming that natural gas supply to residential sector won't increase).

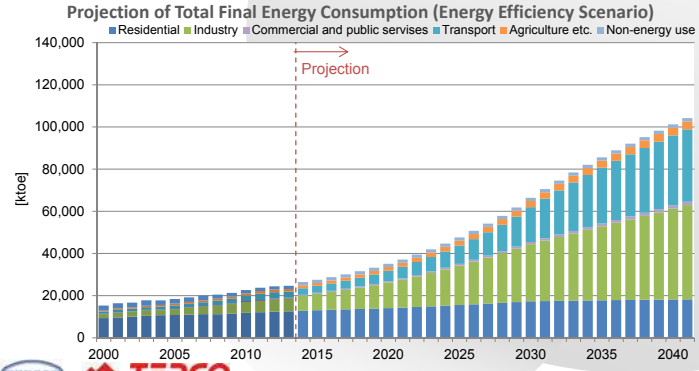


(2) Energy Efficiency Target Setting and Supply-Demand Balance

Energy Efficiency Target Setting

- This study suggests that energy efficiency measures are to be implemented in Bangladesh so that the energy intensity will be lowered to
  - 2.91 toe/million BDT in 2030 (down -15% from 2014) and
  - 2.73 toe/million BDT in 2041 (down -20% from 2014)

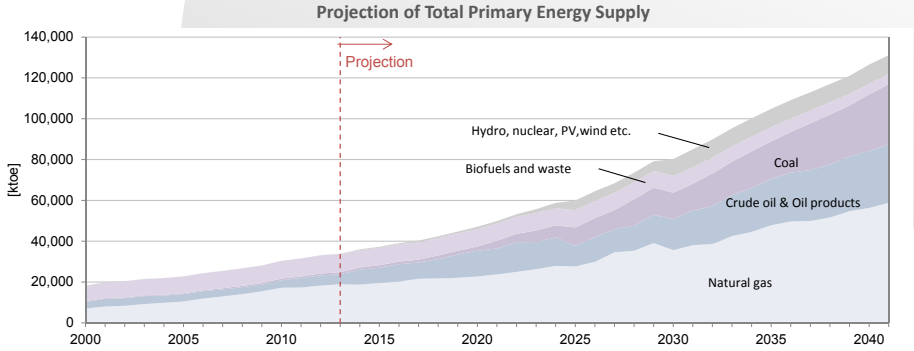
  * The definition of energy intensity is different from that of JICA's Energy Conservation Master Plan (ECMP: March 2015). Using the same definition as that of ECMP, the energy intensity as of 2030 will be -20% down from 2014 (achieving the target proposed by ECMP), and this level will be maintained until 2041.
- After considering the energy efficiency, the total final energy consumption in 2041 will be 104,200 ktoe, about 4.2 times increase from 2013 (5.3% p.a.).



Sectors	TFC in 2041 (ktoe)	Growth ('13-'41)
Residential	18,238 (18%)	1.3%
Industrial	44,711 (43%)	7.4%
Commercial & Public Service	1,598 (2%)	4.7%
Transport	34,295 (33%)	9.2%
Agriculture	3,778 (4%)	4.4%
Others	47 (0%)	0.4%
Non-energy use	1,534 (1%)	-
Total	**104,200 (100%)**	**5.3%**

Total Primary Energy Supply

- Based on the projection of total final energy consumption as seen in the previous slide, the total primary energy supply is forecasted as shown in the following figure.
- In this projection, Scenario 3 of power development plan (i.e. gas and coal account for 35% each in power generation in 2041), and the share of natural gas and oil products in transport sector won't change (i.e. about 1:2). The share of fossil fuel sources may vary depending on the choice of scenarios.



Power Balance Strategy

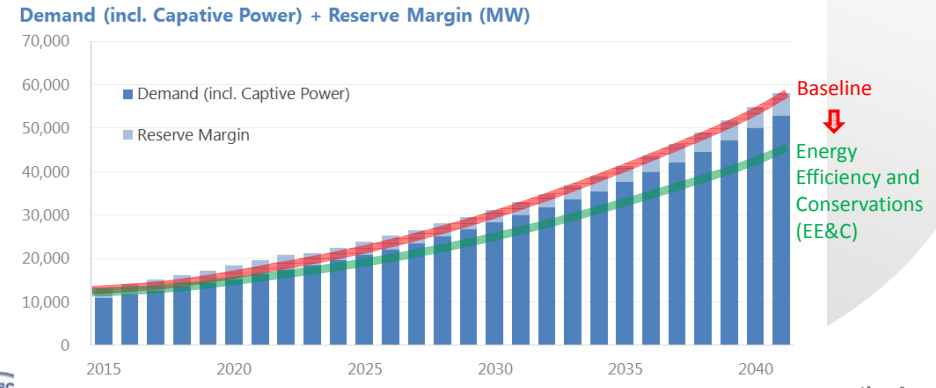
Power Demand Forecast

Assumptions:

- GDP growth rate: around 6% for 2014/41.
- Reserve Margin (RM) kept down to 10% by 2030

Projections:

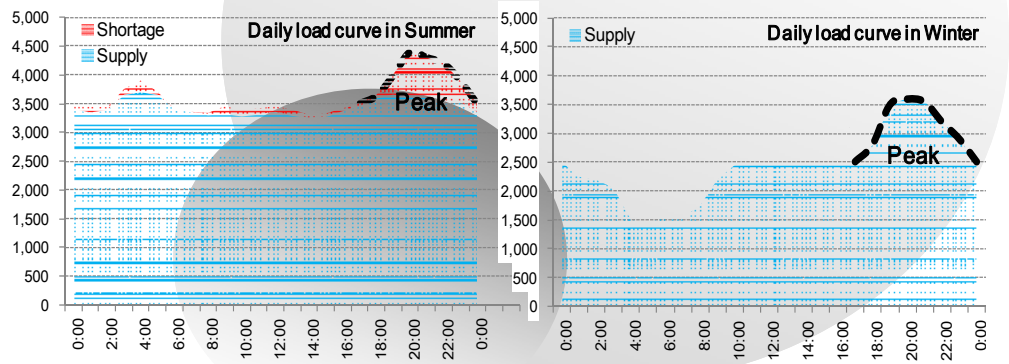
- Required supply will be at 57,000MW including Reserve Margin
- Energy Efficiency and Conservations (EE&C) is challenging and important issue for Bangladesh



Estimation of the maximum power including potential demands

- The power supply has constantly remained strained in peak. Potential demands have not been met, and rotational outage has frequently occurred. The actual recorded maximum power has not included these potential demands.
- To estimate the maximum power that includes potential demands, PSMP adopts a method for calculating the generated power energy with which a compound daily load curve is produced by adding the evening peak demand for lighting, calculated from a daily load curve with no rotational outage on weekends and holidays in winter, to a daily load curve suppressed by rotational outage on weekdays in summer.

Typical daily load curves in Bangladesh in summer and winter

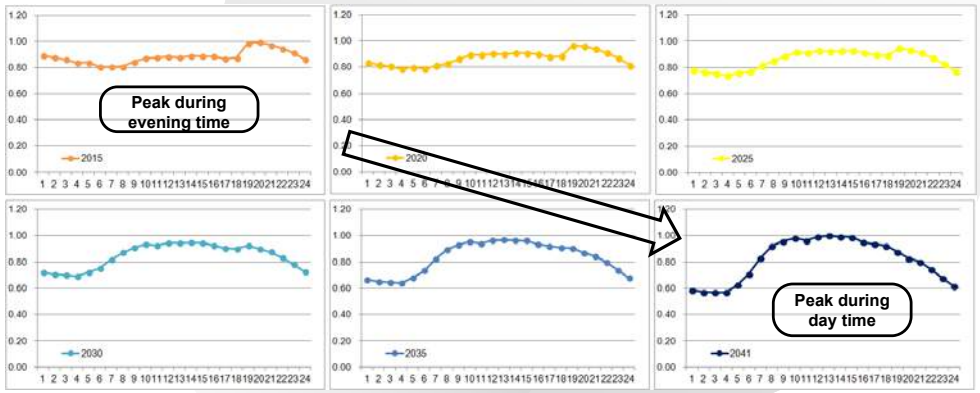


Assumption of daily load curve

General of daily load curve

- Daily load curve in 2015 is estimated based on actual power consumption in Bangladesh.
- Daily load curve is gradually sifted to type of developed country's daily load curve until 2041

Shift of Daily Load Curve (2015-2041)

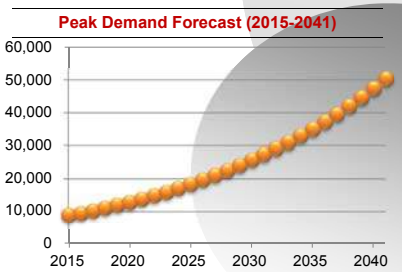


Power Demand Forecast

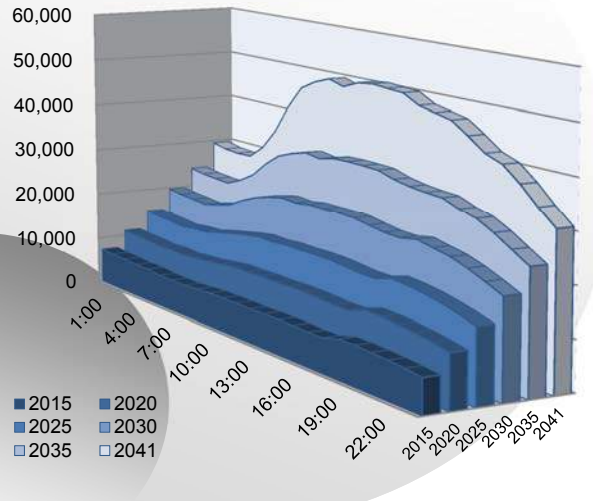
Power Demand Forecast

- Power demand is estimated by multiplying estimated maximum power and estimated daily load curve from 2015 to 2041.
- Estimated power demand forecast from 2015 to 2041 shows shift change of daily load curve from evening peak to daytime peak and increasing peak demand from 8,921 MW to 50,400 MW.

Peak Demand Forecast (2015-2041)



Estimated Power Demand Forecast (2015-2041)



Fuel Price Scenario

Study of Economic Value

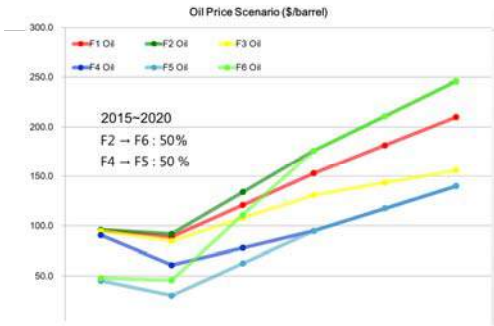
F1 to F5 Scenario of future fuel cost is studied. IEA's scenario of international fuel cost trend is employed as from F1 to F4, and current status in Bangladesh is considered in F5 and F6 Scenario

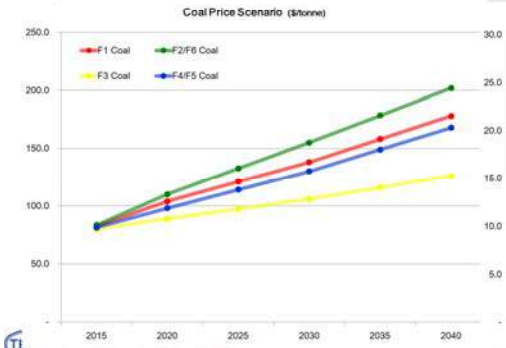
F1 : IEA's New Policies Scenario
F2 : IEA's Current Policies Scenario
F3 : IEA's 450 Scenario
F4 : IEA's Low Oil Price Scenario
F5 : Revised F4 Scenario [Base]
F6 : Revised F2 Scenario [High]

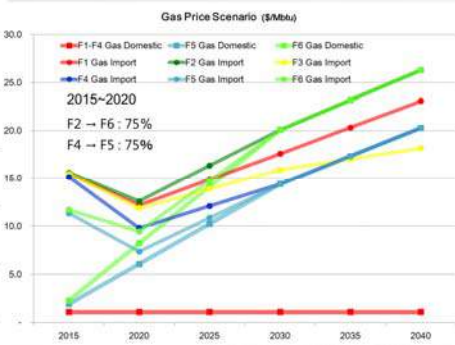
		New Policies Scenario			Current Policies Scenario			450 Scenario			Low Oil Price Scenario		
	2014	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
Nominal terms			F1			F2	F5		F3			F4	F6
IEA crude oil imports ($/barrel)	97	89	153	210	92	176	246	85	131	156	61	95	140
Natural gas ($/MBtu)													
United States	4.4	5.2	8.3	12.3	5.2	8.6	12.8	5.0	7.6	9.7	5.2	8.3	12.3
Europe imports	9.3	8.6	15.1	20.3	9.0	16.9	22.6	8.4	12.7	14.6	6.6	12.1	18.7
Japan imports	16.2	12.2	17.6	23.1	12.6	20.1	26.3	11.9	15.9	18.2	9.8	14.4	20.3
OECD steam coal imports ($/tonne)	78	104	138	178	110	155	202	89	106	126	98	130	168

Notes: MBtu = million British thermal units. Gas prices are weighted averages expressed on a gross calorific-value basis. All prices are for bulk supplies exclusive of tax. The US price reflects the wholesale price prevailing on the domestic market. Nominal prices assume inflation of 1.9% per year from 2014.

Fuel Price Scenario







F5 : Revised F4 Scenario considering with current market

F6 : Revised F2 Scenario considering with current market

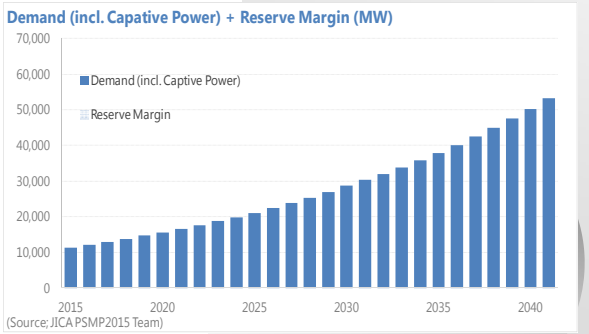
Oil price: 50% of F5 (2015-2020), 100% by 2030

Gas price: 75% of F5 (2015-2020), 100% by 2030

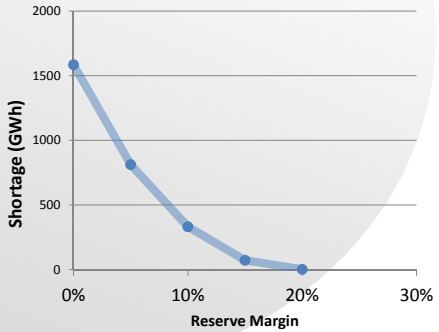
Coal price : 100% (2015-2041)

Supply reliability

- In the case of developing an appropriate power supply plan that corresponds to the assumed power demand, it is necessary to set an appropriate reserve margin in consideration of delay risks connected to project implementation, and fluctuation risks of the power demand forecast.
- Therefore, over the short-terms, the reserve margin is targeted at 0% in consideration of the current status, and the reserve margin will increase gradually afterwards, and will reach 10% by the long-term period.
- As a reference, more than 20% of reserve margin is required at 2015 in order to resolve power shortage.



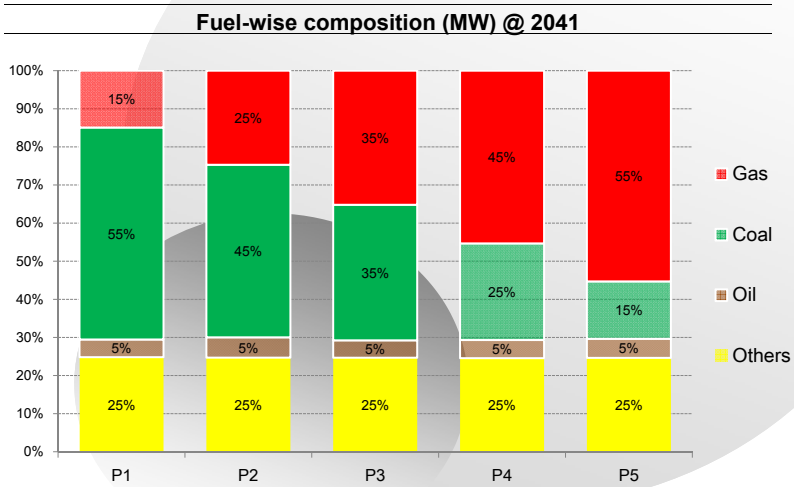
Relationship between shortage and RM @2015



Fuel-wise Composition Scenario

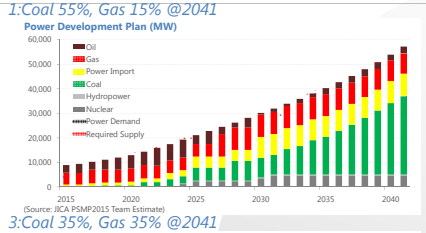
Study of optimum composition of fuel type

P1 to P5 scenario of fuel-wise composition is studied. Only coal and gas balance from 15% to 55% is changed in each Scenario.

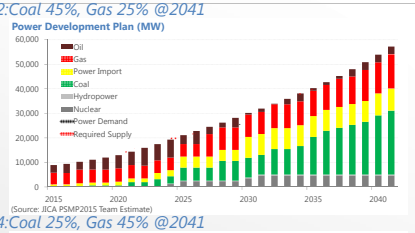


PDP Scenarios

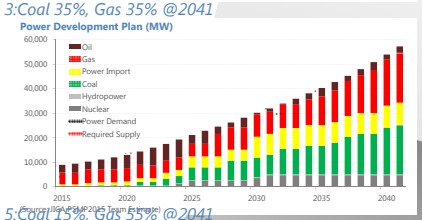
1:Coal 55%, Gas 15% @2041



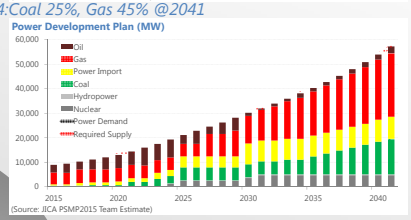
2:Coal 45%, Gas 25% @2041



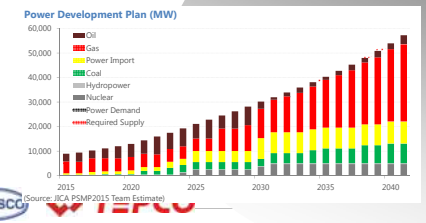
3:Coal 35%, Gas 35% @2041



4:Coal 25%, Gas 45% @2041

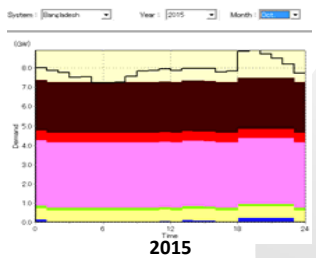


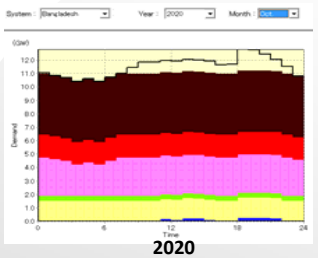
5:Coal 15%, Gas 55% @2041

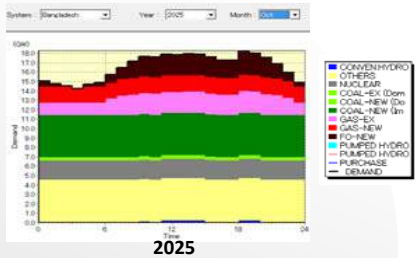


Economy index (PDP Scenarios)

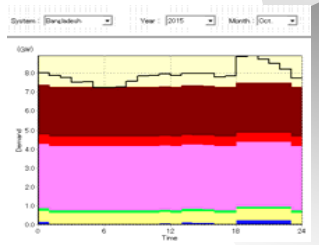
Scenario 1 (F5)

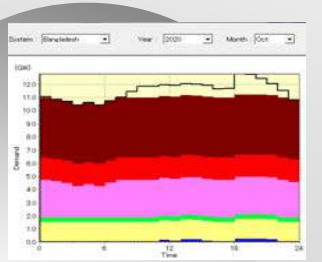


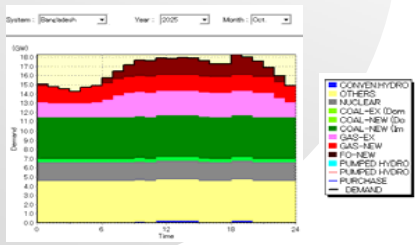




Scenario 1 (F6)

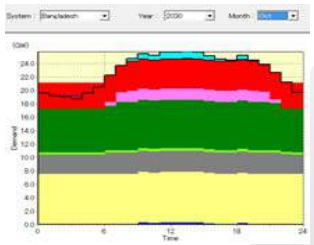


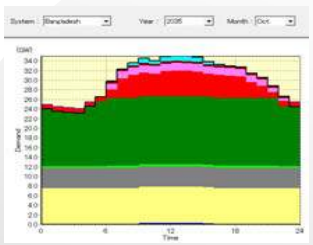


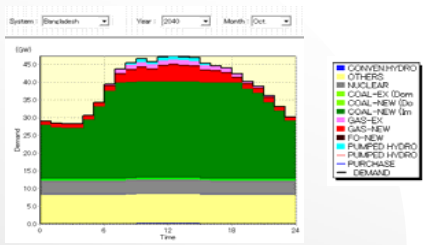


Economy index (PDP Scenarios)

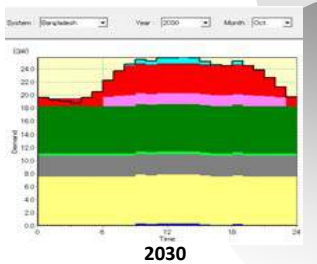
Scenario 1 (F5)

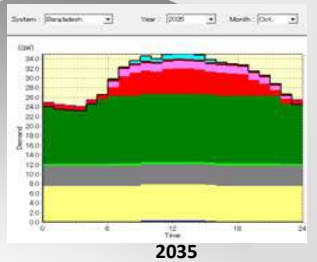


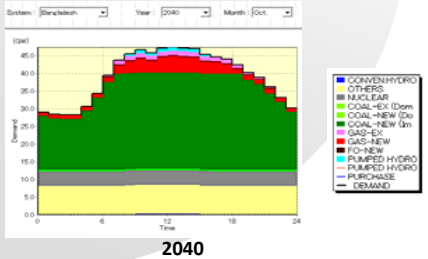




Scenario 1 (F6)

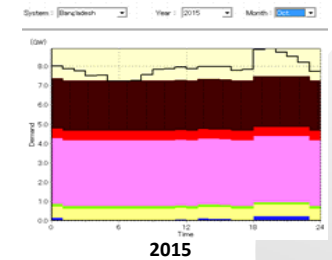


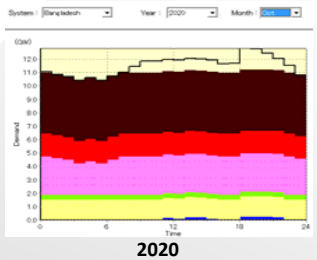


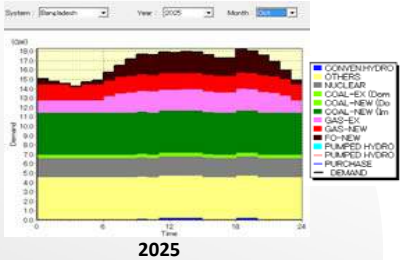


Economy index (PDP Scenarios)

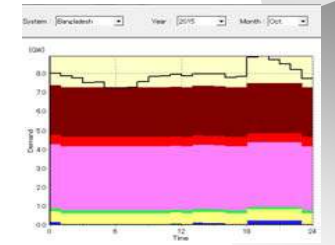
Scenario 2 (F5)

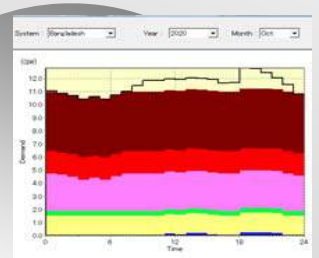


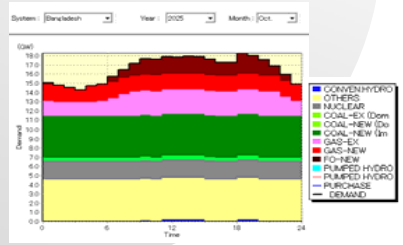




Scenario 2 (F6)

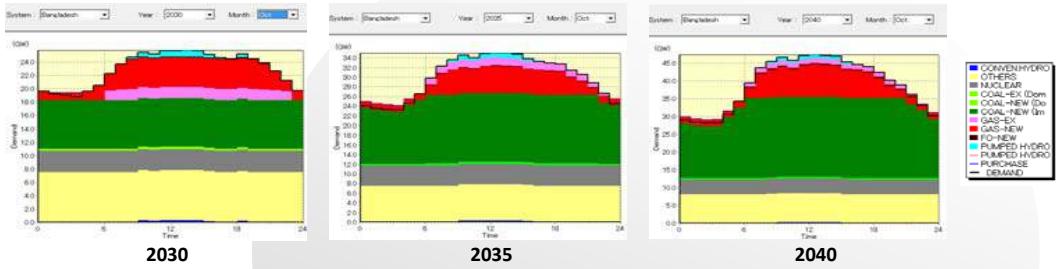




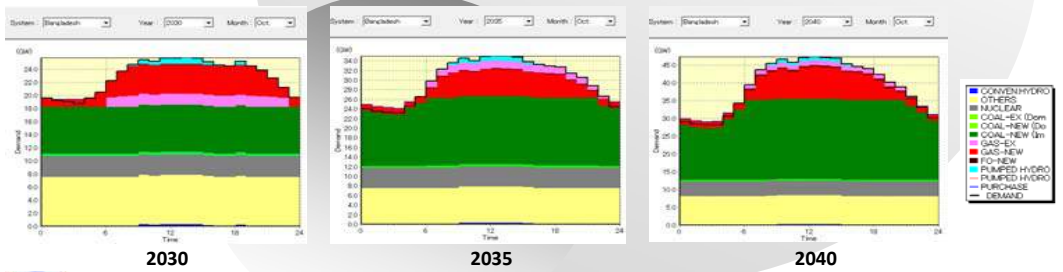


Economy index (PDP Scenarios)

Scenario 2 (F5)

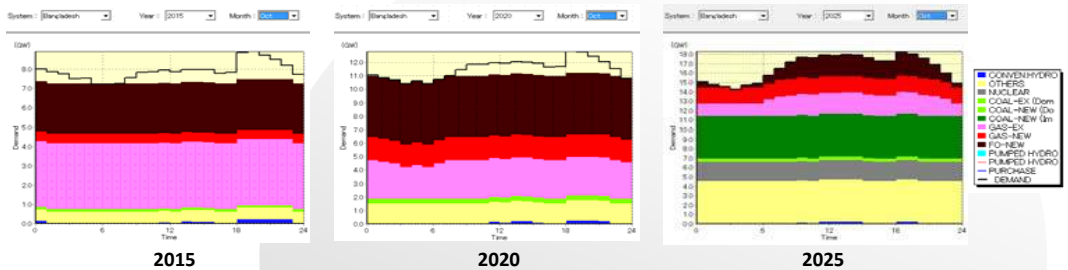


Scenario 2 (F6)

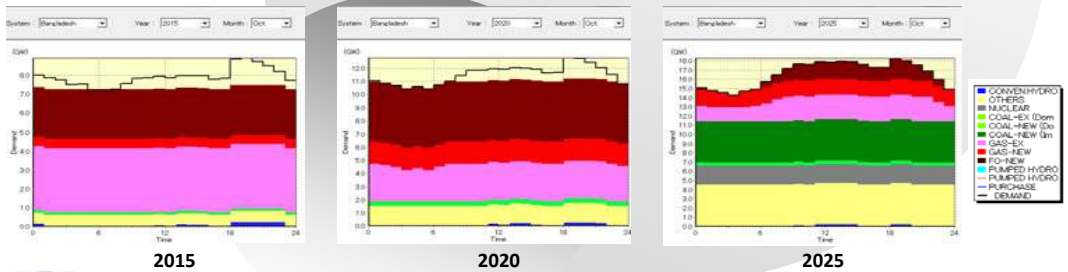


Economy index (PDP Scenarios)

Scenario 3 (F5)

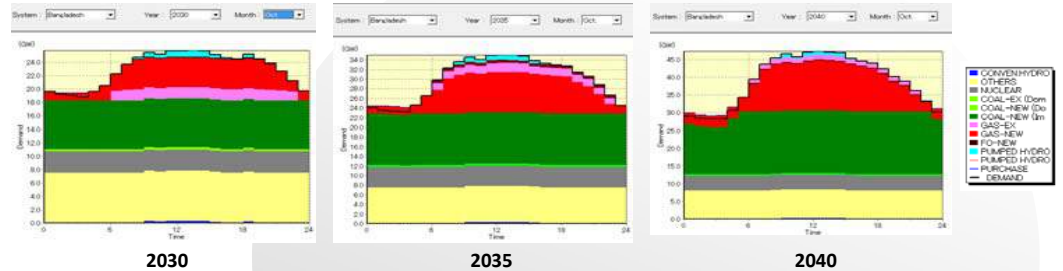


Scenario 3 (F6)

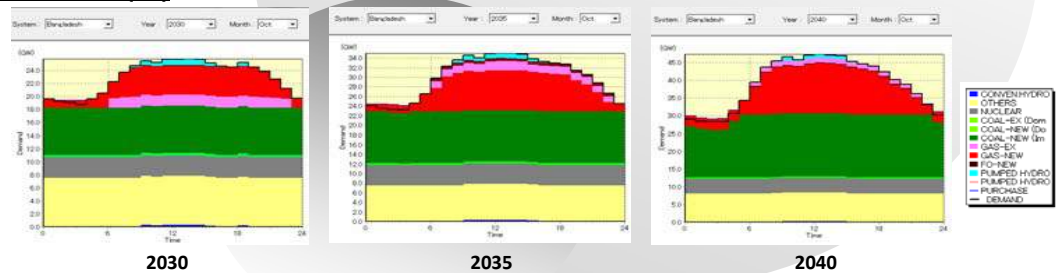


Economy index (PDP Scenarios)

Scenario 3 (F5)

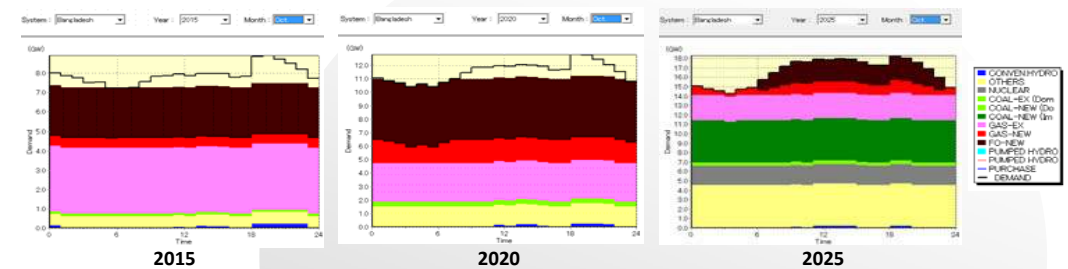


Scenario 3 (F6)

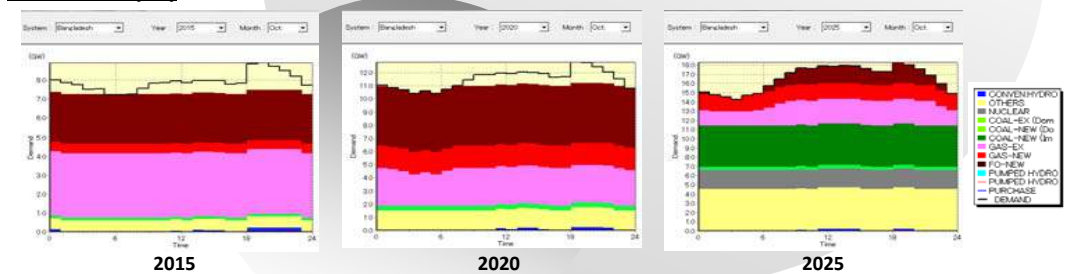


Economy index (PDP Scenarios)

Scenario 4 (F5)

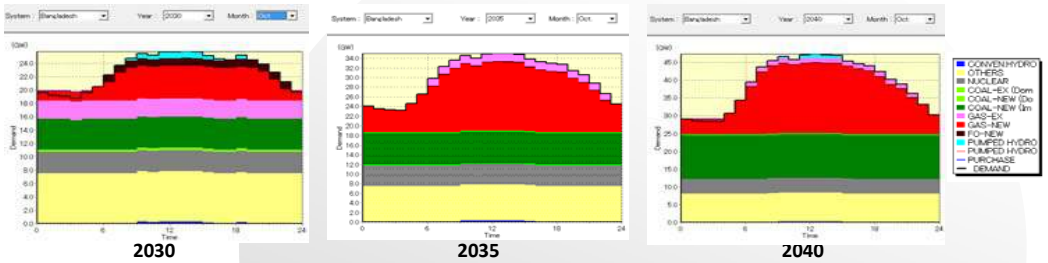


Scenario 4 (F6)

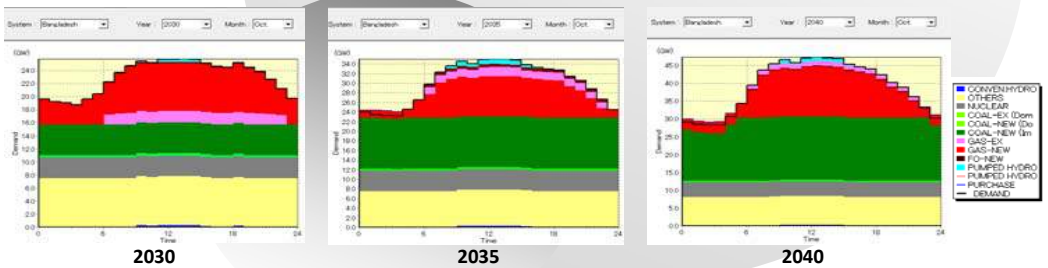


Economy index (PDP Scenarios)

Scenario 4 (F5)

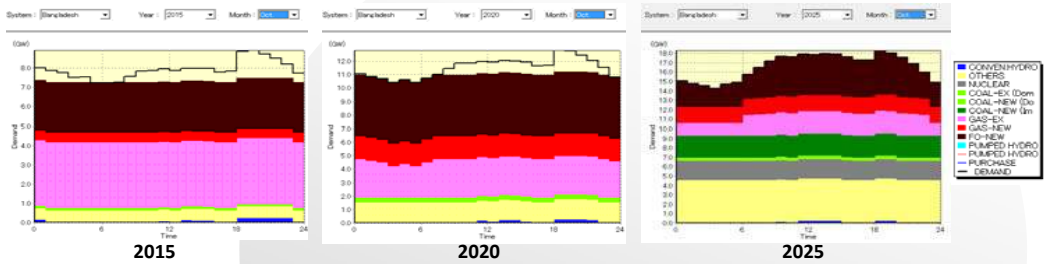


Scenario 4 (F6)

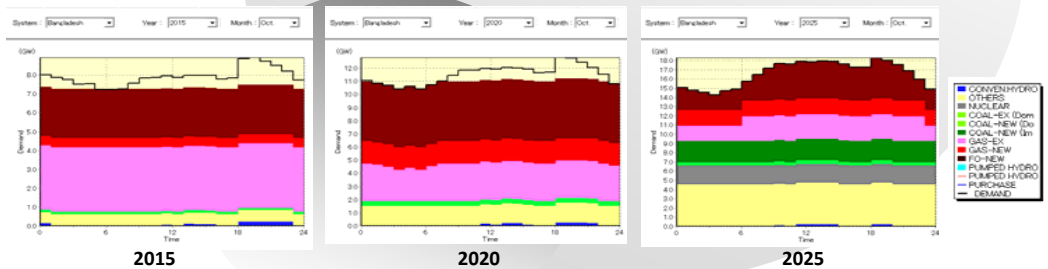


Economy index (PDP Scenarios)

Scenario 5 (F5)

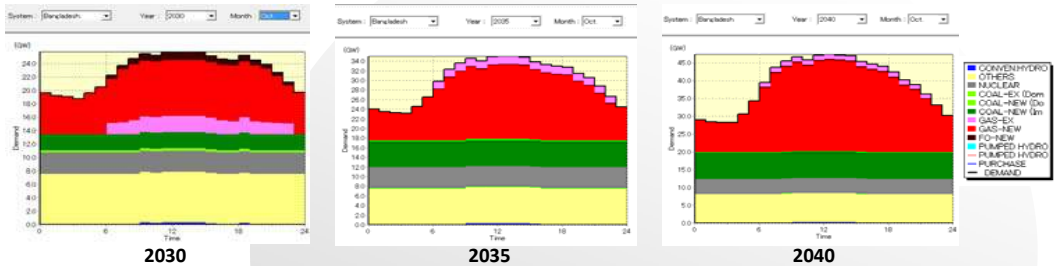


Scenario 5 (F6)

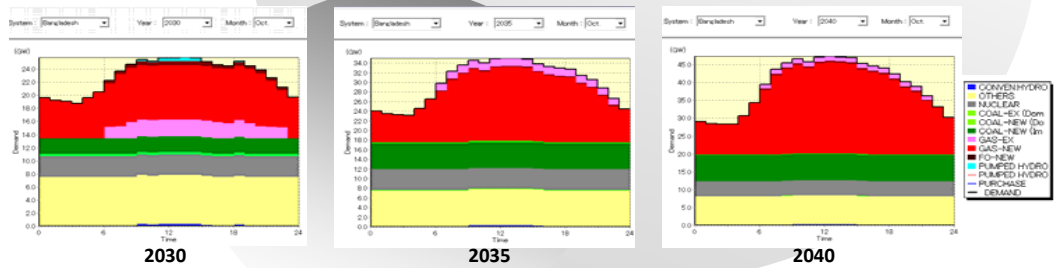


Economy index (PDP Scenarios)

Scenario 5 (F5)



Scenario 5 (F6)



3E Evaluation of Energy Mix Scenarios

- 3E (Economy, Energy Security, and Environment) of 5 scenarios are evaluated using following indices.
- Smaller value of these index shows better composition.

Economic Index	Environmental Index	Energy Security Index	3E Index
Generation cost per electricity supply [US cent / kWh]	Carbon cost per electricity supply [US cent / kWh]	GDP loss when energy is not delivered [US cent / kWh]	Total of these indices [US cent / kWh]

Economic Index

- Generation cost (fixed price + fuel price) per electricity supply
- Assuming fuel price of F5 Scenario (Revised IEA's Low Oil Price Scenario) cf. "Fuel Price Scenario" slide

Environmental Index

- Carbon cost per electricity supply
- Assuming carbon price in IEA's 450 scenario

Table 1.4 ▷ CO_2 price assumptions in selected countries and regions by scenario ($2014 per tonne)

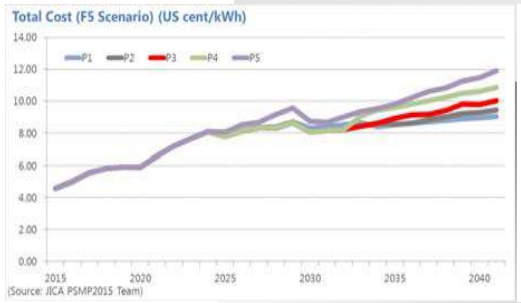
	Region	Sectors	2020	2030	2040
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry	10	75	125

Economic Index

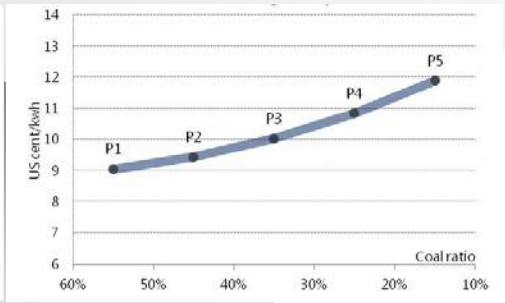
Economic Index
Generation cost (fixed price + fuel price) per electricity supply [US cent / kWh]

- The power generation cost is estimated at 9 to 12 US cents/kWh for 2040 under F5 scenario.
- Comparison of the power generation cost between the five scenarios for energy source ratio shows the power generation cost becomes higher as the ratio of coal to all the energy sources becomes smaller.

Power generation cost under each scenario for energy source ratio



Relationship between Coal ration and power generation cost

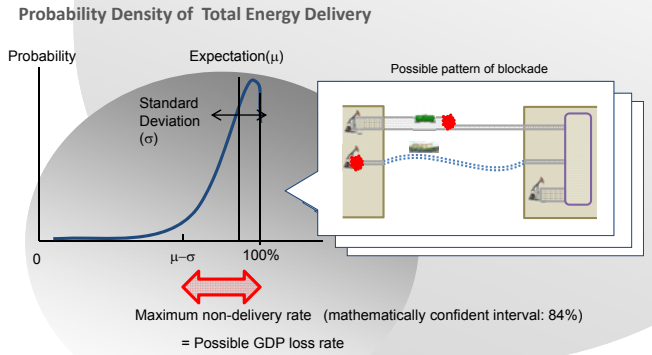


About Energy Security Index

Energy Security Index

- Since every economic activities use energy, possible non-delivery rate can be considered as possible GDP rate.
- Energy security index expressed in monetary value:

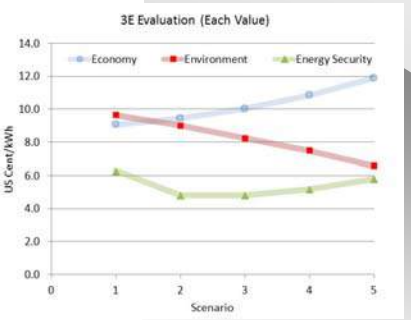
Energy Security Index [$ / kWh]
= GDP[$] x Possible non-delivery rate [%] / Primary Energy Supply [toe] / Generation Efficiency [kWh/toe]

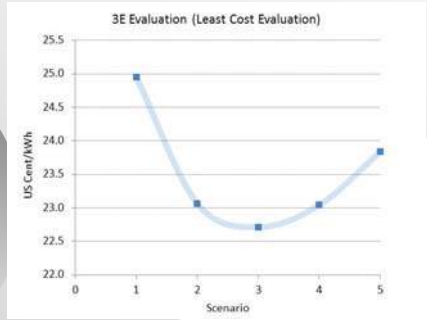


Security index: Evaluation of Risks

- Three indices (Economy, Environment, Energy security) in 2041 are calculated and integrated as follows:

	Composition (MW base)	Economy [US cent/kWh]	Environment [US cent/kWh]	Energy Security [US cent/kWh]	Total [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	9.06	9.64	6.29	25.0
Scenario 2	Gas 25%, Coal 45%	9.45	9.00	4.82	23.1
Scenario 3	Gas 35%, Coal 35%	10.03	8.23	4.81	22.7
Scenario 4	Gas 45%, Coal 25%	10.84	7.48	5.18	23.0
Scenario 5	Gas 55%, Coal 15%	11.89	6.57	5.81	23.8





Power Quality

Fact Findings

Each utility has a strong initiative and accurate understanding to improve power:

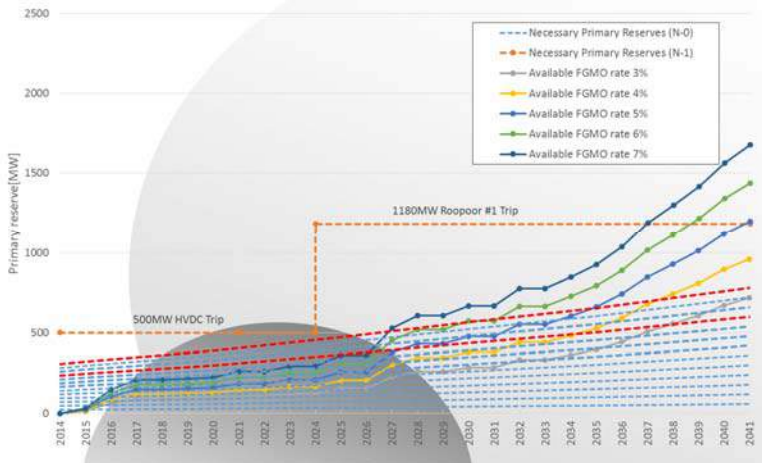
1. Significant deficiency of power source including spinning reserve.
2. No application of automatic control such as LFC, free-governor operation. Instruction by telephone communication only.
3. Inadequate coordination of daily generation scheduling between NLDC and GenCos.
4. NLDC has less regulatory authority to make a balance between demand and supply.

Challenges in NLDC proves Bangladesh has enormous power system quality improvement potential.



Frequency chart of Free Governor mode operation test with Khulna gas turbine generator (158MW)

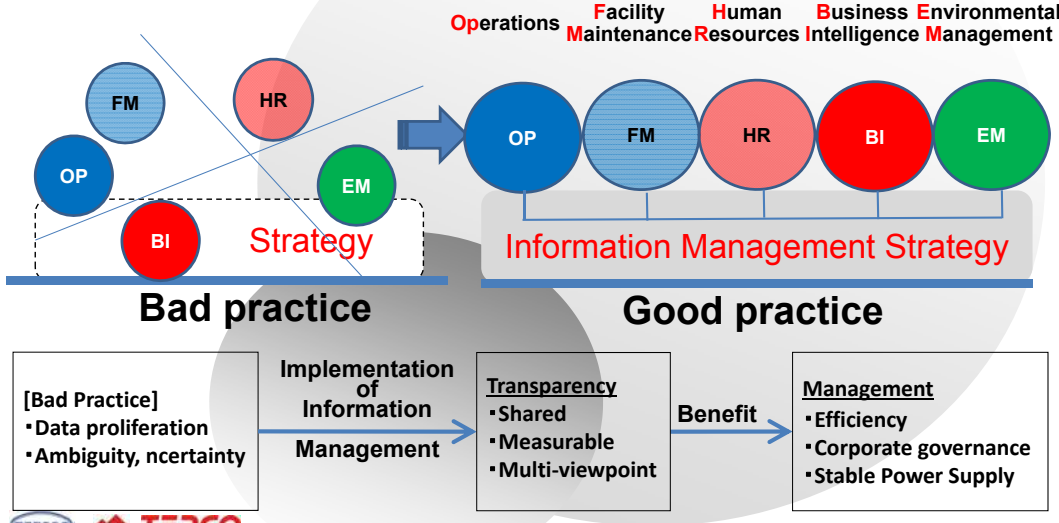
Requirement of primary reserve



	2015	2020	2025	2030	2035	2040	2041
Power demand [MW]	8,920	12,949	19,191	27,434	36,634	49,034	52,034
Requirement for ±0.5Hz [MW]	248	299	364	436	503	582	600
Requirement for ±0.2Hz [MW]	323	389	474	566	654	757	780

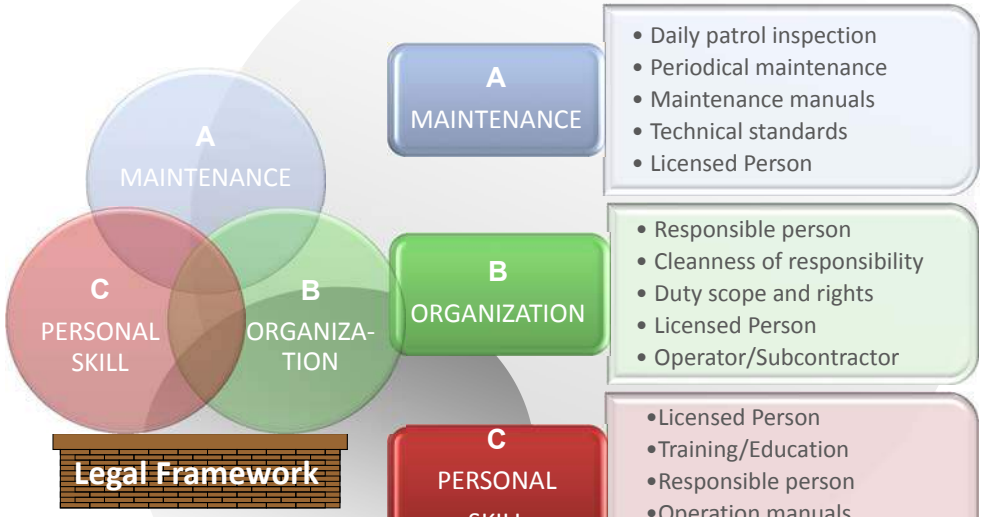
Information Management (1)

Strategic Approach to Integrated Information Management



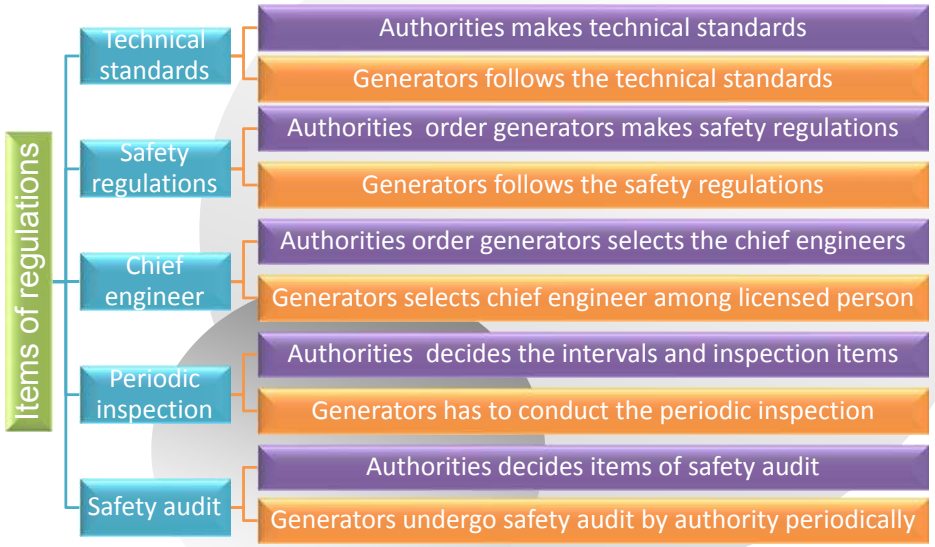
Legal framework

Legal framework should support key factors of O&M



Legal framework -3

Recommended items of regulations for Bangladesh



PSMP2015
High-Level Discussion

MAIN PART

PSMP2015 Key Discussion Points

A Road Map

B PSMP2010 Review

C Global Policy Trends
- SDGs
- COPs

D Economic Development
- GDP Projection
- Economic Growth Scenario
- Policy for Industrial Development

E Energy Balance Strategy
- Projection of Energy Consumption in Bangladesh
- Industrial Sector Energy Demand
- Policy Measures for Promoting Industrial Development
- Transport Sector Energy Demand
- Prospects of Transport Sector in Bangladesh
- Civilian Sector Energy Demand (Residential & Commercial)
- Agricultural Sector Energy Demand
- Energy Supply & Demand Balances
- Gas Supply (Domestic & Import LNG)
- Coal Supply (Domestic & Import)
- Oil and LPG Supply

F Power Balance Strategy
- Demand Forecast and Power System Plan
- 3E (Economy, Energy Security, and Environment)
- Power Quality
- Nuclear and Cross Border
- Universal Access to Modern Energy and Renewable Energy
- Operation and Maintenance (O&M) and Legal Framework

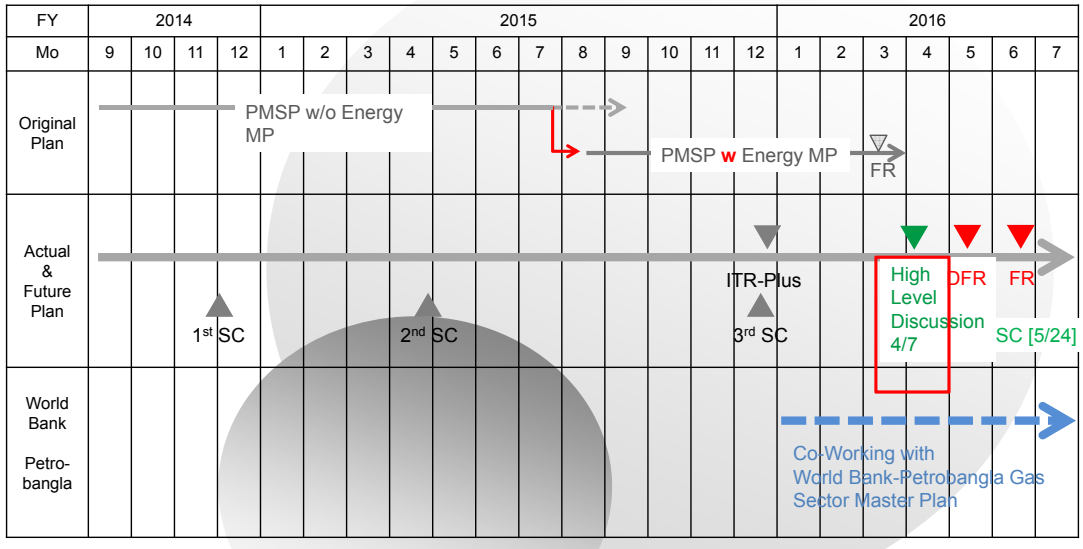
G Energy and Power Tariff Strategy
- Tariff Policy
- Impact on National Economy

High-level Discussion Objectives

- To share PSMP2015 Survey Team's assumptions, especially the Economic Development Scenarios.
- PSMP2015 Survey Team has come up with various [Discussion and Proposals]. These are the basis for Policy Recommendations.
- Without consent from High Level, the Survey Team is not possible to go further to derive appropriate Policy Recommendations.

TO SHARE AND DISCUSS THE ASSUMPTIONS and PROPOSALS, WE JOIN THE HIGH LEVEL DISCUSSION

Implementation Schedule



A Project Outline and Road Map

A-1 Project Outline

Key Issues in Energy Balance Analysis in Bangladesh

Energy Demand

- In Bangladesh, where the energy demand is expected to grow rapidly, the energy supply infrastructure needs to be developed so that the supply shortage won't impair the development of national economy.
- Forecasting the long-term economic development should consider a non-linear structural changes of the national economy in the future. Scenario planning analysis referring to the experiences in Asian countries is recommended.

Primary Energy Supply

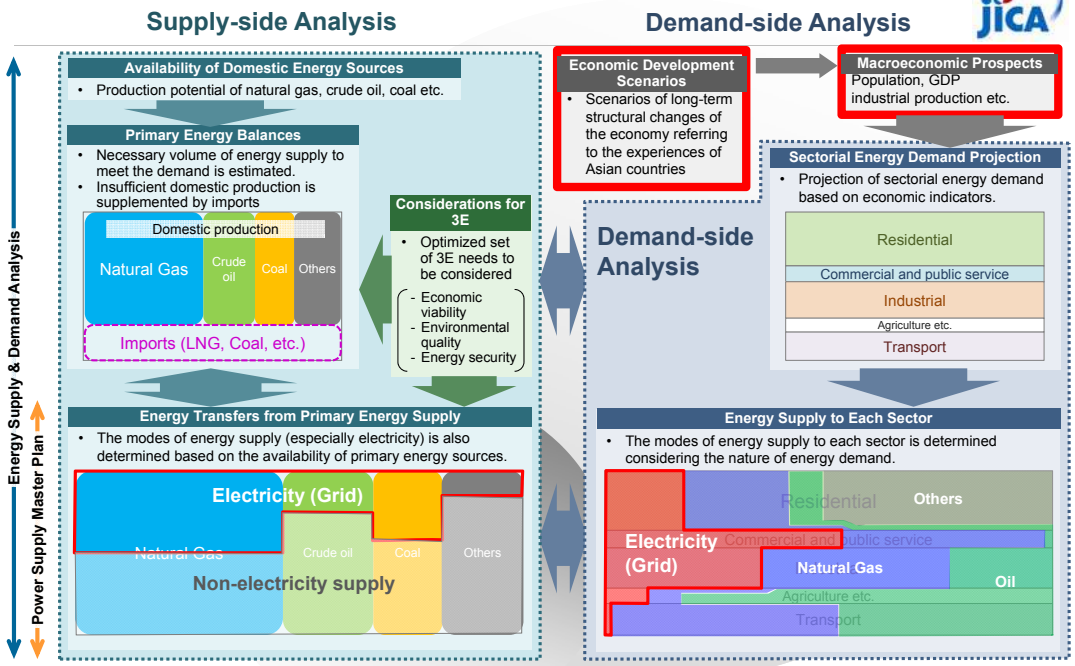
- Energy supply in Bangladesh has been heavily dependent on the domestic production of the primary energy sources, especially natural gas.
- Though the domestic production is expected to start depreciating and the energy import will gain importance, the optimized utilization of domestic production remains to be the core of energy supply.
- In addition, consideration for environmental issues and energy security will be a factor to confine the availability of energy sources

Modes of Energy Supply to End Consumption

- From demand-side, necessary capacity of electricity supply should consider not only the increasing energy demand but also the electrification of energy demand (shift to electricity supply from other modes of supply) though the extent of electrification varies among sectors.
- From supply-side, the capacity of electricity supply is affected by the available sources for electricity generation (including the geographical conditions of energy supply infrastructure).

→ Composition of the modes of energy supply (especially electricity supply) will be determined both by demand-side and by supply-side.

Flow of Energy Balances Analysis



B PSMP2010 Review

Summary

- "Common" GDP growth forecast needs to be applied for primary energy demand forecasts and other national-level infrastructure strategies should follow.
  - But no such figure is yet established.
- How the growing needs of primary fuel will be met in the next two decades? This question must be answered as soon as possible
  - Specifically domestically produced coal, natural gas, oil and LPG – domestic fuel should come first, import later.
- How to determine Optimum Primary Energy Balance and Power System Development Plan, considering 3E(Economic, Environment, and Energy Security. O&M and Quality of Power requires new legal systems. Power Quantity and Power Quality.
  - Without high-level commitment, such new system never works

TO HIGHLIGHT AND ADDRESS THESE ISSUES, WE JOIN THE Discussion

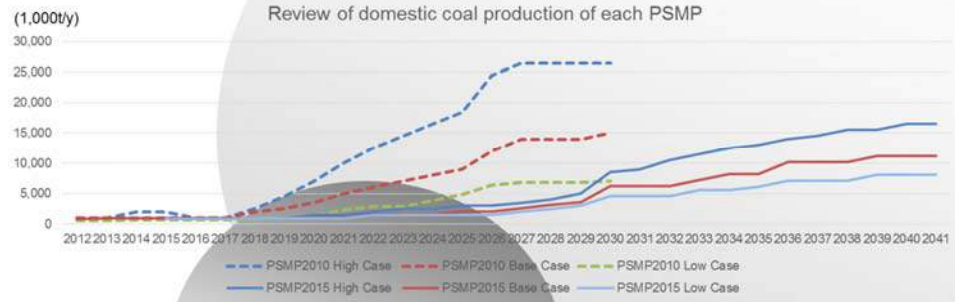
Comparison of 2010/2015

		PSMP2010 Outline	PSMP2015 Outline	PSMP2015 Discussions Perspectives
GDP		3 Scenario *Government Policy Scenario *6% Growth Scenario *7% Growth Scenario (In case of Government Policy Scenario Below)	PSMP2015 Scenario based on Macroeconomic Analysis	Economic Development
Power Demand	2020	17,304 MW	12,949 MW	
	2030	33,708 MW	27,434 MW	
	2041	-	52,034 MW	
Power Supply (Installed Capacity)	2020	23,809 MW	12,949 MW	Energy Balance Strategy -Domestic Gas to be developed? -Domestic Coal to be developed? Power Balance Strategy -3E analysis Economic Development -Impact on Economy
	2030	38,685 MW	30,178 MW	
	2041	-	57,238 MW	
Diversification	Gas	25%	15%-55%	
	Coal	30%	15%-55% (Domestic: 1% or above)	
	Oil	5%	5%	
	Others(Nuclear, Import, Hydro)	20%	25%	
Features		*Proposal of Prioritized Projects (Matarbari PP) *Financing	*Integrated Discussion on Energy, Power, and Economy *Power Quality	

Coal Review

National Coal Development Policy

[Fact Finding]



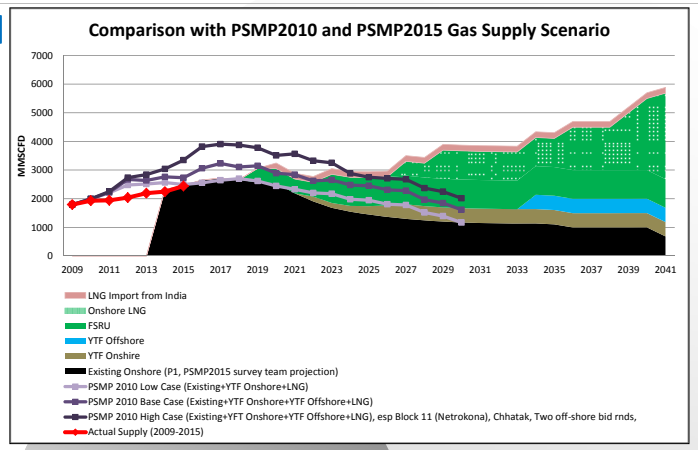
The reasons that lowered amount of production of PSMP2015 in comparison with PSMP2010 are following the fact that;

(1) Coal Policy was almost ready for public and domestic coal development was strongly recommended by the Government in PSMP2010.

(2) Domestic coal development is in a difficult social situation in PSMP2015, and urge for importing.

Gas Review

[Fact Finding]

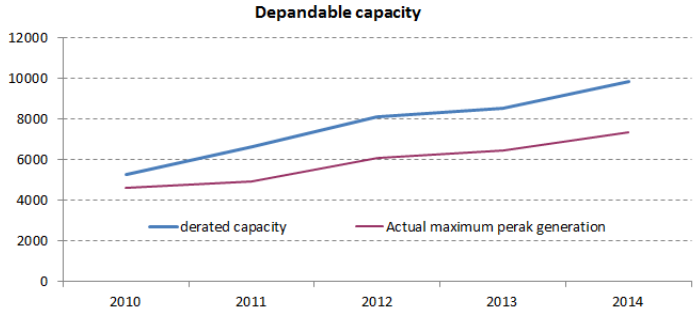


- Gas Supply Projection in PSMP2010 was reviewed against Actual Gas Production Record from 2009 through to 2015.
- PSMP2010 employed HCU resource projection. This was more optimistic resource count than what PSMP2015 employs (RPS Energy & Petrobangla)
- PSMP2010 assumed more optimistic timeline of YTF resource development. (both onshore and offshore)

Power Development Plan (Dependable capacity)

Dependable Capacity for existing generations

[Fact Finding]



Items	2009	2010	2011	2012	2013	2014
Actual maximum perak generation	4,162	4,606	4,890	6,066	6,434	7,356
Derated capacity	5,166	5,271	6,639	8,100	8,537	9,821
Depandable capacity ratio (max/capacity)	81%	87%	74%	75%	75%	75%
Recent 5 year average						77%

C Global Policy Trends

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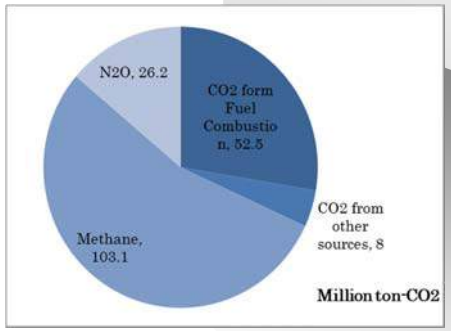
C-1 Sustainable Development Goals (SDGs)

C-2 Environmental Policy

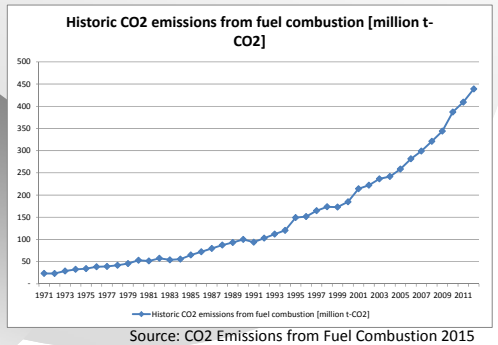
Environmental Policy: Current Status of GHG Emission

- In Bangladesh, CO2 emissions from fuel combustion accounts for less than one third of total green house gas(GHG) emissions , according to IEA publication.
- In this context, power sector may not be the first priority to deal with in GHG emissions reduction.
- However, CO2 emissions from fuel combustion, including power sector, has been increasing and it is supposed to account for the largest share of GHG emissions in the near future.

Estimated GHG emissions by gases in Bangladesh in 2010



CO2 emissions from fuel combustion in Bangladesh



Source: CO2 Emissions from Fuel Combustion 2015

Bangladesh's Involvement in UNFCCC

- At COP19 Meeting (Bali Island, 2012), Countries have agreed to publicly outline what post-2020 climate actions they intend to take under a new international agreement. The action is called Intended Nationally Determined Contributions (INDCs).
- Bangladesh government submitted INDC to UNFCCC secretariat in September 2015. Other countries also submitted INDC and all the submitted INDCs cover around 90% of total CO2 emissions in the world.
- Particularly, Bangladesh stated on power sector's action in INDC as measures assumed conditional contribution.

Proposed Commitments of Bangladesh Government

Mitigation contribution

- Unconditional contribution (Contribution assuming no additional international support)
  - Reduce GHG emissions in the power, transport, and industry sectors by 12 MtCO2e by 2030 or 5% below BAU emissions for those sectors
- Conditional contribution (Contribution assuming additional international support)
  - Reduce its GHG emissions in the power, transport, and industry sectors by 36 MtCO2e by 2030or 15% below BAU emissions for those sectors

Existing mitigation actions(Measures assumed in Unconditional contribution)

- Power
  - A target to deliver 5% of energy from renewable sources by 2015, and 10% by 2020 (2008Renewable Energy Policy)
  - Construction of Combined Cycle Power Plant (CCPP) by the Government of Bangladesh and utilities companies

Additional mitigation actions in power, industry and transport (Measures assumed in Conditional contribution)

- Power
  - Ensure all new coal generation uses super-critical technology (100% of new coal based power plants use super-critical technology by 2030)
  - Increased penetration of wind power（400 MW of wind generating capacity by 2030)
  - Implement grid-connected solar plant to diversify the existing electricity generation mix (1000 MW of utility-scale solar power plant)

Commitments of Other Asian Countries

- Among the other Asian countries that submitted INDC, India especially expresses proactive commitments to address the GHG emission in power sector.
- It is noted that India shows an expectation on the next-generation clean-coal technologies such as IGCC and IFGC and nuclear power.

Summary of INDC Submitted by India

Target of Reducing GHG Emission	Technologies to be Promoted
▪ Reduce the emissions intensity of its GDP by 33 to 35 percent by 2030 from 2005 level. • Achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF). • Create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030 ▪ India declared a voluntary goal of reducing the emissions intensity of its GDP by 20–25%, over 2005 levels, by 2020, despite having no binding mitigation obligations as per the Convention	▪ Clean Coal Technologies (CCT) • Pulverized Combustion Ultra Super Critical (PC USC) • Pressurised Circulating Fluidised Bed Combustion, • Super Critical, Combine Cycle (PCFBC SC CC) • Integrated Gasifier Combined Cycle (IGCC) • Solid Oxide Fuel Cell (SOFC) • Integrated Gasifier Fuel Cell (IGFC) • Underground Coal gasification (UCG) ▪ Nuclear Power • Pressurized water reactor • Integral pressurized water reactor • Advanced Heavy Water Reactor (AHWR) • Fast breeder reactor (FBR) • Accelerated-driven systems in advanced nuclear fuel cycles

COP21 Paris Conference



Source: UNFCCC

- First and most outcome of COP21 (Paris, December 2015) was adoption of the Paris Agreement, that covers several issues including long-term goal, individual country's contribution (INDC), loss and damage, technology development and transfer and finance.
- For long term target, it describes ambitious visions up to both 2050 and 2100 as below.

Article 2
1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:
(a) Holding the increase in the global average temperature to well below 2 ° C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 ° C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

Article 4
1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible *(omission)* so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

INDC submission and "global stocktake"

- As a manner to contribute to the long term target, each country shall prepare, communicate and maintain successive intended nationally determined contributions(INDC), which is thought to be include emissions reduction target.

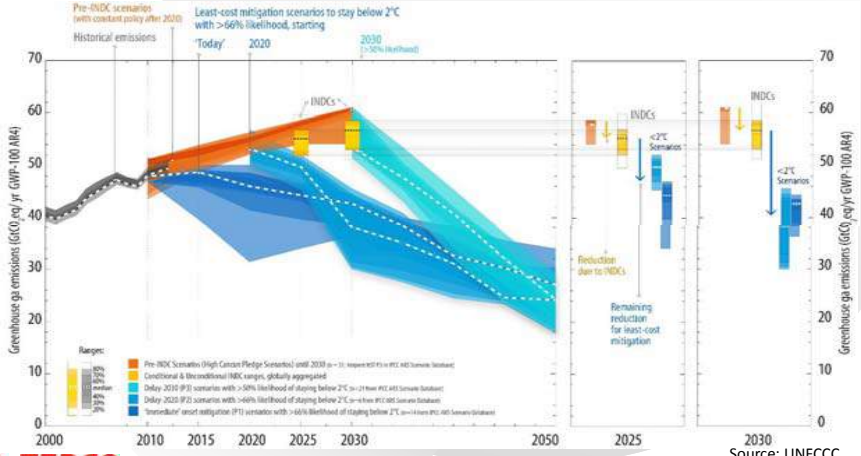
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2028	2030	2033
UNFCCC	Adoption of Paris agreement	open for signature				enter into force?			global stocktake			global stocktake		global stocktake
Individual countries	First INDC	signature and ratification				INDC update					INDC update		INDC update	

Article 4
9. Each Party shall communicate a nationally determined contribution(INDC) every five years *(Omission)* and be informed by the outcomes of the global stocktake referred to in Article 14.

Article 14
1. The Conference of the Parties serving as the meeting of the Parties to this Agreement shall periodically take stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals (referred to as the "global stocktake").
2. The Conference of the Parties serving as the meeting of the Parties to this Agreement shall undertake its first global stocktake in 2023 and every five years thereafter unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to this Agreement.
3. The outcome of the global stocktake shall inform Parties in updating and enhancing, in a nationally determined manner, their actions and support in accordance with the relevant provisions of this Agreement, as well as in enhancing international cooperation for climate action.

Remaining GHG reduction for the ambitiousness

- UNFCCC recognizes large amount of remaining GHG reduction needed in the light of 2 ° C goal, in spite of declaration of ambitiousness as described in the chart below.
- It is presumed that Bangladesh might be one country who is under political pressure of drastic GHG emission reduction in future at the "global stocktake" year, under Paris agreement applicable to all the countries.



Source: UNFCCC

Other Environmental Considerations

- In Bangladesh, reduction of GHG emission from other sectors than energy supply also needs to be dealt with priority.
- Recently more attention has been paid to short-lived climate pollutants such as black carbon and tropospheric ozone, which have relatively short lifetime in the atmosphere but have strong greenhouse effect
- An international initiative called CCAC (Climate and Clean Coalition) summarizes the main issues concerning short-lived climate pollutants as follows. This study will also discuss this, especially focusing on those related to energy supply.
  - Cook stoves: black carbon
  - Brick kilns: black carbon
  - Vehicular emission: black carbon
  - Open burning: black carbon
  - Rice parboiling systems: black carbon
  - Paddy rice cultivation: methane
  - Municipal waste deposits: methane
  - Livestock (manure and enteric fermentation): methane





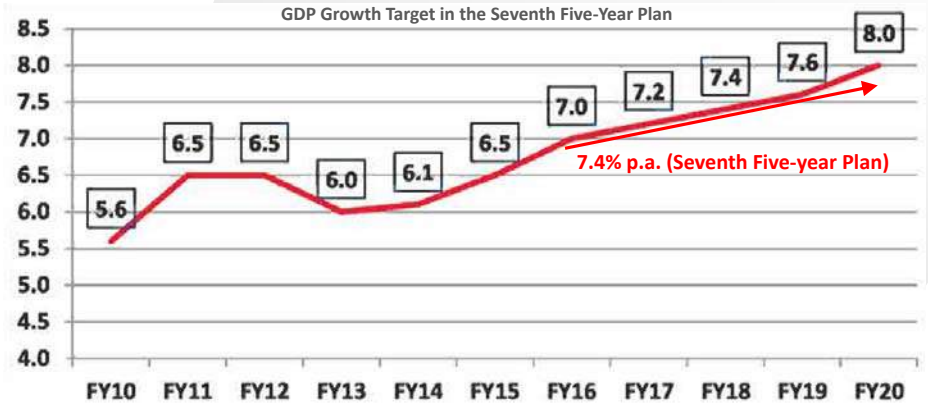
Source:
http://www.unep.org/ccac/Portals/50162/COP20/docs/11Dec_Agriculture_side_event/Raisul_Alam_Mondal_Bangladesh_Presentation_CCAC_COP20_11_Dec_Agriculture.pdf

D Economic Development

D-1 GDP Projection

GoB's Seventh Five-Year Plan

- The Seventh Five-Year Plan of the Government of Bangladesh (Planning Commission) sets the country's GDP growth target to be 7.4% p.a. during the five-year period (FY2016-FY2020).
- The growth rate is expected to increase steadily from 6.5% in FY2015 to 8.0% in FY2020.
- The government sees that the upward trend of GDP growth rate since FY2013 is expected to continue.



Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

GDP Prospects in Previous Five-Year Plans and Actual Performance

- Looking back the historical performance, the actual GDP growth rate has seen an acceleratedly increasing trend, from 3.8% p.a. in 1985-1990 to 6.3% p.a. in 2011-2015.
- However, compared to the Government's five-year plan in the past, the actual growth rate has been underperforming. GoB explains that the main factors of this gap are the "constrained growth of the service sector", "shortfall in the investment rate, both public and private" and "inability to achieve the projected growth rate in agriculture".
- Considering the improved productivity of national economy and the strengthened international competitiveness, the country's economy is capable of keeping higher than 6% growth rate for the upcoming 5 years.
- However, 7.4% growth target appears be too ambitious unless policy measures are ideally implemented.

Comparison between the Government's Projection of GDP Growth Rate and Actual Performance

Specific Plan	Plan Periods (FY)	Average GDP Growth Rate		Per Capita GDP growth
		Plan (%)	Actual (%)	(%)
First Plan	1973-1978	5.5	4.0	1.3
Second Plan	1980-1985	5.4	3.8	1.5
Third Plan	1985-1990	5.4	3.8	1.6
Fourth Plan	1990-1995	5.0	4.2	2.4
Fifth Plan	1997-2002	7.1	5.1	3.5
Sixth Plan	2011-2015	7.3	6.3	4.9



Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

Comparison with International Organizations' Projection

- International organizations, such as International Monetary Fund (IMF), World Bank and Asian Development Bank (ADB), expect Bangladesh's GDP to grow at 6.7% or higher in 2016 and afterwards.
- These projections reflect the recent performance of Bangladesh's economy growth and is considered to be very positive.
- However, GoB's GDP growth projection is still more ambitious than the projection of international organizations.
- Recent slowdown of global economy, as typically seen in China, may also affect the economic growth of Bangladesh.

Projection of GDP Growth Rate in Bangladesh: Comparison with International Organizations (real GDP)

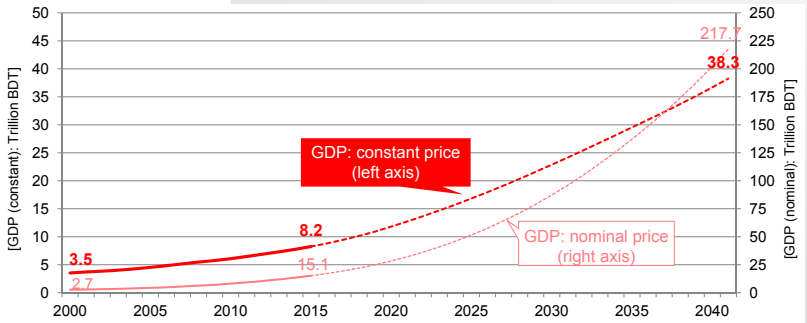
	2015	2016	2017	2018	2019	2020
IMF "World Economic Outlook" (October 2015)	6.5%	6.8%	7.0%	7.0%	7.0%	6.7%
World Bank "Global Economic Prospects" (January 2016)	6.5%	6.7%	6.8%	6.8%	-	-
ADB "Asian Development Outlook 2015" (update: September 2015)	6.5%	6.7%	-	-	-	-
GoB "Seventh Five-Year Plan" (December 2015)	6.5%	7.0%	7.2%	7.4%	7.6%	8.0%

Source: Publications from International Monetary Fund, World Bank and Asian Development Bank

Comparison with International Organizations' Projections

- The study team considers that the 7.4% p.a. growth from 2016 to 2020 might be overstretching and that the growth rate between 6.5 and 7.0%, as projected by international organizations, may be more realistic.
- However, considering the consistency with the economic development plan officially made public by GoB, this study follows the GoB's economic growth target, i.e. 7.4% p.a. from 2016 to 2020, assuming that all the necessary policy measures to achieve this target will be optimally in place.
- Real GDP (constant at 2005 price) as of 2041 is estimated to reach 38 trillion BDT, about 4.6 times of the current level (8.2 trillion BDT). The average growth rate from 2016 to 2041 is 6.1% p.a.
- Nominal GDP (current price) is estimated to become about 220 trillion BDT in 2041.

GDP Projection Up to 2041



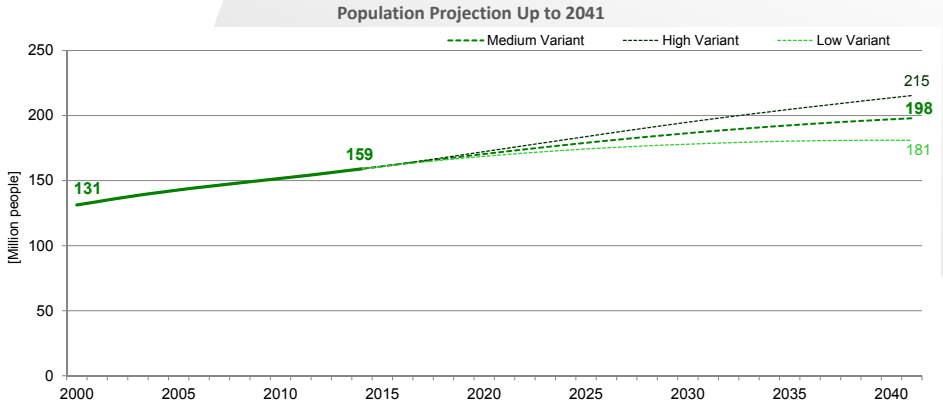
Average growth rate (real GDP)	
2011-2015	6.3%
2016-2020	7.4%
2021-2025	7.4%
2026-2030	6.3%
2031-2035	5.3%
2036-2041	4.4%
2016-2041	6.1%

Source: Prepared by the Study Team

D-2 Economic Growth Scenario

Population Projection

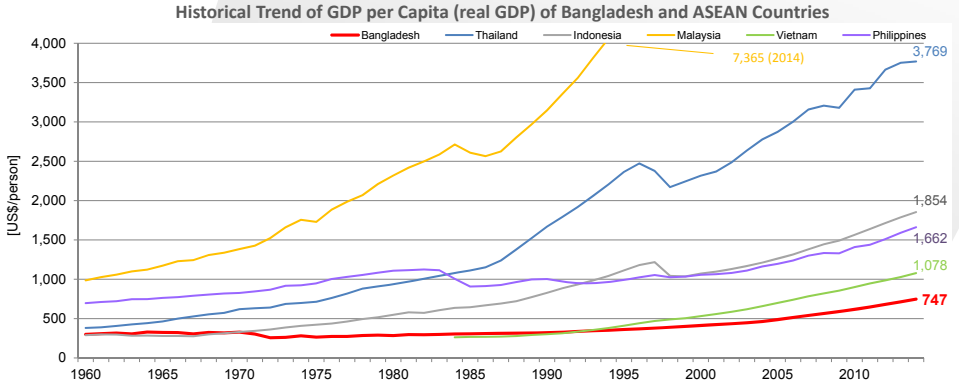
- Population projection refers to United Nations' "World Population Prospects 2015". In the "Medium Variant" scenario (adopted for GDP projection), the population as of 2041 is expected to reach 198 million, i.e. 0.8% p.a. growth from 2014.
  - The growth rate is expected to decline from 1.2% to 0.4%.
- In the "Low Variant" scenario, the total population starts decreasing from 2039.



Source: United Nations "World Population Prospects 2015"

GDP per Capita (historical trend compared with ASEAN countries)

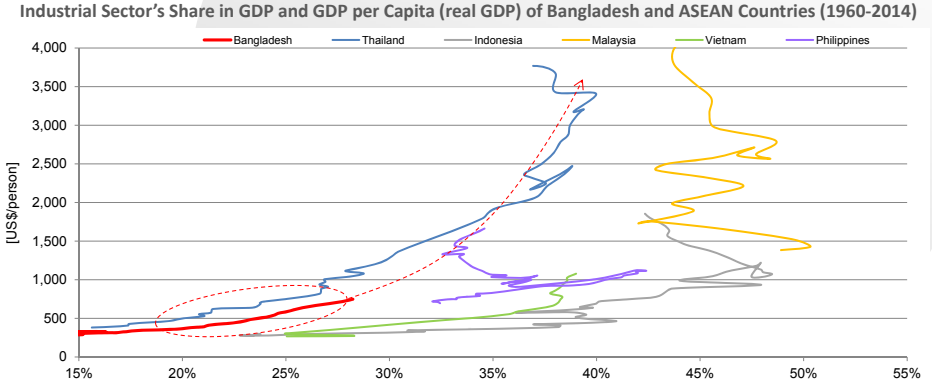
- Bangladesh's real GDP per capita (constant at 2005 price) in 2014 was 48,664 BDT. which is equivalent to 747 US$.
- Since around the year 2000, GDP per capita started growing acceleratedly.
- Considering that ASEAN countries saw a rapid growth of GDP per capita after it reached 1,000 USD, Bangladesh is also supposed to have a good potential of economic growth to follow this trend.



Source: World Bank database

Economic Development Scenario for Bangladesh

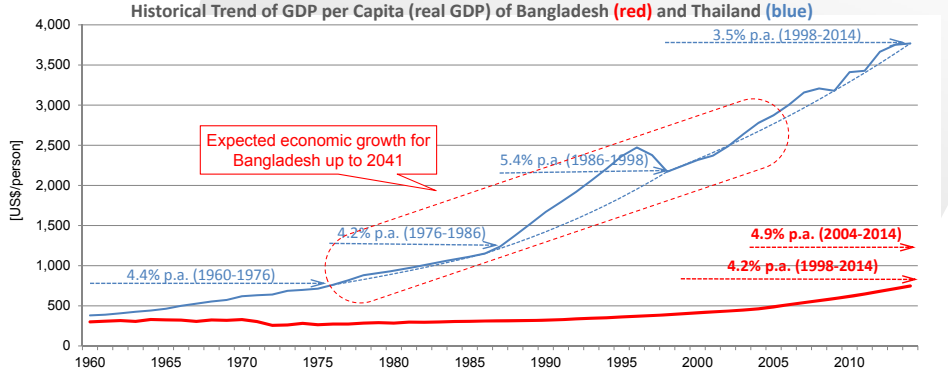
- The following figure plots the relation between the share of industrial sector in GDP (horizontal axis) and the GDP per capita of Bangladesh and five ASEAN countries since 1960.
- As a general trend, the industrial sector's share in GDP increases up to a certain level along with the growth of GDP per capita.
- Bangladesh's GDP capita started increasing rapidly when the industrial sector's share exceeded 20%. Recently the trend curve has been taking a similar track to what Thailand experienced before.



Source: Prepared by the Study Team using World Bank database

Economic Development Scenario for Bangladesh (continued)

- Bangladesh's GDP per capita as of 2014 (747 USD) was almost equivalent to that of Thailand around 1976.
- Bangladesh saw a 4.2% p.a. growth of GDP per capita from 1998 to 2014 (16 years). This can be compared with Thailand's growth rate (4.4% p.a.) from 1960 to 1976 (16 years).
- Assuming that Bangladesh follows the track of Thailand's economic growth in the past, the accelerated growth is expected to continue.
- In addition, considering the follower advantage for Bangladesh (4.9% p.a. growth for the past 10 years), the growth rate of GDP per capita can be still higher than the past track of Thailand.

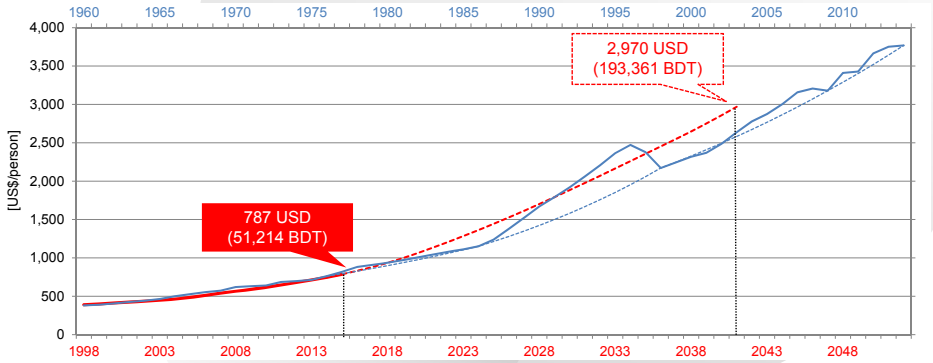


Source: Prepared by the Study Team using World Bank database

Economic Development Scenario for Bangladesh (continued)

- This study assumes that Bangladesh's economic development follows the track of Thailand's and is expected to grow rapider. The expected growth rate of GDP per capita from 2014 to 2041 is 5.2% p.a., about 10% higher that of Thailand from 1976 to 2003 (4.7% p.a.).
- Bangladesh's GDP per capita (real) as of 2041 is expected to reach about 3,000 USD.
  - The estimated trend curve of Bangladesh's future development was smoothed so that the growth rate gradually accelerates until early-2020s and then becomes gradually moderate.

Historical Trend (and Estimation) of GDP per Capita (real GDP) of Bangladesh (red) and Thailand (blue)



Source: Prepared by the Study Team. All the numbers in this figure are expressed at 2005 price.

Summary Tables of GDP Projection

- This study's projection of GDP (real, nominal, and PPP) up to 2041 is summarized as follows.
  - In projecting nominal GDP, inflation rate is expected to become gradually moderate, down to 3.2% in 2041.

Real GDP Projection (constant at 2005 price)

	2015	2020	2025	2030	2035	2041
GDP(million USD)	126,630	181,282	258,598	351,109	453,642	587,665
GDP(billion BDT)	8,245	11,804	16,838	22,862	29,538	38,265
Growth rate (USD, BDT)		7.4% p.a.	7.4% p.a.	6.3% p.a.	5.3% p.a.	4.4% p.a.
Exchange rate	65.1	65.1	65.1	65.1	65.1	65.1
Per Capita (USD)	787	1,063	1,444	1,883	2,357	2,970
Per Capita (BDT)	51,215	69,245	94,035	122,611	153,446	193,361

Nominal GDP Projection (current price)

	2015	2020	2025	2030	2035	2041
GDP(million USD)	194,300	340,576	585,615	943,451	1,423,643	2,175,520
GDP(billion BDT)	15,136	28,320	51,559	87,237	137,132	217,738
Growth rate (USD)		11.9% p.a.	11.4% p.a.	10.0% p.a.	8.6% p.a.	7.3% p.a.
Growth rate (BDT)		13.3% p.a.	12.7% p.a.	11.1% p.a.	9.5% p.a.	8.0% p.a.
Exchange rate	77.9	83.2	88.0	92.5	96.3	100.1
GDP deflator	5.8%	5.3%	4.8%	4.3%	3.8%	3.2%
Per Capita (USD)	1,207	1,998	3,270	5,060	7,396	10,993
Per Capita (BDT)	94,015	166,131	287,938	467,860	712,373	1,100,271

GDP Projection (PPP, constant at 2011 price)

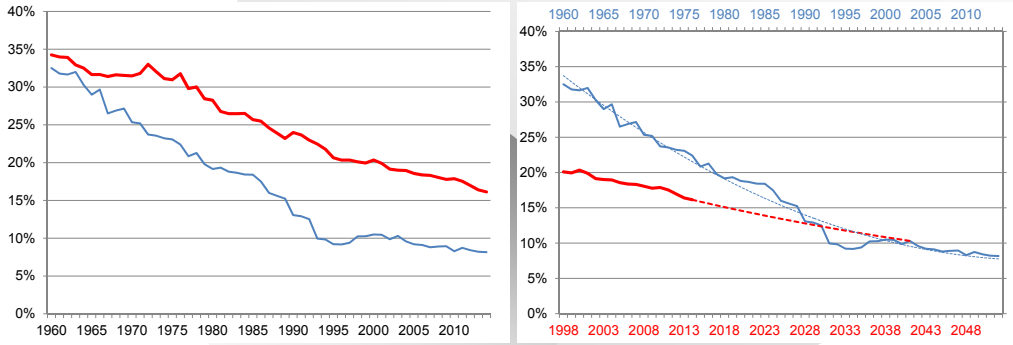
	2015	2020	2025	2030	2035	2041
GDP(million USD)	504,770	722,625	1,030,822	1,399,588	1,808,308	2,342,549
Per Capita (USD)	3,135	4,239	5,757	7,506	9,394	11,837

Source: Prepared by the Study Team

Sectorial Breakdown of GDP: Agriculture

- In Bangladesh, percentage of agriculture in GDP (value added) has been declining constantly.
- Thailand saw a rapider decrease of agricultural share in the national economy until mid-1990s, but since then it has been keeping a relatively constant share around 8-10%. This is because the country's agriculture has been modernized to shift from self-sufficiency to more value-added products and gained international competitiveness.
- Assuming that Bangladesh follows this policy, the share of agriculture in GDP is expected to keep 10% even in 2041 though it continues to decline.

Share of Agriculture in GDP (constant at 2005 price): Bangladesh (red) and Thailand (blue)



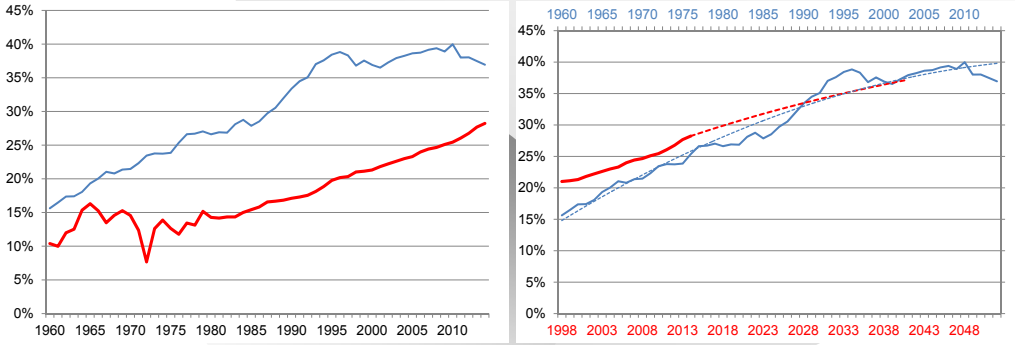
Source: World Bank database

Source: Prepared by the Study Team

Sectorial Breakdown of GDP: Industrial

- In Thailand, the share of industrial sector in GDP increased constantly until mid-1990, and since then it has been relatively constant between 35% and 40%. This is considered that the country's industrialization came to a certain level of maturity.
- Assuming that Bangladesh follows this track, industrial sector is expected to account for about 37% of the country's GDP in 2041.

Share of Industrial Sector in GDP (constant at 2005 price): Bangladesh (red) and Thailand (blue)



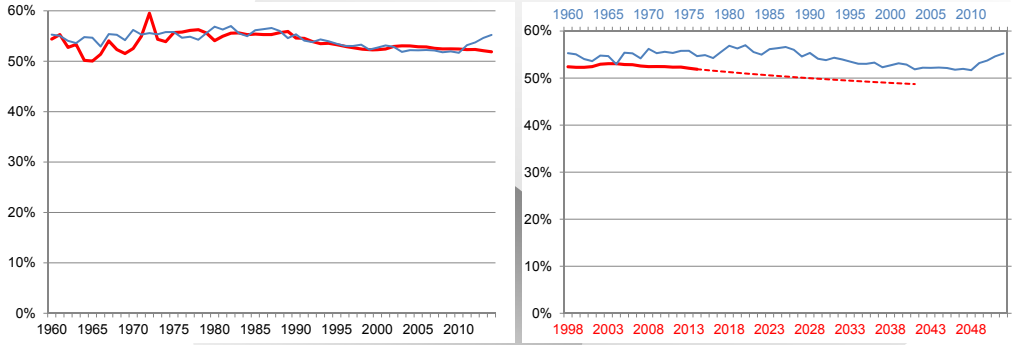
Source: World Bank database

Source: Prepared by the Study Team

Sectorial Breakdown of GDP: Commercial & Public

- Since 1990s, the share of commercial and public sector in Bangladesh's GDP has been relatively stable between 50% and 55% and has seen a slightly declining trend.
- Its share is expected to maintain about half of the country's GDP in 2041.

Share of Commercial & Public Sector in GDP (constant at 2005 price): Bangladesh (red) and Thailand (blue)



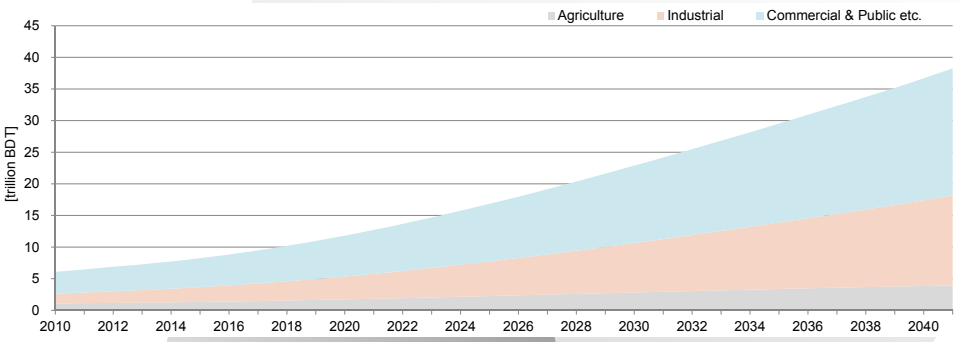
Source: World Bank database
Note: In the source data, the sum of agriculture, industrial and commercial & public sectors' share is not exactly 100% but is a little smaller.

Source: Prepared by the Study Team

Sectorial Breakdown of GDP

- As of 2041, the value added of agriculture, industrial sector, and commercial & public sector is expected to grow to 3.9 trillion BDT, 14.2 trillion BDT, and 20.1 trillion BDT respectively (real GDP).

Sectorial Breakdown of GDP Projection (Real GDP, constant at 2005 price)



Source: Prepared by the Study Team

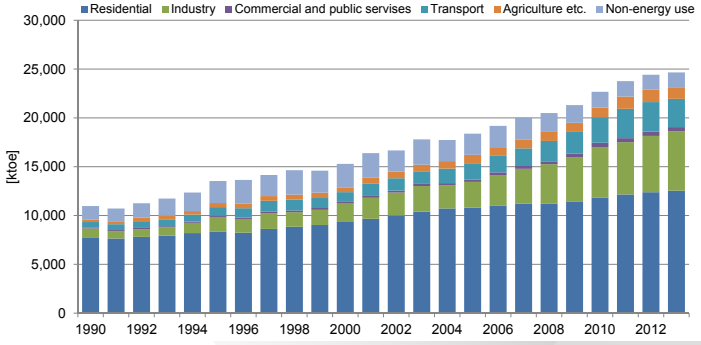
E Energy Balance Strategy

E-1 Projection of Energy Consumption in Bangladesh

Historical Trend of Total Final Energy Consumption

- According to IEA energy balance statistics, the total final consumption (TFC) of energy in Bangladesh grew from 10,877 ktoe in 1990 to 24,660 ktoe in 2013, 2.3 times (3.6% p.a.) in 23 years.
- Whereas the residential sector accounts for the largest share in the total energy consumption, the industrial sector, which grew by 6.3 times (8.3% p.a.) during that period, has been the main drive of rapid growth of energy consumption.
- The transport sector, which still accounts for 12% share in the final consumption, also sees a rapid growth (5.3 times, 7.5%)

Historical Trend of Total Final Energy Consumption in Bangladesh



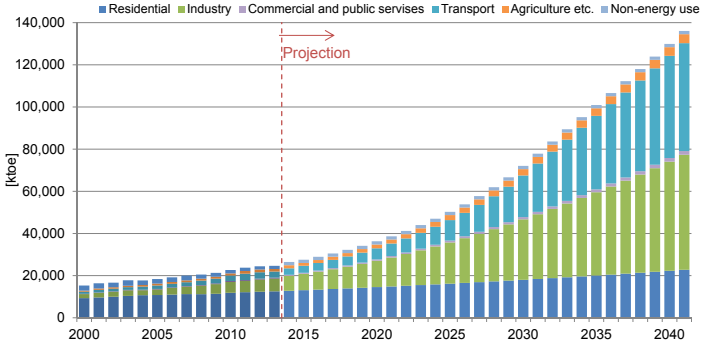
Sectors	TFC in 2013 (ktoe)	Growth ('90-'13)
Residential	12,545 (51%)	2.1%
Industrial	6,072 (25%)	8.3%
Commercial & Public Service	442 (2%)	6.0%
Transport	2,893 (12%)	7.5%
Agriculture	1,141 (5%)	6.5%
Others	42 (0%)	9.7%
Non-energy use	1,525 (6%)	-
Total	**24,660 (100%)**	**3.6%**

Source: IEA Energy Balances

Total Final Energy Consumption (BAU Case)

- The total final energy consumption of Bangladesh in the BAU case, i.e. without additional energy efficiency measures, is expected to reach about 136,000 ktoe in 2041, about 5.5 times growth (6.3% p.a.) from 2013.
- While the residential sector sees a relatively moderate growth (2.2% p.a.), the industrial sector will grow faster (8.2% p.a.) and become the largest sector of energy consumption from mid-2020s.
- The energy consumption of the transport sector will grow still faster (10.8% p.a.) and will become the second-largest sector of energy consumption.
- Scenarios of energy consumption considering energy efficiency target will be discussed in the later section.

Projection of Total Final Energy Consumption (BAU Case)



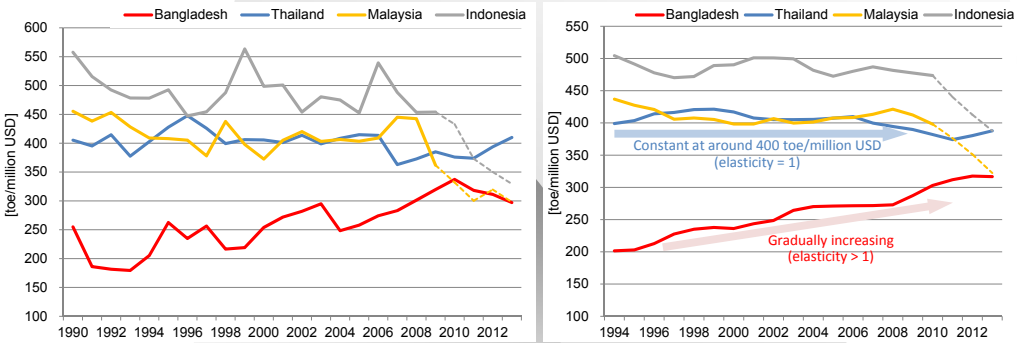
Sectors	TFC in 2041 (ktoe)	Growth ('13-'41)
Residential	22,797 (17%)	2.2%
Industrial	54,526 (40%)	8.2%
Commercial & Public Service	1,776 (1%)	5.1%
Transport	51,187 (38%)	10.8%
Agriculture	4,197 (3%)	4.8%
Others	47 (0%)	0.4%
Non-energy use	1,534 (1%)	-
Total	**136,604 (100%)**	**6.3%**

E-2 Industrial Sector Energy Demand

GDP Elasticity of Industrial Sector's Energy Consumption

- This study analyzed the industrial sector's energy intensity, i.e. energy consumption divided by the sectorial valued added (= GDP) of manufacturing (not the total GDP), which indicates how much energy (toe) is consumed for the industrial sector to yield a value of 1 million USD.
  - If this ratio is constant, GDP elasticity of energy consumption is 1.
  - If this ratio increases/decreases from the previous year, GDP elasticity is higher/lower than 1.
- Whereas this ratio is relatively constant in Thailand, Malaysia and Indonesia, Bangladesh has seen a gradually increasing trend.

Industrial Sector's Energy Consumption per Sectorial Value Added (5-year moving average)

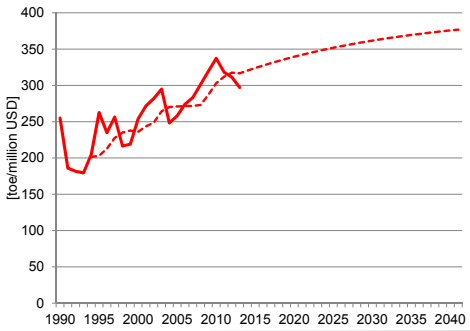


Source: Prepared by the Study Team using World Bank database and IEA statistics
Note: Declining trend of energy consumption in Malaysia and Indonesia from 2010 is considered a statistical error

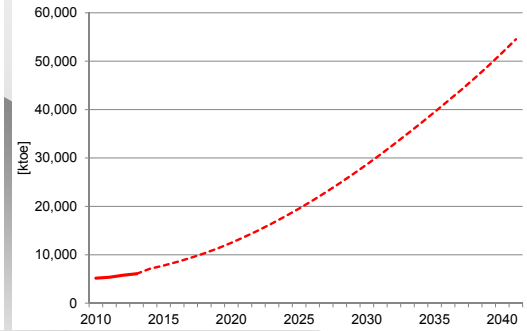
Projection of Industrial Sector Energy Consumption

- The main reason why the ratio of industrial sector's energy consumption to sectorial GDP is creeping up (GDP elasticity higher than 1) in Bangladesh is that the economic development is still at an early stage and that a shift from labour-intensive industries to energy-consuming industries is still in process.
- This study projects that this trend is expected to continue and the energy consumption of the industrial sector will be about 54,500 ktoe, about nine times increase from 2013.

Energy Consumption per Sectorial Value Added (projection)



Sectorial Energy Consumption (projection)



E-3 Policy Measures for Promoting Industrial Development

Process of Industrialization

- Manufacturing is the driver of industrial growth, and the main driver of manufacturing growth is the export market as mentioned in 7th FIVE YEARS Plan.
- According to the academic researches, it is found that there are 3 phases for industrialization in Asian developing countries.
  - Phase1: Import Substitution Industrialization by labor intensive and light industries under infant industry protection policies.
  - Phase2: Export Oriented Industrialization by labor intensive industries like textile and footwear industry under export industry development policies.
  - Phase3: Export Oriented Industrialization by technology and capital intensive industries like metal parts and machine industry.



Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

Industrial Policy Adopted by Thailand

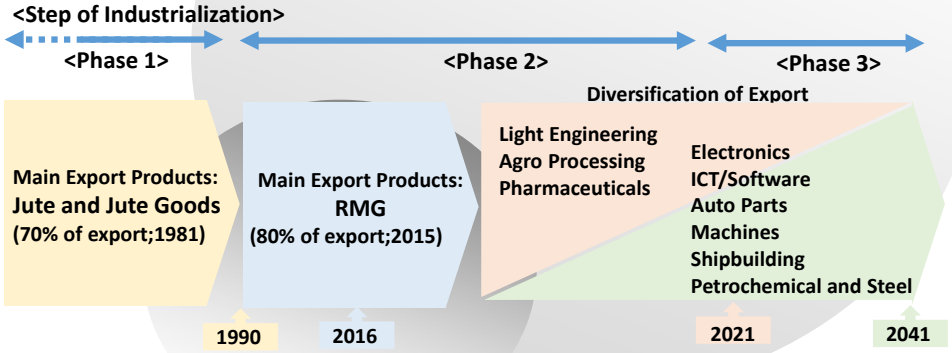
- Thailand adopted import substitution industrialization policy at 1961 and started industrialization (Phase1).
- Thailand changed the policy from import substitution industrialization policy to export oriented industrialization one at 1971(Phase2) and entered into Phase 3 at middle of 1980s. (see previous slide)
- The National Plans and adopted policies during the period of industrialization in Thailand are shown in the figure below.

National Plan	Period	Main policy
1st	1961~1966	● protection of domestic industry
2nd	1966~1971	● import substituting industrialization ● promote investment by private sector
3rd	1971~1976	● promote exports ● export-driven industrialization ● selective foreign capital introduction policy
4th	1976~1981	● continue of promotion of export-driven industrialization
5th	1981~1986	● development of petro-chemical industry
6th	1986~1991	● promote investment by private sector ● privatisation of energy sector
7th	1991~1996	● put emphasis on the industry for promotion with high value added or technology transfer ● local dispersion of the industrial development ● improve of quality of life
8th	1996~2001	● industrial Restructuring Plan(1998) ● maintain international competitiveness and promote Small and Medium Enterprises
9th	2001~2006	● human resource development ● improve of quality of life ● poverty eradication

Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

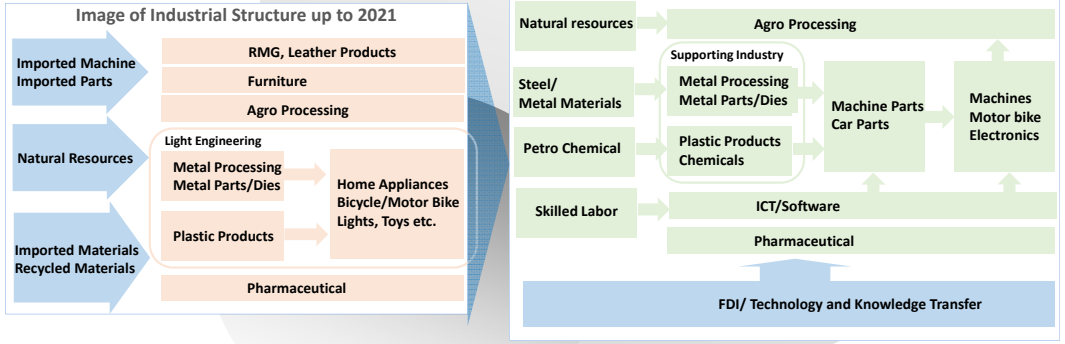
Future Image of Industrial Development in Bangladesh

- Jute and Jute goods were main export products at 1981 in Bangladesh.
- It is said that Bangladesh proceeded from Phase1 to Phase2 around 1990 and now Bangladesh is in the Phase2 whereas Thailand proceeded from Phase1 to Phase2 at 1971 and entered into Phase 3 at middle of 1980s.
- Until 2021, although the Bangladesh economy will remain to depend much on traditional industries, RMG (ready-made garment), Jute and Leather etc., the new industries will expand gradually and the export products will be diversified during the same period and from 2021 the tendency will be accelerated.



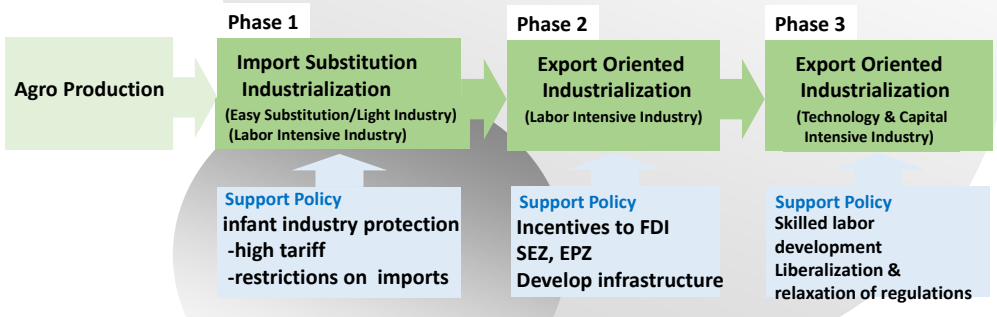
Future Image of Industrial Structure in Bangladesh

- Until 2021, Bangladesh Industry will depend on natural resources, imported materials and imported parts & machines and will diversify gradually including Light Engineering and Pharmaceutical.
- After 2021 towards 2041, Bangladesh Industry will be able to provide row materials and machines for itself and will be a high value added industry by introducing FDIs and taking advanced technologies and knowledges.
- Agro industry is always important because it can absorb huge labor force and can secure food supply. Furthermore Agro industry can be high value added industry by agro processing. We can see a good example for it at present Thailand.



Measures Needed for Industrialization in Bangladesh

- For Import Substitution Industrialization, policies for infant industry protection should be needed (ex. High tariff, restriction on imports).
- For Export Oriented Industrialization, policies on provision of incentives to FDI, construction of Industrial zone like SEZ for foreign enterprises and development of various infrastructures like port ,road, railway, power supply must be needed.
- In the stage of Phase3, in addition to the above mentioned policies in Phase2, skilled labor development and liberalization & relaxation of regulations are needed for realizing the industrialization among international competition.

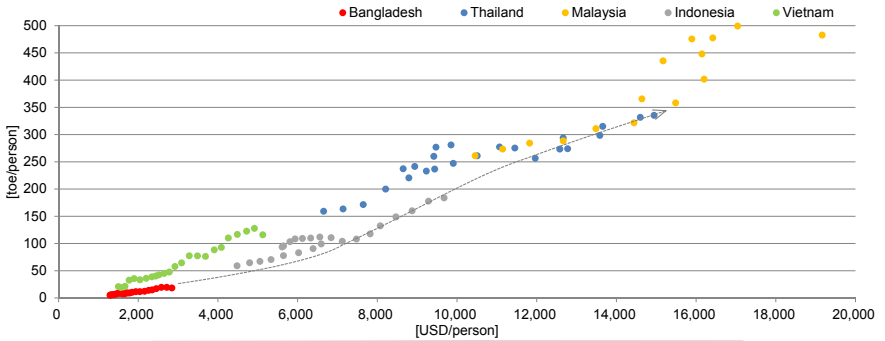


E-4 Transport Sector Energy Demand

General Trend of Energy Consumption

- The growth of transport sector's energy consumption is expected to take a S-shaped curve so that:
  - Energy consumption increases acceleratedly when the economic development comes to a certain level and the car ownership (motorization) increases rapidly, and
  - The growth rate of energy consumption becomes moderate when the economic development reaches a certain level of maturity and the transport with private vehicles is taken over by the advanced public transport system especially in the urban area.
- The following figure shows that the historical trend of transport sector energy consumption in ASEAN countries is tracing a S-shaped curve.

Historical Trend of GDP per Capita (PPP) and Transport Sector's Energy Consumption per Capita

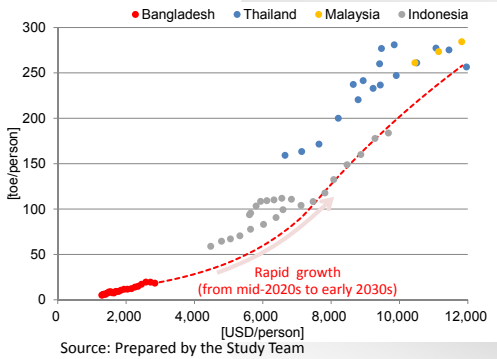


Source: Prepared by the Study Team using World Bank database and IEA energy balances

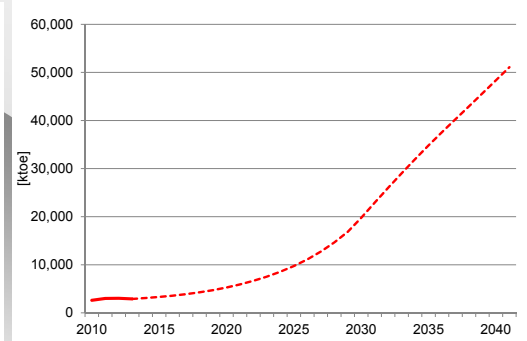
Projection of Transport Sector Energy Consumption

- Referring to the historical trend of Indonesia and Thailand that the transport sector's energy consumption per capital starts growing steeply when GDP capita reached around 5,000-6,000 USD and the growth becomes moderate when it exceeds 8,000 USD, this study considers that the car ownership increases rapidly during that period.
- Bangladesh is expected to follow this track, i.e. the transport sector energy consumption, driven by car ownership, will increase rapidly from mid-2020s to early 2030s.
- The sector's energy consumption will reach around 51,000 ktoe in 2041.

Sectorial Energy Consumption per Capita (projection)



Sectorial Energy Consumption (projection)



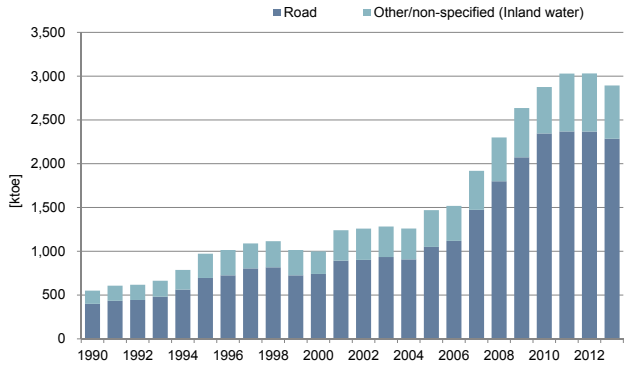
Source: Prepared by the Study Team

E-5 Prospects of Transport Sector in Bangladesh

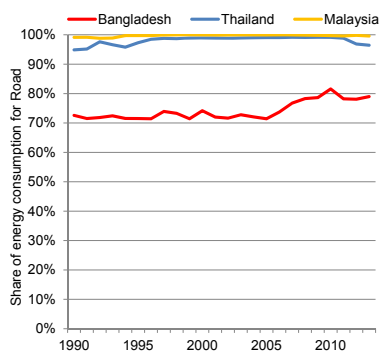
Structure of Transport Sector in Bangladesh

- The energy consumption for road transport accounts for about 80% in the transport sector in Bangladesh. It has increased by 5.7 times in 23 years (7.9% p.a.) from 400 ktoe in 1990 to 2,285 ktoe in 2013.
- Bangladesh has the large inland waterway networks. The share of energy consumption for inland water transport was approximately 30% in 1990, but decreasing to 20% in 2013. This trend will continue because of replace by road transport.

Historical Trend of Transport Sector's Energy Consumption in Bangladesh



Share of Energy Consumption for Road

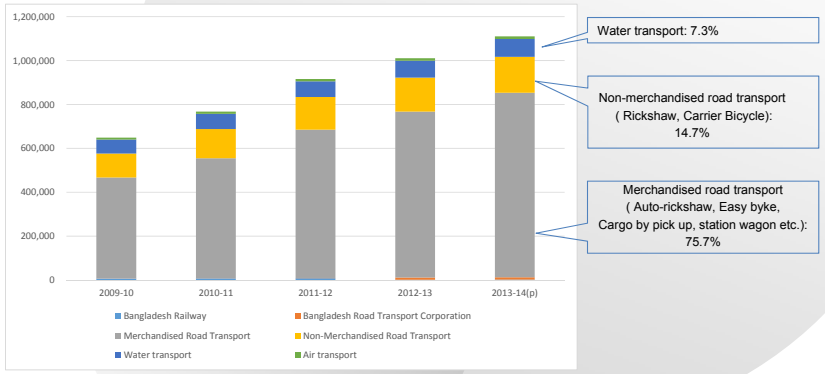


Source: IEA Energy Balances

Modal Share in Transport Sector

- In terms of economic value, more than 90% of value added in transport sector is from road transport
- The National Integrated Multimodal Transport Policy, 2013 has been prepared as a latest long term policy in transport sector in Bangladesh in order to redress the imbalance by an overemphasis on road subsector to address all modes of transport in an integrated way so that future investment can take account of the best.

Value Added in Transport Sub-Sector (current price)

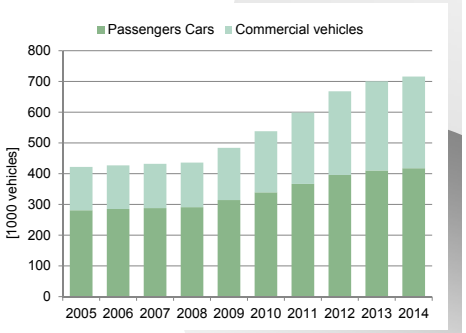


Source: Bangladesh National Accounts Statistics(BBS)

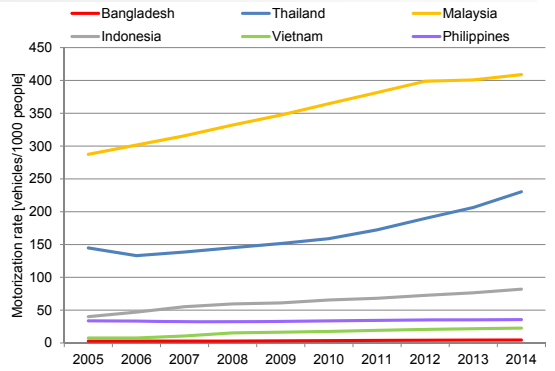
Vehicles in Bangladesh

- According to the International Organization of Motor Vehicle Manufacturers (OICA), number of vehicles owned in Bangladesh has increased from 422,000 in 2005 to 716,000 in 2014, 1.7 times (6.1% p.a.) in 9 years.
- However, the level of motorization rate (vehicles per 1,000 people) in Bangladesh is lower than those in ASEAN countries.

Number of Vehicles Owned in Bangladesh



Motorization Rate of Bangladesh and ASEAN Countries



Source: Prepared by the Study Team using World Bank database and OICA statistics

The Number of Motor Vehicle in Bangladesh

- Another statistics, the number of registered vehicles obtained from Road Transport Authority, also shows that the car ownership in Bangladesh is increasing rapidly.
- The number of private passenger car is 292 thousands in Bangladesh, and most of them, 227 thousands, are in Dhaka. In the meanwhile, Auto Rickshaws are still dominant outside of Dhaka.

→ There's a huge potential for private car ownership to increase rapidly especially in rural area.

Number of Registered Motor Vehicles in Bangladesh <Bangladesh> <Dhaka>

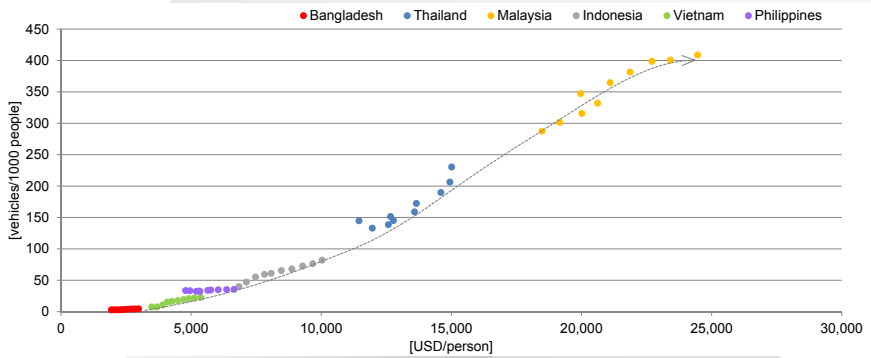
Sl. No	Type of Vehicles	Upto-2010	2011	2012	2013	2014	2015	29-Feb-16	Grand Total	Grand Total
1	Ambulance	2793	219	181	243	338	480	78	4332	2487
2	Auto Rickshaw	126763	20423	23545	15697	19897	20000	1999	228324	8435
3	Auto Tempo	14266	175	626	395	500	1095	136	17193	1664
4	Bus	27778	1761	1439	1107	1488	2391	577	36541	24565
5	Cargo Van	3522	489	282	687	608	399	64	6051	5727
6	Covered Van	5658	2354	1421	2271	2869	2354	416	17343	13742
7	Delivery Van	17063	1004	774	894	1176	1719	281	22911	16725
8	Human Hauler	6520	1152	715	385	225	1142	501	10640	4371
9	Jeep(Hard/Soft)	32286	2134	1569	1314	1870	3601	777	43551	28926
10	Microbus	66379	4051	3044	2537	4313	5224	1062	86610	63959
11	Minibus	25644	276	249	148	256	323	73	26969	10068
12	Motor Cycle	759257	114616	101588	85808	90685	240358	41467	1433779	390062
13	Pick Up (Double/Single Cabin)	32240	10460	7625	6553	9554	10257	1512	78201	54116
14	Private Passenger Car	219830	12950	9224	10472	14699	21062	3910	292147	226645
15	Special Purpose Vehicle	6371	396	226	227	172	296	78	7766	1078
16	Tanker	2706	317	195	226	362	324	64	4194	1536
17	Taxicab	44380	75	172	51	374	88	4	45144	36466
18	Tractor	20600	5200	3494	1885	1522	1699	423	34823	22066
19	Truck	82871	7327	4335	5129	8136	6330	958	115086	48258
20	Others	1317	7	1	1080	1595	2073	572	6645	3498
	TOTAL	1498244	185386	160705	137109	160639	321215	54952	2518250	964394

Source: Bangladesh Road Transport Authority (http://www.brta.gov.bd/statistics.html)

General Trend of Motorization

- The following figure shows a correlation between GDP per capita and motorization rate in ASEAN countries.
- When the economic development comes to a certain level, motorization rate increases rapidly.
- The motorization rate of Bangladesh is expected to follow those of ASEAN countries.

Historical Trend of GDP per Capita (PPP) and Motorization Rate



Source: Prepared by the Study Team using World Bank database and OICA statistics

Measures for Dealing with Rapidly Growing Road Transport

- Bangkok, the capital of Thailand, is infamous for its traffic jams like Dhaka. Various measures for mitigating traffic congestion are taken and considered in Thailand shown in table below.
- The following effects are expected by introducing these measures:
  - Increase of average vehicle speed
  - Reduction of fuel consumption, CO2 emission, exhausted toxic gas
  - Reduction of time loss for transportation, stress of driver and traffic accident

Measures for Mitigating Traffic Congestion

Categories	Main Measures
Mordal Shift	construction of urban railways (METRO etc.)
	introduction of Bus Rapid Transit
	introduction of Park & Ride System
Road Development	widening of a road
	develop ring road
	construction of flyover
Regulation	road pricing
	time dispersion(staggered commuting, flex time etc.)
Provision of Road Information by ICT	Smart Traffic Sign
	Traffic Signal Control

Source: JICA study team

Case of Thailand: Introducing Energy Efficient Automobile

- Thailand launched 'Eco car program' at 2007 and 2013 which offered preferential tax treatment to car manufacturers producing Eco-car for inviting FDI.
- There are various requirements such as a fuel consumption of 20 km or more per liter and compliance with the European exhaust gas regulations"EURO 4" at the 1st Eco car program, and as a fuel consumption of 23.3km or more per liter and compliance with "EURO 5" at the 2nd Eco car program.
- Thailand is making efforts to prove more energy efficient automobile in the market.

Outline of Eco Car Project Conducted in Thailand

	eco car program	2nd eco car program
start year	2007	2013
main requirement	1300cc or less(gasolin car) 1400cc or less(diesel car) fuel consumption 20km/l or more clear the standard of EURO4 CO2 emission 120g/km or less	1300cc or less(gasolin car) 1500cc or less(diesel car) fuel consumption 23.3km/l or more clear the standard of EURO5 CO2 emission 100g/km or less start production by 2019
main benefit to manufacture	income tax free for maximum 8 years import tax free for production machine	income tax free for 6 years etc. import tax free for production machine
benefit to consumer	consumption tax 17% (30% for passengers car for 2000cc or more)	consumption tax 14%

Source: JICA study team

E-6 Civilian Sector Energy Demand (Residential & Commercial)

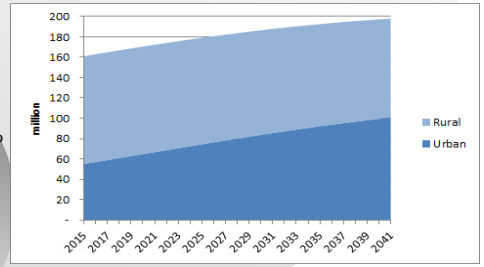
Residential Sector: Assumptions

Key Assumptions

		2014		2031		2041
		Urban	Rural	Urban	Rural	Urban/Rural
Population (thousands)		159,078		187,779		197,134
Urban population (% of total)		34%		46%		51%
Rate of electrification (%)		74%		100%		100%
Energy source	Air conditioner	Electricity (Fans,ACs)	Electricity (SHS) (Fans)	Electricity (ACs)	Electricity (SHS) (Fans, ACs)	Electricity (ACs)
	Cooking (fridge/refridge)	Electricity	-	Electricity	Electricity (SHS)	Electricity
	Cooking (heating), Heating water	Natural gas	Biomass, Natural gas	Natural gas	Biomass, LPG	LPG, Natural gas, Biomass
	Lighting	Electricity(fluorescent light)	Kerosene, Electricity (SHS)	Electricity(LED)	Electricity(LED)	Electricity(LED)

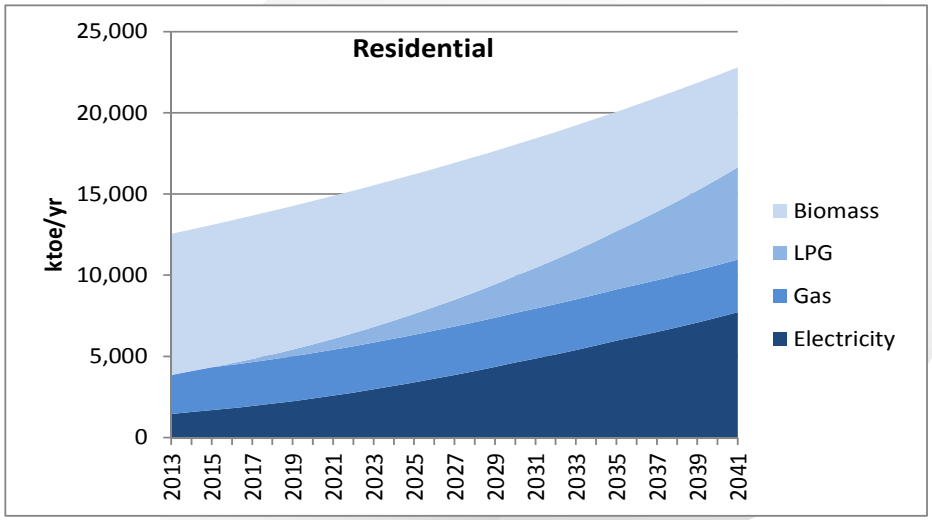
- Population will steadily grow with half of them residing in urban areas by 2041.
- 100% electrification will be achieved by 2021.
- Replacement of biomass and natural gas with LPG for cooking purpose will be encouraged.
- Energy efficient home appliances such as ACs, refrigerators, fans and LEDs will be promoted. Policies will promote improved (more efficient) cook stoves (70% of biomass , 40% of gas cook stoves' market share).

Population Growth



Source: UN" World Population Prospects 2014,2015"

Residential Sector: Energy Demand Forecast



Residential Sector: Current status

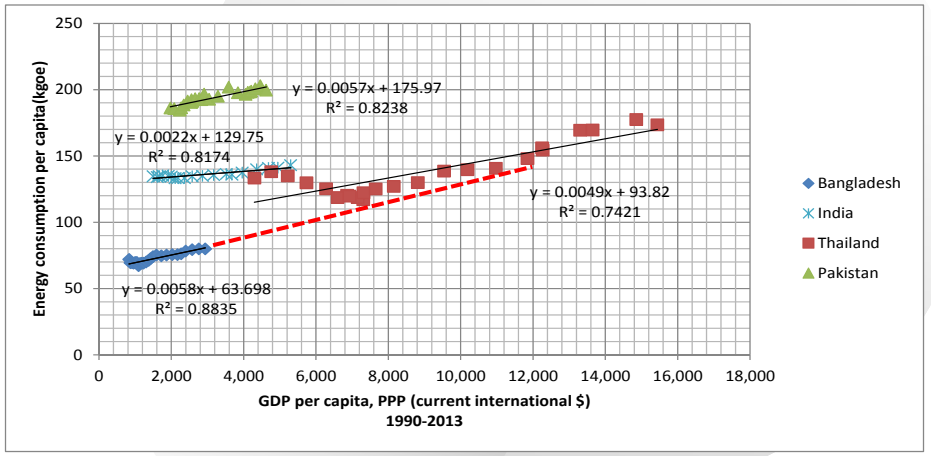
Category	Data Source
Total	IEA
Electricity	Derived from household expenditure on electricity ◆The Household Income & Expenditure Survey 2010 =>Distribution of expenditure on fuel & lighting by monthly household income groups, 2010 =>Expenditure on Electricity ◆Electricity Tariff (3.8tk/kwh, Dhaka Electricity Company) ◆Population UN"World Population Prospects 2014"
Gas	Petrobangla "Sector-wise Gas Consumption"
LPG	US EIA 2013 and 2014 data derived from average consumption growth rate from 2010-2012.
Others	Derived as "Total – Electricity – Gas – LPG"

Residential Sector: Forecast

Category	Data Source/Calculation
Total	Growth rate is derived from the historical trend (1990-2013) (2.2%).
Electricity	Derived from the general trend in Asian countries ◆ Electricity consumption per capita/ GDP per capita PPP ◆ GDP forecast
Gas	Gas consumption/population will remain constant after 2015. i.e. The growth of gas consumption equals to population growth.
LPG	According to Petrobangla "Five Year Gas Supply Strategy (2015-2019)", gas demand in the residential sector will grow at 4.8%. Assuming that this growth rate will remain constant until 2041, and that gas supply only increases to the above mentioned volume, the remaining demand is to be met by LPG.
Others	Derived as "Total – Electricity – Gas – LPG"

Residential Sector: Forecast (total)

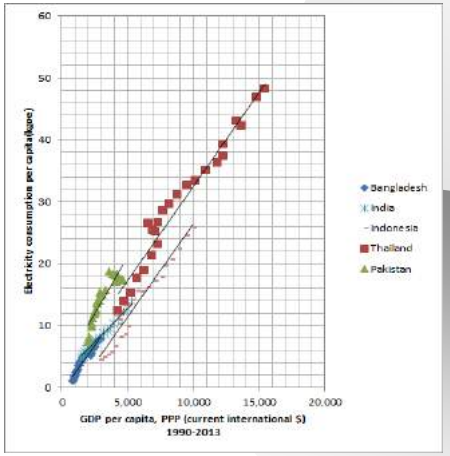
- **Overall energy consumption is expected to grow roughly as the historical trend.**

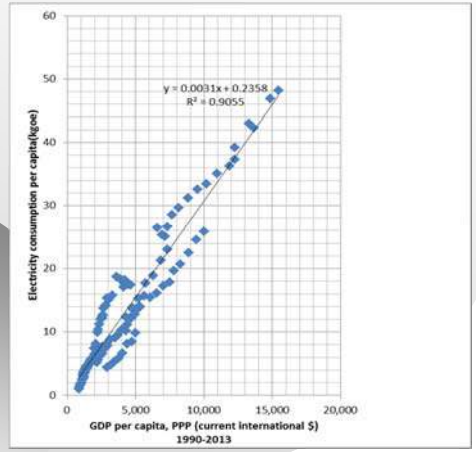


Source: survey team based on data from WB and IEA

Residential Sector: Forecast (electricity)

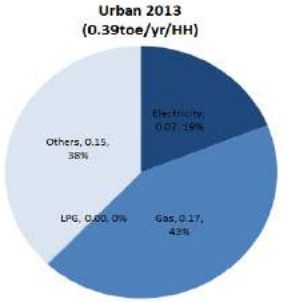
- **Electricity consumption/capita and GDP/capita are correlated in Asian countries.**
- **Electricity consumption in Bangladesh is estimated to increase according to this formula.**

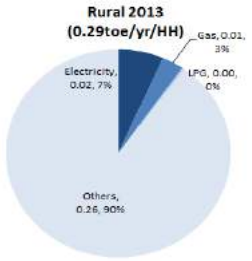




Source: survey team based on data from WB and IEA

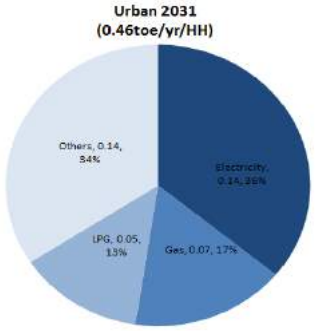
Residential Sector: Forecast (snapshots)

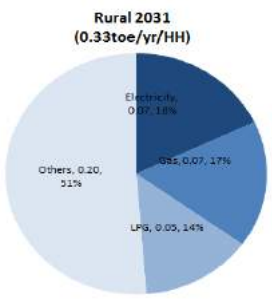


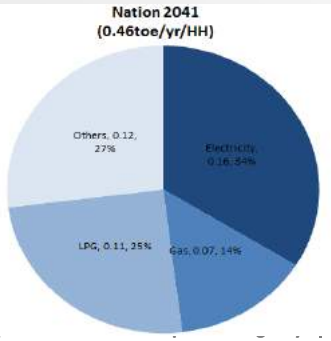


- Urban and Rural household energy consumption in 2013/2031/2041.

Source: survey team based on data from WB, IEA and EIA





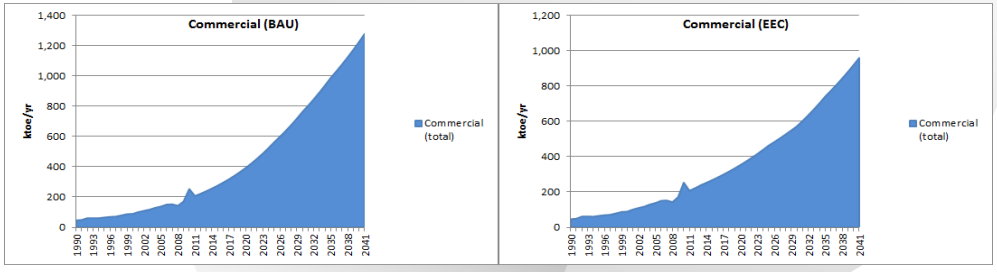


Commercial Sector: Assumptions and Energy Demand Forecast

Key Assumptions

- The commercial sector will continue to grow.
- Various policies and programs will be implemented, therefore energy efficiency in buildings will be improved, achieving 25% energy reduction compared to Business as Usual by2030.

Energy Demand Forecast



Commercial Sector: Current status and Forecast

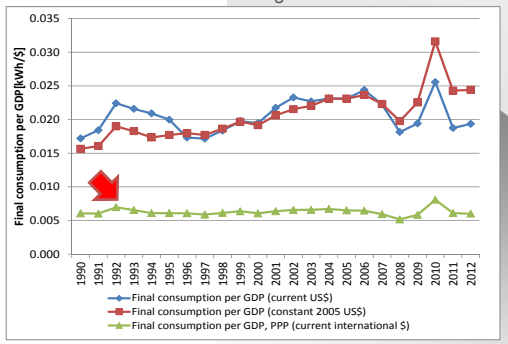
Current Data

- IEA data for total energy consumption in commercial sector.

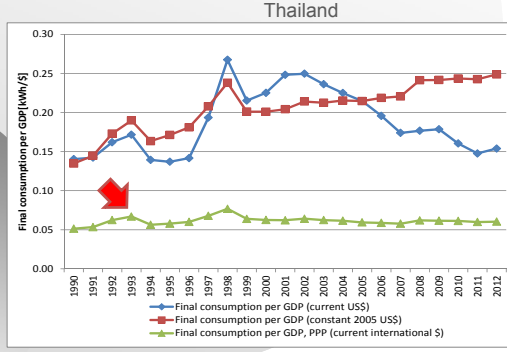
Forecast

- The ratio against PPP-based GDP sees an almost flat line, implying a possibility of strong correlation.

Bangladesh



Thailand



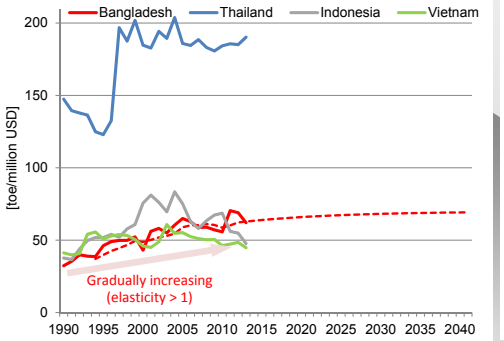
E-7 Agricultural Sector Energy Demand

Agricultural Sector Energy Demand

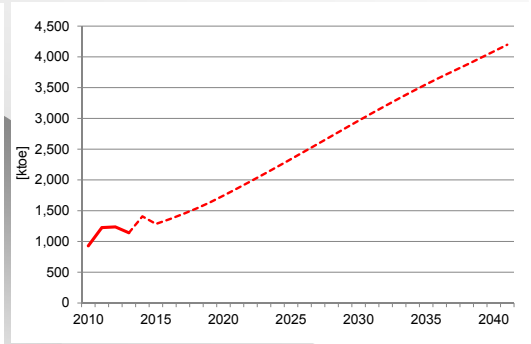
Projection of Agricultural Sector Energy Consumption

- Agricultural sector's energy intensity, i.e. a ratio of energy consumption to sectorial valued added (= GDP) is formulated to analyze how much energy (toe) is consumed for the sector to yield of 1 million USD.
- In Bangladesh, energy intensity has taken an gradually increasing trend (GDP elasticity > 1), which is considered due to the modernization of production process. In the meanwhile, in Indonesia and Vietnam, where the energy intensity is almost as high as in Bangladesh, a constant or declining trend is observed.
- This study assumes that the sector's energy intensity will be almost constant and projects that the sector's energy consumption will reach around 4,200 ktoe in 2041, about four times increase from 2013.

Energy Consumption per Sectorial Value Added (projection)



Sectorial Energy Consumption (projection)



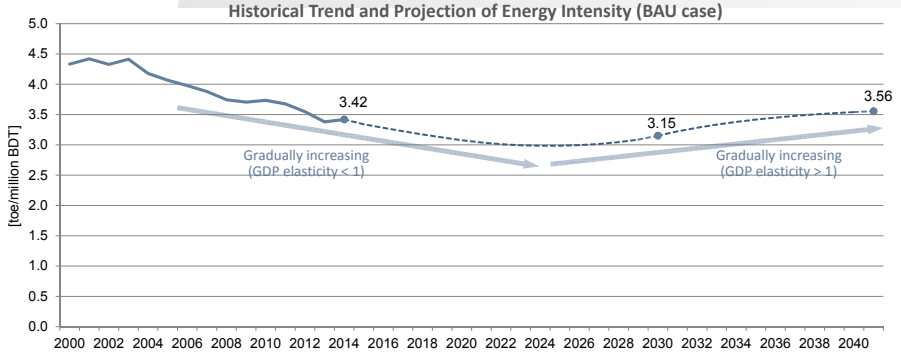
E-8 Energy Supply & Demand Balances

Energy Supply & Demand Balances

Energy Intensity of Total Final Energy Consumption

- The energy intensity, which is the ratio of total final energy consumption divided by GDP (real base) is expected to decrease continuously until mid-2020s, down from 3.42 toe/million BDT in 2014 to around 3 toe/million BDT (-12% down), due to the moderate growth of residential sector energy consumption.
  - In other words, GDP elasticity of energy consumption will be lower than 1 during that period.
- However, the energy intensity will start increasing afterwards (GDP elasticity >1) and become 3.15 toe/million BDT in 2030 (-8% down from 2014), and then 3.56 toe/million BDT in 2041 (4% up from 2014).
- The increase of energy intensity after mid-2020s is mainly driven by industrial sector and transport sector that are expected to grow higher than GDP continuously.

Historical Trend and Projection of Energy Intensity (BAU case)



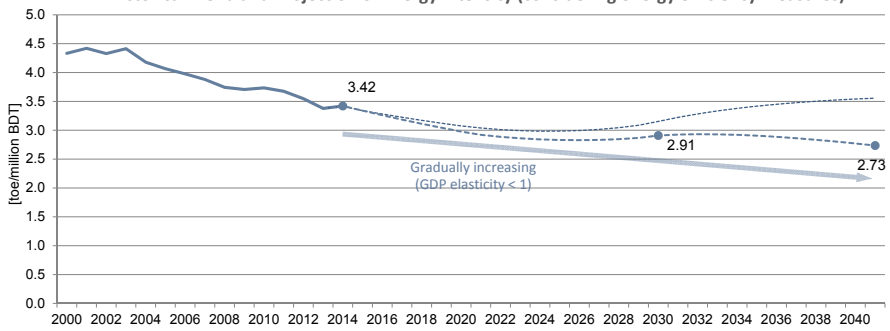
Energy Efficiency Target Setting

- The JICA study suggests that energy efficiency measures are to be implemented in Bangladesh so that the energy intensity will be lowered to
  - 2.91 toe/million BDT in 2030 (down -15% from 2014) and
  - 2.73 toe/million BDT in 2041 (down -20% from 2014)

* The definition of energy intensity is different from that in JICA's Energy Conservation Master Plan (ECMP: March 2015), in that:
- ECMP's energy intensity does not include transport sector energy consumption and biofuel consumption in the residential sector;
- Instead ECMP considers the combustion loss during power generation;

Using the definition of Energy Conservation Master Plan, the energy intensity as of 2030 is 2.35 toe/million BDT, down -20% from 2.94 toe/million BDT in 2014, and the energy intensity around 2.35 toe/million BDT will be maintained until 2041

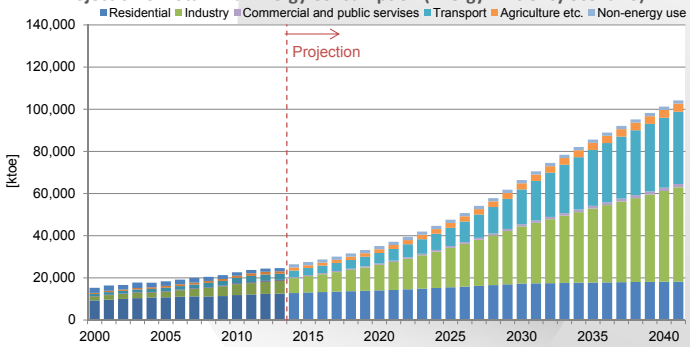
Historical Trend and Projection of Energy Intensity (considering energy efficiency measures)



Energy Efficiency Target Setting

- After considering the energy efficiency, the total final energy consumption in 2041 will be 104,200 ktoe, about 4.2 times increase from 2013 (5.3% p.a.).
- In order to achieve this, the energy efficiency target for each sector needs to be achieved as follows:
  - Residential sector: 20% reduction from BAU case;
  - Industrial sector: 18% reduction from BAU case;
  - Commercial & public sector: 10% reduction from BAU case;
  - Transport sector: 33% reduction from BAU case;
  - Agriculture: 10% reduction from BAU case;

Projection of Total Final Energy Consumption (Energy Efficiency Scenario)

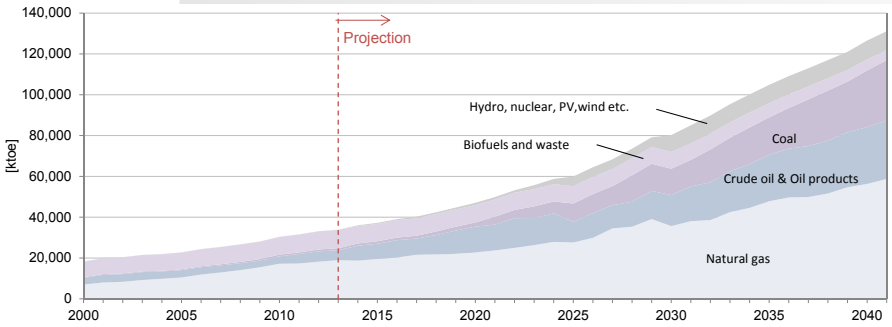


Sectors	TFC in 2041 (ktoe)	Growth ('13-'41)
Residential	18,238 (18%)	1.3%
Industrial	44,711 (43%)	7.4%
Commercial & Public Service	1,598 (2%)	4.7%
Transport	34,295 (33%)	9.2%
Agriculture	3,778 (4%)	4.4%
Others	47 (0%)	0.4%
Non-energy use	1,534 (1%)	-
Total	**104,200 (100%)**	**5.3%**

Total Primary Energy Supply

- Based on the projection of total final energy consumption as seen in the previous slide, the total primary energy supply is forecasted as shown in the following figure.
- In this projection, Scenario 3 of power development plan (i.e. gas and coal account for 35% each in power generation in 2041), and the share of natural gas and oil products in transport sector won't change (i.e. about 1:2). The share of fossil fuel sources may vary depending on the choice of scenarios.

Projection of Total Primary Energy Supply



E-9 Gas Supply (Domestic & Import LNG)

Domestic Natural Gas: On-site Survey

Onshore Exploration and Supply

- **Aging Existing Gas Fields (The Folding Bed in the Eastern Part of Bangladesh)**

Fact Finding: Heavily relying on existing gas production fields but the production is declining. New gas field to be developed to maintain at least current gas production level.

- **Best Industrial Practice through competitive bid**

Fact Finding: Fast Truck Program signed between GoB and Gazprom resulted in a higher cost for GoB to pay. On the other hand, BGFCL has introduced Best Industrial practice through competitive bidding. It appears to be working successfully.

Proposals: Introduction of competitive bidding for cost and quality of services, including drilling, 2D/3D surveys etc. to be encouraged.

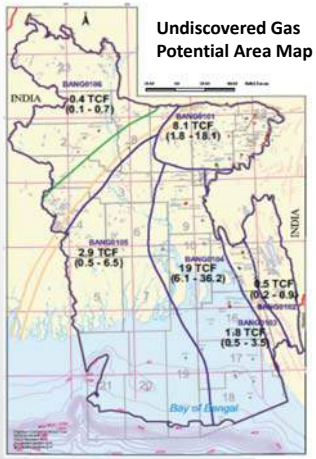
- **Maximize the recovery of condensate**

Fact Finding: Produced gas still contain fair amount of condensate.

Proposals: The recovery of condensate to be maximized to minimize the lost profit opportunities and to protect pipe from potential corrosion.

- **Review of the Impact of LNG introduction**

Proposals: Significant amount of LNG will be introduced into the gas infrastructure. Current gas transmission, distribution systems, and performance of gas production facilities needs to be reviewed.



Domestic Natural Gas: On-site Survey

- **Modernization of Gas Infrastructure**

Proposals: Gas flow to/from the gas infrastructure needs to be monitored. Electronic mapping and monitoring system to be in place to prepare for emergency transactions.

Discussions and Proposals

- **Introduction of PSC to new Onshore Exploration Areas (Folding Bed Areas and Fore-Deep Basin)**

  In order to enhance the technological skills and also mitigate risks in the exploration, introduction of Product Sharing Contract (PSC) with experienced IOCs partnered with BAPEX/BGFCL/SGFL to be considered.

- **Exploitation of Confirmed Potentials**

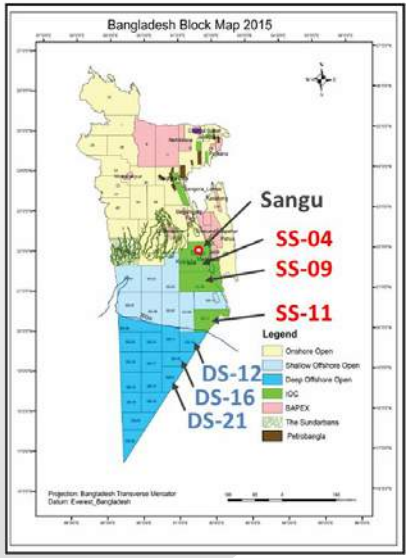
  Resume Chhatak and Feni Gas Field Development

- **Offshore Exploration**

  Review Model PCS to attract IOCs. Consider farm in Gas development project in Myanmar.

- **Role of BAPEX to be re-defined**

  Review the role of BAPEX and transform the organization to match IOCs and other NOCs (ONGC, CNPC and PETRONAS), and allow BAPEX to acquire energy assets overseas.



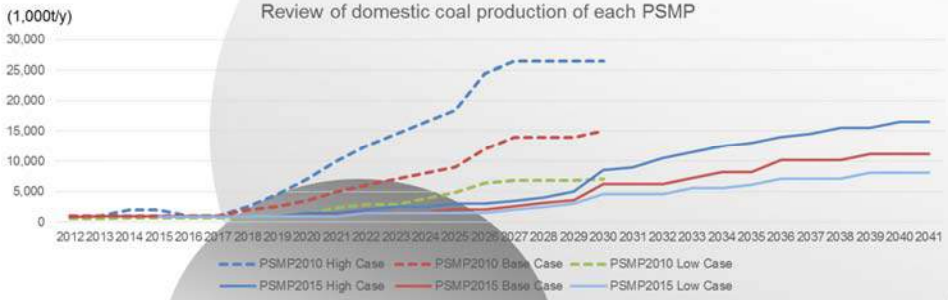
E-10 Coal Supply (Domestic & Import)

Coal Review

National Coal Development Policy

PSMP2010 Review

[Fact Finding]



The reasons that lowered amount of production of PSMP2015 in comparison with PSMP2010 are following the fact that;

(1) Coal Policy was almost ready for public and domestic coal development was strongly recommended by the Government in PSMP2010.

(2) Domestic coal development is in a difficult social situation in PSMP2015, and urge for importing.

Coal

National Coal Development Policy

The present situation of the coal policy

[Fact Finding]

The particularly new movement is nothing about the coal policy.

[Discussion and Proposal]

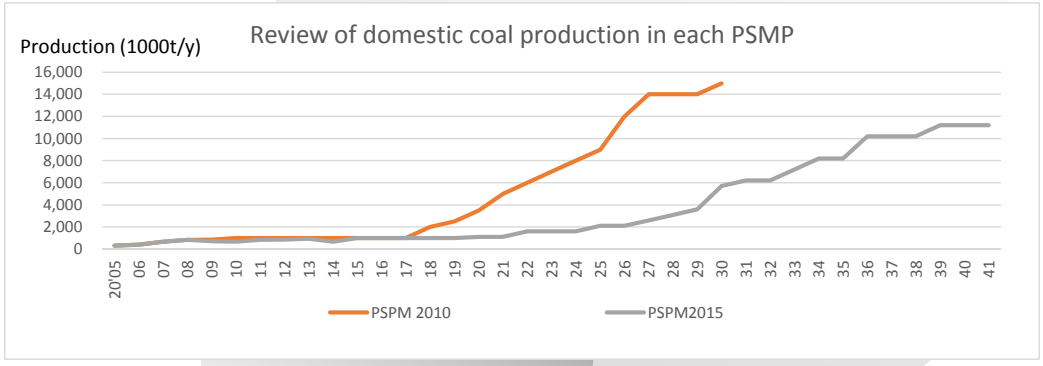
- The coal is the cheapest primary energy resources now and in the future.
- On the other hand, a coal-fired power station in the Southern Asia including Bangladesh is increasing rapidly, and coal demand increases simultaneously.
- As a result, the supply, quality and price of import coal become very unstable.
- Therefore, domestic coal development becomes important in future. Because there are abundant coal of high grade quality in Bangladesh.

Coal

National Coal Development Policy

PSMP2010 Review

[Fact Finding]



Coal

Current Situations and Issues of Supply and Demand of Domestic Coal

Coal reserve of each coal field and estimated minable coal reserve

[Fact Finding]

As a new coal development field, Dighipara and Khalaspir will be nominated. But They are still waiting for a mining approval from government, though they completed Feasibility Study.

Table 8-3 Minable Coal Reserve depending on Mining Method

	Coal field name	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured reserves (million tons)	Mining method	Minable coal reserve (million t)
1	Barapukuria (Dinajpur)	118 -506	6	51	303	U/G (15%)	45.5
2	Phulbari, (Dinajipur)	150 -240	2	15-70	572	O/C (60%)	343.2
3	Khalaspir, (Rangpur)	257 -483	8	42.3	143	U/G (15%)	21.5
4	Dighipara, (Dinajipur)	328 -407	5	62	150	U/G (15%)	22.5
5	Jamalgonj, (Bogra)	640-1,158	7	64	1,053		
6	Kuchma, (Bogra)	2,380 -2,876	5	51.8			
Total					3,300		438
Source: Edited by PSMP Study Team							

Coal

Current Situations and Issues of Supply and Demand of Domestic Coal

Current situation and issue of Barapukuria coal mine (BCMCL)

[Fact Finding]

- Petrobangla and XMC-CMC in China concluded an agreement of MPM & M in 2011. Though designed capacity is one million ton /year, but the production did not reach the capacity after 10 years due to some difficult mining conditions.
- F/S of the expansion plan is carrying out now to be approved by the government
- 250MW coal-fired power station is in operation, and a study is on the table to build expansion of 125MW power station.
- A small-scale open-cast mining is feasible. The Indian company's TATA suggested open cut mining, but the government does not give a conclusion at present.

[Discussion and Proposal]

As U/G mining technology is establishing now at BCMCL, it is the most important issue to cultivate Bangladeshi engineers to be able to manage a coal mine by themselves in mining and safety.

Coal

Current Situations and Issues of Supply and Demand of Domestic Coal

An aspect of un-developing coal field

[Fact Finding]: The particularly new movement is nothing.

Forecast of domestic coal production

[Fact Finding]

Year	Total coal production (HC) (1,000t/y)	Total coal production (BC) (1,000t/y)	Total coal production (LC) (1,000t/y)	Production of Domestic Coal Mine (1,000t/y)														
				Existing Coal Mine & New O/C					New Coal Mine (U/G & O/C)									
				Barapukuria U/G & new O/C					Kalaspir(U/G)			Dighipara(U/G)			Phulbari(O/C)		
				U/G			O/C		U/G			U/G			O/C		U/G
				(HC)	(BC)	(LC)	(HC)	(BC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)
2014-15		676			676												
2020-21	1,500	1,100	1,000	1,500	1,100	1,000											
2030-31	8,000	5,700	3,600	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	1,000	1,000	1,000	500	500	500
2040-41	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000
2041-42	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000

[Discussion and Proposal]

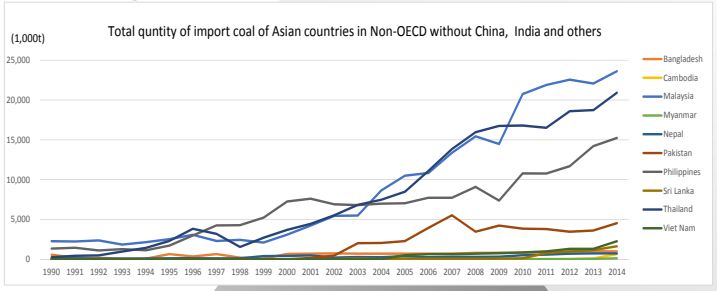
The development of a new coal mine will be considered after import coal increase in the near future. On the other hand, the preparation of a new coalmine is required at least 5 years. Therefor, basic study for a new coalmine should be carried out at present.

Coal

The Present Aspect and Issues of the Import coal

General view

[Fact Finding]



The Quantity of Import Coal of Southeast Asian Countries in Non-OECD without China, India and Others

[Discussion and Proposal]

The Bangladeshi coal import environment will become severer and severer.

Coal

The Present Aspect and Issues of the Import coal

Import coal price

[Fact Finding]

The Coal Price of 1,000kcal/kg Movement at Newcastle Port in Australia



Total Coal Cost including FOB, Freight, Insurance and Handling Cost to High Grade Coal from Australia

Year	FOB Price of 6,300kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	50.5	15.0	16.0	81.5	0	65.5
2020	67.7	17.8	17.8	103.3	0	85.5
2025	85.0	20.5	19.7	125.1	0	105.5
2030	102.2	23.2	21.5	147.0	0	125.5
2035	119.5	26.0	23.4	168.9	0	145.5
2040	136.8	28.7	25.2	190.7	0	165.5

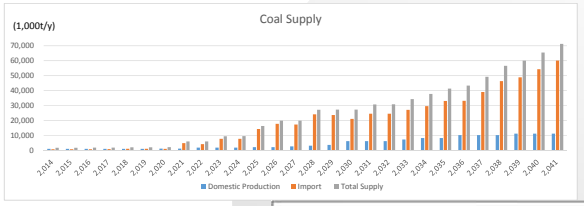
Total Coal Cost including FOB, Freight, Insurance and Handling Cost *to* Low Grade Coal from Indonesia

Year	FOB Price of 4,700kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost (US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	34.61	9.1	16.0	59.7	0	43.7
2020	46.43	10.7	17.8	75.0	0	57.2
2025	58.26	12.4	19.7	90.3	0	70.7
2030	70.09	14.1	21.5	105.7	0	84.1
2035	81.92	15.7	23.4	121.0	0	97.6
2040	93.76	17.4	25.2	136.4	0	111.1

Coal

Prediction of Coal Demand

[Fact Finding]



			2014	2015	2020	2025	2030	2035	2040	2041
Demand	Power Sttion	New Coal fired Power Station				14,129	24,917	38,837	62,904	68,704
		Barapukuria PS(125MW x 2)	433	433	433	433	433	433	433	433
		Barapukuria PS(125MW x 1)			217	217	217	217	217	217
	Industry	Forcast following IEA Import figures	1,000	1,023	1,136	1,249	1,362	1,475	1,588	1,610
		Present Local user at BCMCL	300	300	300	300	300	300	300	300
		Total Demand	1,733	1,755	2,085	16,327	27,228	41,261	65,441	71,263
Supply	Domestic	BCMCL & Other new mine	1,000	1,000	1,100	2,100	6,200	8,200	11,200	11,200
	Import	Balance Between Total Demand And Domestic Production	733	755	985	14,227	21,028	33,061	54,241	60,063
		Total Supply	1,733	1,755	2,085	16,327	27,228	41,261	65,441	71,263

[Discussion and Proposal]

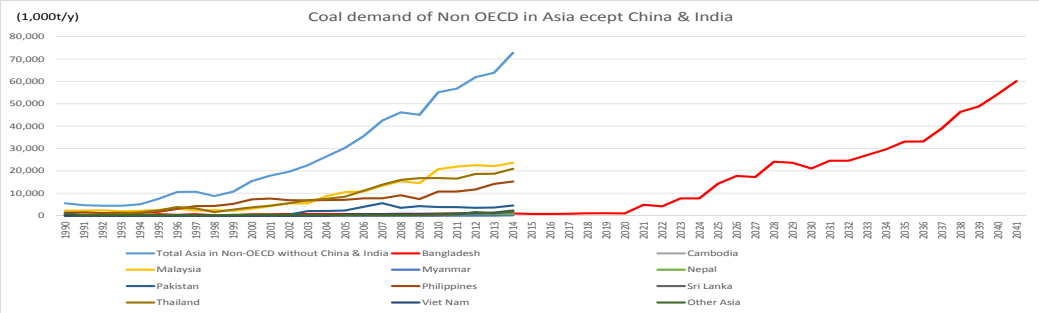
It is an important issue to make strategy how Bangladesh secures quantity of future coal demand.

Coal

Prediction of Coal Demand

[Fact Finding]

The amount of import coal of Bangladesh in 2041 is almost same as total amount of import coal of all Non OECD countries except China and India in 2014.



[Discussion and Proposal]

➢Stable supply of coal in future is a critical issue in Bangladesh.

➢The domestic coal development is the choice that is not avoided.

E-11 Oil and LPG Supply

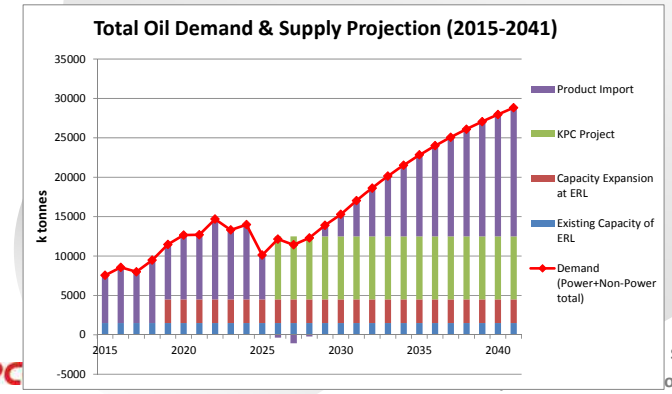
Oil (Crude oil & Oil Products)

Total oil demand (Power + Non-Power) in 2041 will become 4-fold from 2015 (5.2% p.a.).

Oil demand in Non-power sector in 2040 will become 8-hold from 2015 (7.4% p.a.):

- This growth is mainly led by Transport sector demand growth (11-fold).
- Oil demand for Power sector will continue to increase until early 2020s, when Matarbari Coal USC becomes online, but later decline.

Note: The growth projection of non-power sector is different between PSMP2015 and Data Collection Survey on Integrated Development for Southern Chittagong Region. It will be discussed later.



Source: JICA Survey Team

LPG

GoB will soon adopted a new policy and households will use LPG as modern cooking fuel. LPG is cleaner and less CO2 fuel than other fossil fuels, but it is expensive solution for most of Bangladesh people

- LPG "actually marketed" price is much higher than "official rate" – For one 12kg Cylinder, Tk.1050 (Mkt in Bogra) vs. Tk.700 (Official)
- The difference of the unit price of LPG (marketed price) and the current pipelined natural gas is big – approx. 8:1.

	Fixe Price for one burner	Unit Sales Price	Heat Value per Unit	Unit Price per MJ
Natural Gas	Tk 600 Tk/month	Tk 8.33 /m3	39.59 MJ/m3	Tk 0.21 /MJ
LPG	Tk 1,050 Tk/12 kg (1 cylinder)	Tk 87.50 /kg	50.80 MJ/kg	Tk 1.72 /MJ

- [Discussion & Proposal] Does GoB consider any countermeasure (e.g. regulation) to correct the current actual-official price gap?
- [Discussion & Proposal] LPG may be affordable for Dhaka households, but not for poor rural households. Does GoB consider any countermeasure, .e.g. cross subsidy among petroleum products, or alternative such as off-grid biogas for rural poor?
- [Discussion & Proposal] Unlike crude oil, LPG pricing is "in practice" dominantly determined by Aramco. Too much dependence on LPG may hamper Bangladesh's energy security

Source: JICA Survey Team

F Power Balance Strategy

F-1 Power Demand Forecast and Development Plan Conditions

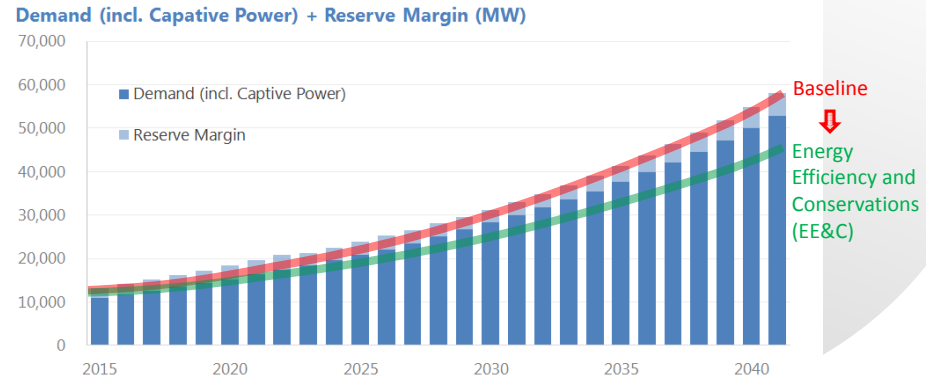
Power Demand Forecast

Assumptions:

- GDP growth rate: around 6% for 2014/41.
- Reserve Margin (RM) kept down to 10% by 2030

Projections:

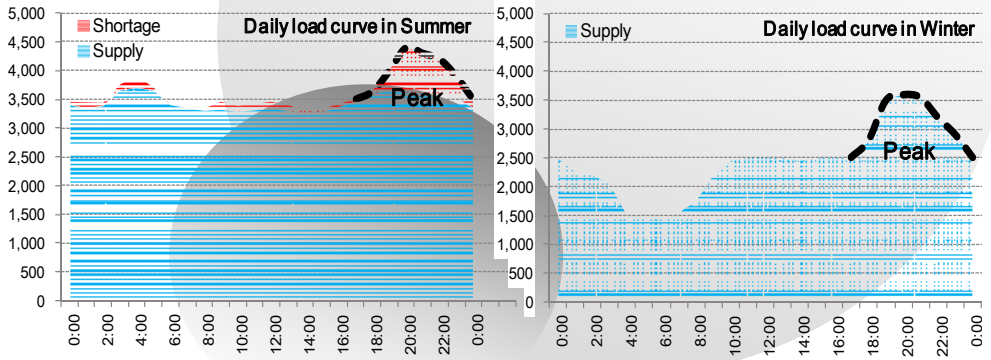
- Required supply will be at 57,000MW including Reserve Margin
- Energy Efficiency and Conservations (EE&C) is challenging and important issue for Nation



Estimation of the maximum power including potential demands

- The power supply has constantly remained strained in peak. Potential demands have not been met, and rotational outage has frequently occurred. The actual recorded maximum power has not included these potential demands.
- To estimate the maximum power that includes potential demands, PSMP adopts a method for calculating the generated power energy with which a compound daily load curve is produced by adding the evening peak demand for lighting, calculated from a daily load curve with no rotational outage on weekends and holidays in winter, to a daily load curve suppressed by rotational outage on weekdays in summer.

Typical daily load curves in Bangladesh in summer and winter



Estimation of the maximum power including potential demands

- The actual recorded maximum load in fiscal 2015 was 7,356 MW.
- The maximum load estimated by giving consideration to latent intermediate load, peak load and actual efficiency in the assumed base load of 6,170MW is approximately 8,921MW. Accordingly, in prediction of the long-term demands up to fiscal 2041, 8,921MW reached in this study will be adopted as an initial value for fiscal 2015.

Estimated maximum power including potential demands(2005-2015)

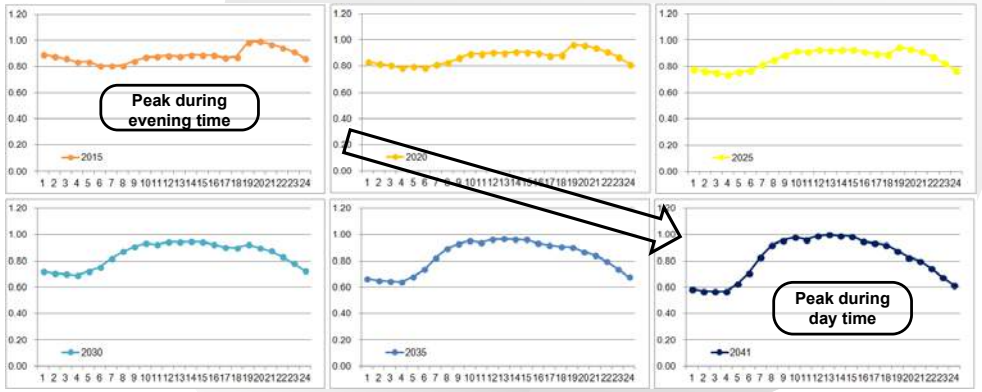
Fiscal Year	Estimated Base Load (MW)	Estimated Intermediate Load (MW)	Estimated Base Over Peak Load (MW)	Estimated Peak Load (MW)	Actual Net/Gross	Estimated Net Peak Load(MW)	Growth (%)	Actual Net Peak Load (MW)	Growth (%)
2005	3,097	-	1,379	4,476	0.95	4,230		3,900	
2006	3,600	-	1,413	5,013	0.95	4,737	12.00%	4,200	7.70%
2007	4,050	-	1,063	5,113	0.95	4,832	2.00%	4,500	7.10%
2008	4,190	-	1,484	5,674	0.95	5,362	11.00%	4,600	2.20%
2009	4,150	-	1,500	5,650	0.95	5,339	-0.40%	5,050	9.80%
2010	4,300	817	1,462	6,579	0.95	6,258	16.40%	5,550	9.90%
2011	4,400	836	1,496	6,732	0.95	6,411	2.30%	5,550	0.00%
2012	5,000	950	1,700	7,650	0.96	7,326	13.60%	6,600	18.90%
2013	5,300	1,007	1,802	8,109	0.96	7,764	6.00%	6,600	0.00%
2014	5,487	1,043	1,811	8,341	0.96	8,039	2.90%	7,356	11.50%
2015	6,170	1,111	1,974	9,255	0.96	8,921	11.00%	7,500	2.00%

Assumption of daily load curve

General of daily load curve

- Daily load curve in 2015 is estimated based on actual power consumption in Bangladesh.
- Daily load curve is gradually sifted to type of developed country's daily load curve until 2041

Shift of Daily Load Curve (2015-2041)

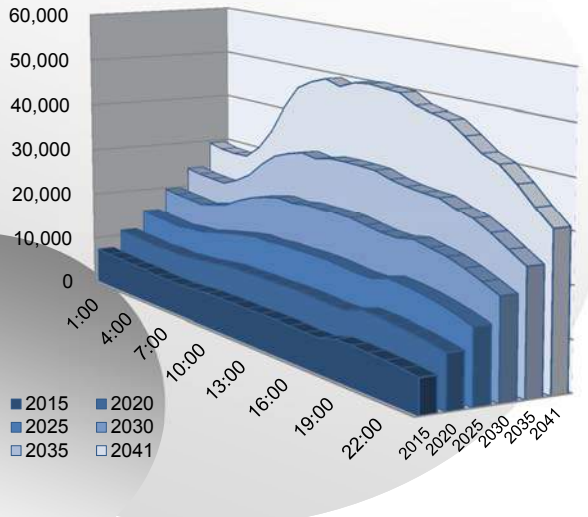


Power Demand Forecast

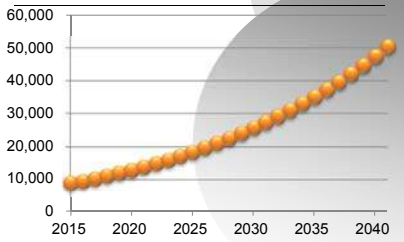
Power Demand Forecast

- Power demand is estimated by multiplying estimated maximum power and estimated daily load curve from 2015 to 2041.
- Estimated power demand forecast from 2015 to 2041 shows shift change of daily load curve from evening peak to daytime peak and increasing peak demand from 8,921 MW to 50,400 MW.

Estimated Power Demand Forecast (2015-2041)



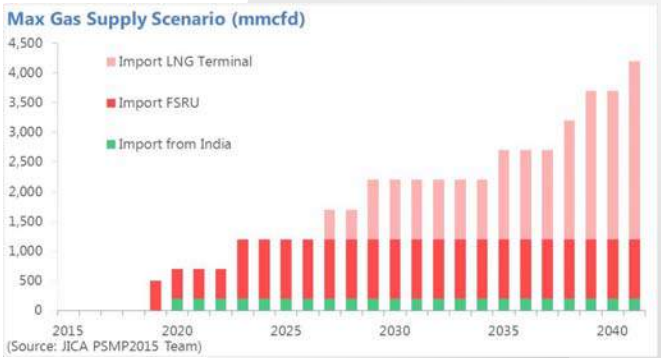
Peak Demand Forecast (2015-2041)



Fundamental condition for Import Fuel/Port/PDP Core Zone LNG Import Infrastructure

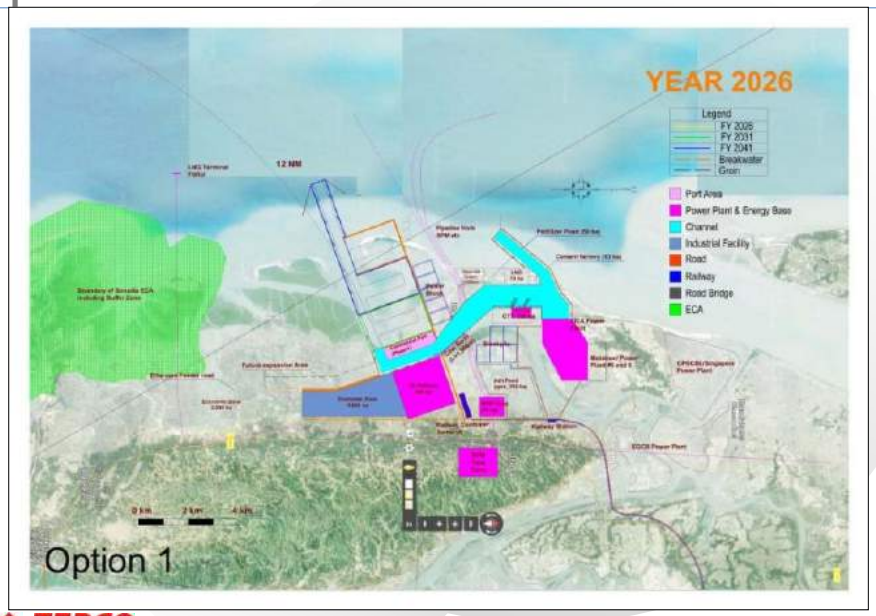
Southern Chittagong M/P shows a key layout of sea port facility for LNG development.

Around 4,000mmcfd capacity of LNG facility is being planned.

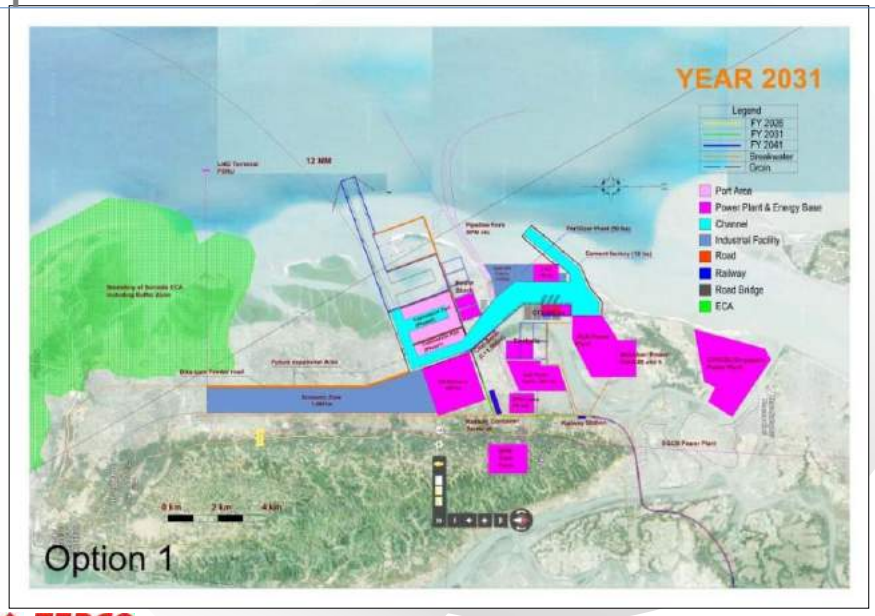


FY	New LNG Terminal					
	FSRU		Onshore Terminal			Total of New LNG Terminal
	Energy Div		Energy Div.	Power Div.		
	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd
2015	0	0	0	0	0	0
2016	0	0	0	0	0	0
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
2019	500	0	0	0	0	500
2020	500	0	0	200	0	700
2021	500	0	0	200	0	700
2022	500	0	0	200	0	700
2023	500	500	0	200	0	1,200
2024	500	500	0	200	0	1,200
2025	500	500	0	200	0	1,200
2026	500	500	0	200	0	1,200
2027	500	500	0	200	500	1,700
2028	500	500	0	200	500	1,700
2029	500	500	500	200	500	2,200
2030	500	500	500	200	500	2,200
2031	500	500	500	200	500	2,200
2032	500	500	500	200	500	2,200
2033	500	500	500	200	500	2,200
2034	500	500	500	200	500	2,200
2035	500	500	1,000	200	500	2,700
2036	500	500	1,000	200	500	2,700
2037	500	500	1,000	200	500	2,700
2038	500	500	1,500	200	500	3,200
2039	500	500	2,000	200	500	3,700
2040	500	500	2,000	200	500	3,700
2041	500	500	2,500	200	500	4,200

Fundamental condition for Import Fuel/Port/PDP Core Zone LNG Import Infrastructure



Fundamental condition for Import Fuel/Port/PDP Core Zone LNG Import Infrastructure



Fundamental condition for Import Fuel/Port/PDP Core Zone LNG Import Infrastructure



CO2 Emission by fuel type

- CO2 emission is estimated by below equation in each fuel type.

CO2 Emission [kg-CO2/Mcal]
= Carbon content per calorific value [t-CO2/TJ] / Calorie consumption per calorific value [kcal/MJ]

Item	CO2 emission (kg-CO2/Mcal)
COAL (Domestic)	0.39615
COAL (Import)	0.40229
HSD	0.30095
OIL	0.30709
GAS	0.23492

Fuel Price Scenario

Study of Economic Value

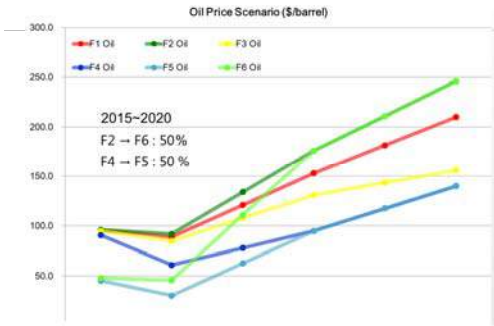
F1 to F5 Scenario of future fuel cost is studied. IEA's scenario of international fuel cost trend is employed as from F1 to F4, and current status in Bangladesh is considered in F5 and F6 Scenario

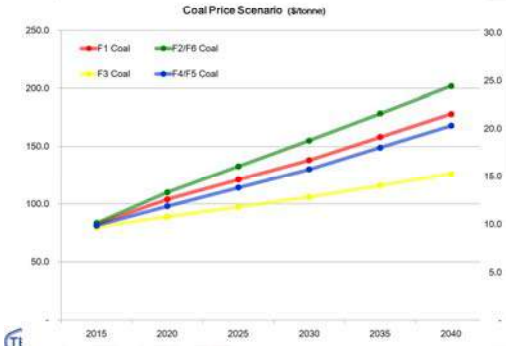
F1 : IEA's New Policies Scenario
F2 : IEA's Current Policies Scenario
F3 : IEA's 450 Scenario
F4 : IEA's Low Oil Price Scenario
F5 : Revised F4 Scenario [Base]
F6 : Revised F2 Scenario [High]

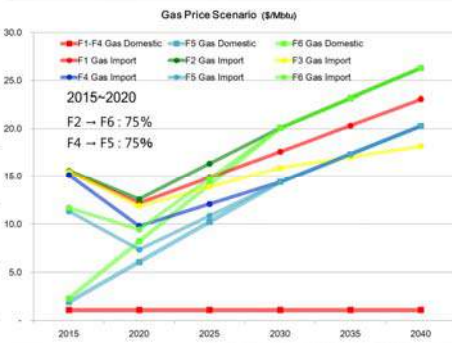
		New Policies Scenario			Current Policies Scenario			450 Scenario			Low Oil Price Scenario		
	2014	2020	2030	2040	2020	2030	2040	2020	2030	2040	2020	2030	2040
Nominal terms			F1			F2	F5		F3			F4	F6
IEA crude oil imports ($/barrel)	97	89	153	210	92	176	246	85	131	156	61	95	140
Natural gas ($/MBtu)													
United States	4.4	5.2	8.3	12.3	5.2	8.6	12.8	5.0	7.6	9.7	5.2	8.3	12.3
Europe imports	9.3	8.6	15.1	20.3	9.0	16.9	22.6	8.4	12.7	14.6	6.6	12.1	18.7
Japan imports	16.2	12.2	17.6	23.1	12.6	20.1	26.3	11.9	15.9	18.2	9.8	14.4	20.3
OECD steam coal imports ($/tonne)	78	104	138	178	110	155	202	89	106	126	98	130	168

Notes: MBtu = million British thermal units. Gas prices are weighted averages expressed on a gross calorific-value basis. All prices are for bulk supplies exclusive of tax. The US price reflects the wholesale price prevailing on the domestic market. Nominal prices assume inflation of 1.9% per year from 2014.

Fuel Price Scenario







F5 : Revised F4 Scenario considering with current market

F6 : Revised F2 Scenario considering with current market

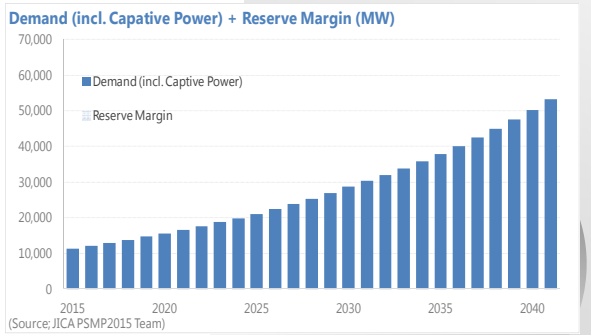
Oil price: 50% of F5 (2015-2020), 100% by 2030

Gas price: 75% of F5 (2015-2020), 100% by 2030

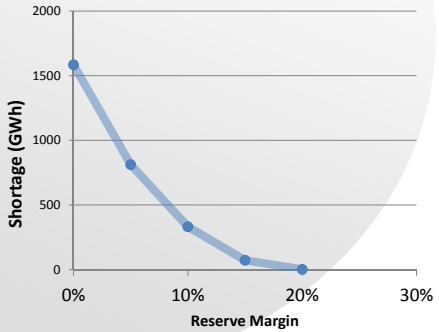
Coal price : 100% (2015-2041)

Supply reliability

- In the case of developing an appropriate power supply plan that corresponds to the assumed power demand, it is necessary to set an appropriate reserve margin in consideration of delay risks connected to project implementation, and fluctuation risks of the power demand forecast.
- Therefore, over the short-terms, the reserve margin is targeted at 0% in consideration of the current status, and the reserve margin will increase gradually afterwards, and will reach 10% by the long-term period.
- As a reference, more than 20% of reserve margin is required at 2015 in order to resolve power shortage.



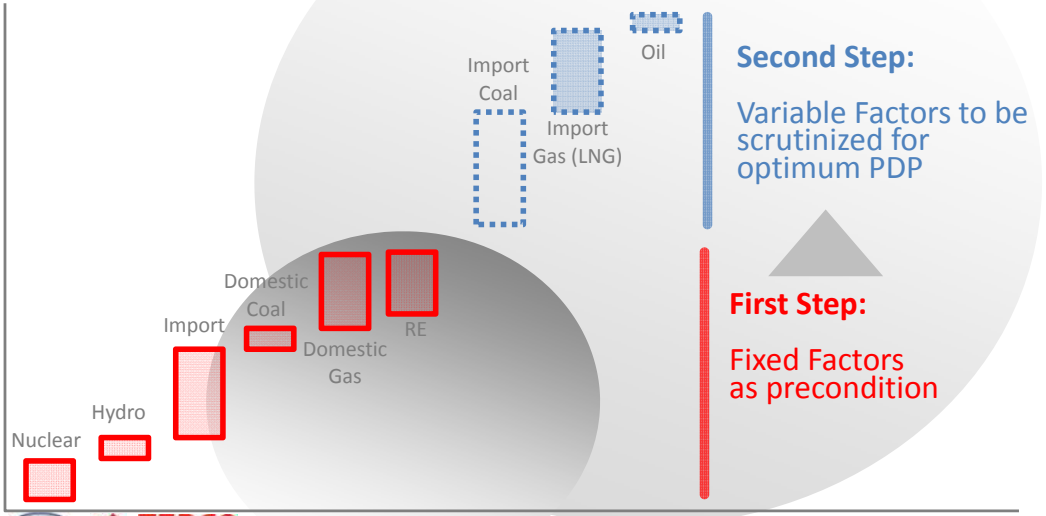
Relationship between shortage and RM @2015



Fixed and Variable Factors for PDP

Assumptions:

- Fixed Factor: Nuclear, Power Import, Dom Coal, Dom Gas and Renewable Energy
- Variable Factor: Imp Coal, Imp Gas and Oil



F-2 3E (Economy, Energy Security, and Environment)

3E Evaluation of Energy Mix Scenarios

- 3E (Economy, Energy Security, and Environment) of 5 scenarios are evaluated using following indices.
- Smaller value of these index shows better composition.

Economic Index	Environmental Index	Energy Security Index	3E Index
Generation cost per electricity supply [US cent / kWh]	Carbon cost per electricity supply [US cent / kWh]	GDP loss when energy is not delivered [US cent / kWh]	Total of these indices [US cent / kWh]

Economic Index

- Generation cost (fixed price + fuel price) per electricity supply
- Assuming fuel price of F5 Scenario (Revised IEA's Low Oil Price Scenario) cf. "Fuel Price Scenario" slide

Environmental Index

- Carbon cost per electricity supply
- Assuming carbon price in IEA's 450 scenario

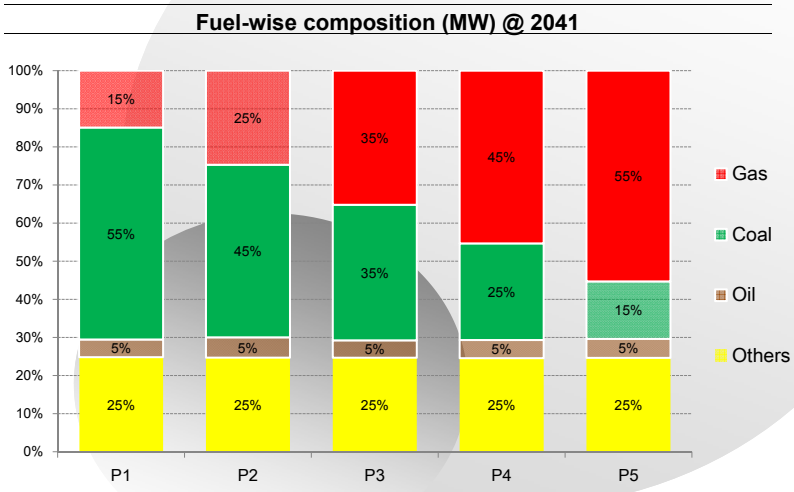
Table 1.4 CO_2 price assumptions in selected countries and regions by scenario ($2014 per tonne)

	Region	Sectors	2020	2030	2040
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry	10	75	125

Fuel-wise Composition Scenario

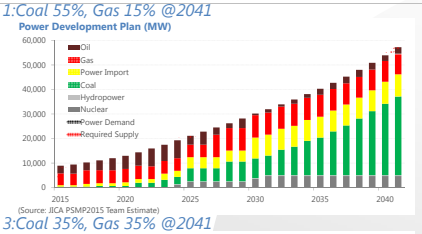
Study of optimum composition of fuel type

P1 to P5 scenario of fuel-wise composition is studied. Only coal and gas balance from 15% to 55% is changed in each Scenario.

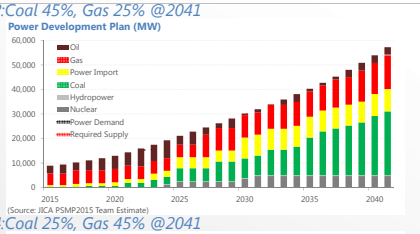


PDP Scenarios

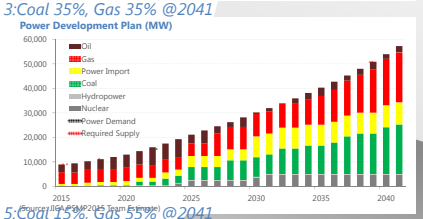
1:Coal 55%, Gas 15% @2041



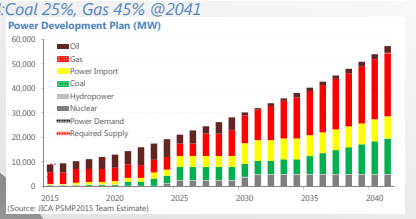
2:Coal 45%, Gas 25% @2041



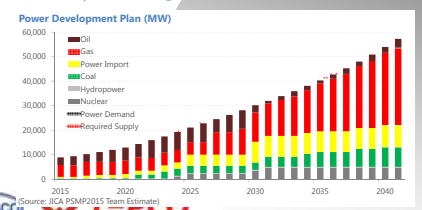
3:Coal 35%, Gas 35% @2041



4:Coal 25%, Gas 45% @2041



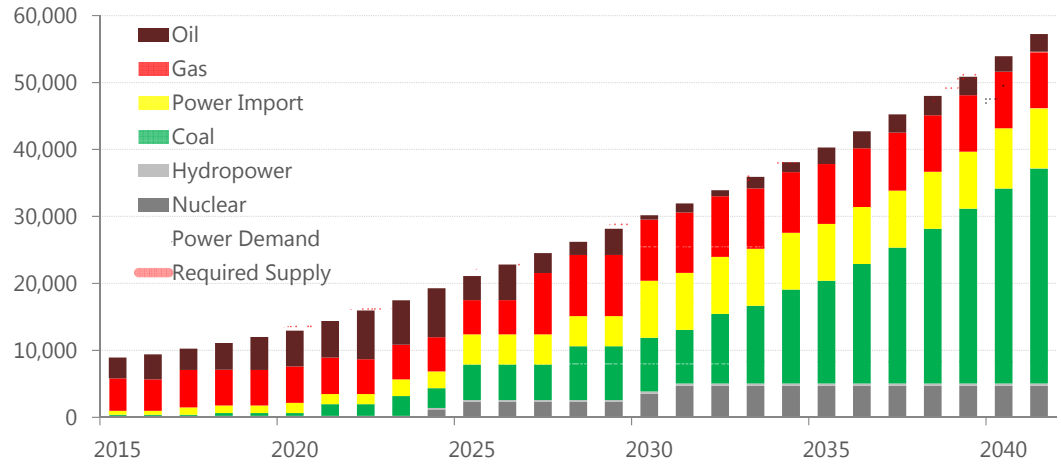
5:Coal 15%, Gas 55% @2041



Scenario 1: Coal Max

Coal 55%, Gas 15% @2041

Power Development Plan (MW)

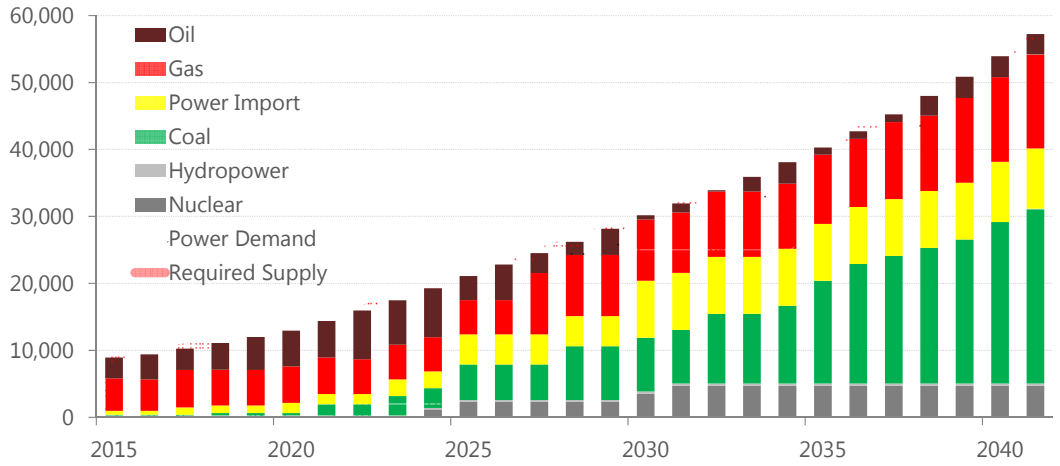


(Source: JICA PSMP2015 Team Estimate)

Scenario 2

Coal 45%, Gas 25% @2041

Power Development Plan (MW)

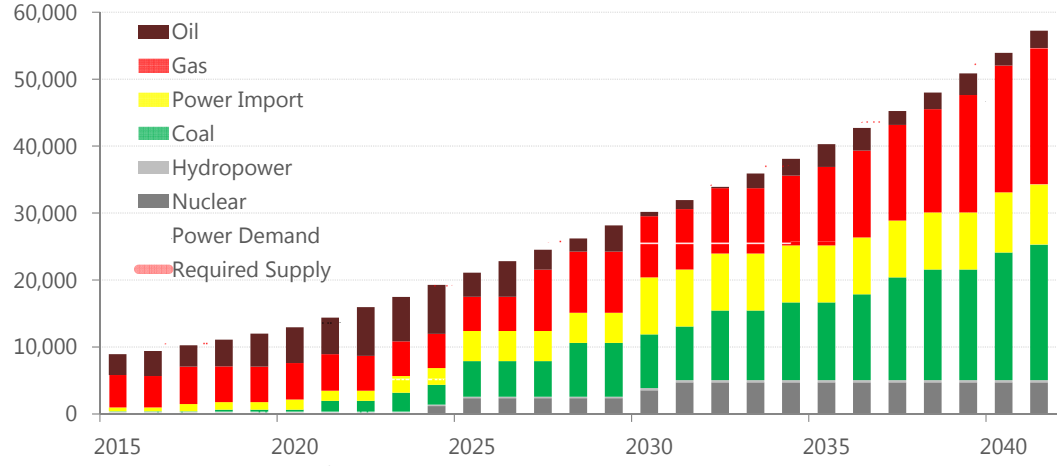


(Source: JICA PSMP2015 Team Estimate)

Scenario 3: Mid

Coal 35%, Gas 35% @2041

Power Development Plan (MW)

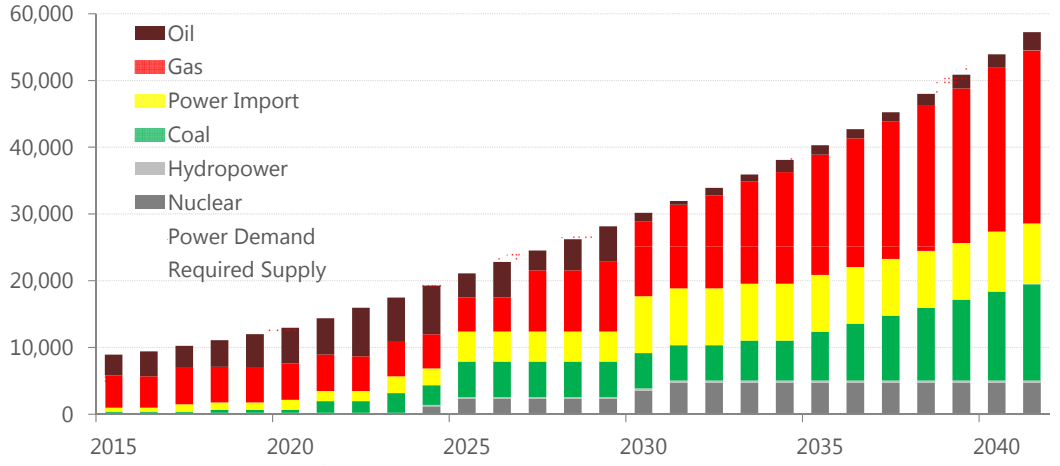


(Source: JICA PSMP2015 Team Estimate)

Scenario 4:

Coal 25%, Gas 45% @2041

Power Development Plan (MW)

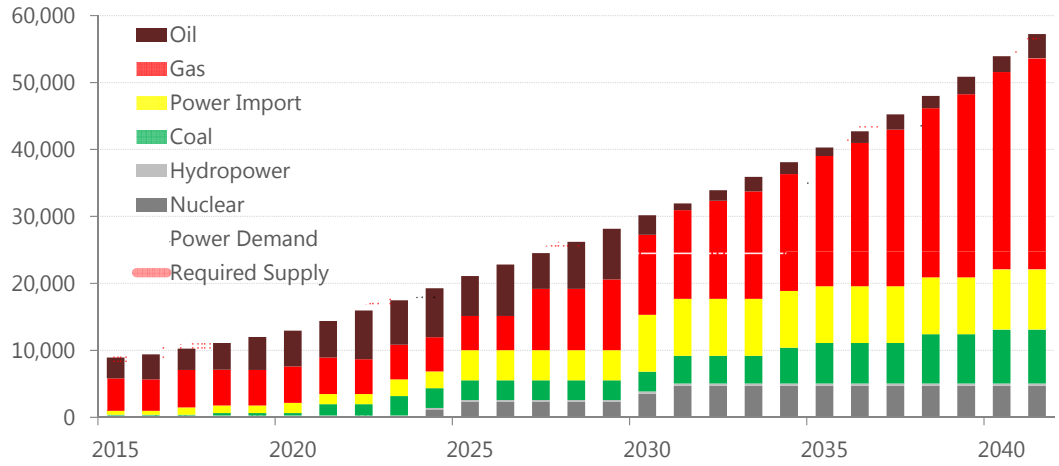


(Source: JICA PSMP2015 Team Estimate)

Scenario 5: Gas Max

Coal 15%, Gas 55% @2041

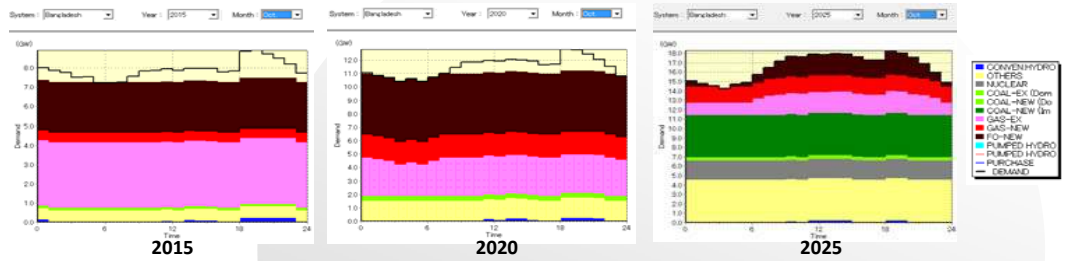
Power Development Plan (MW)



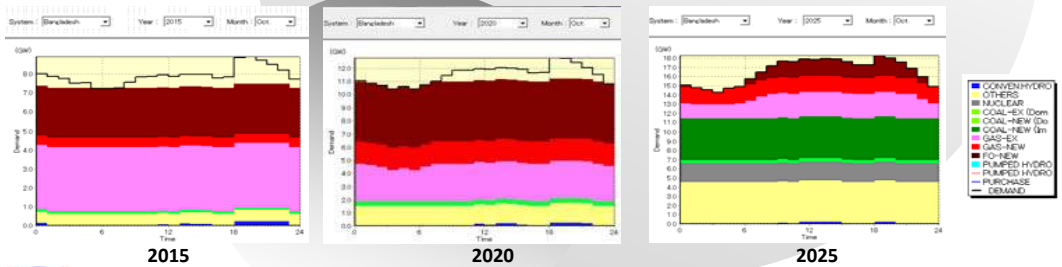
(Source: JICA PSMP2015 Team Estimate)

Economy index (PDP Scenarios)

Scenario 1 (F5)

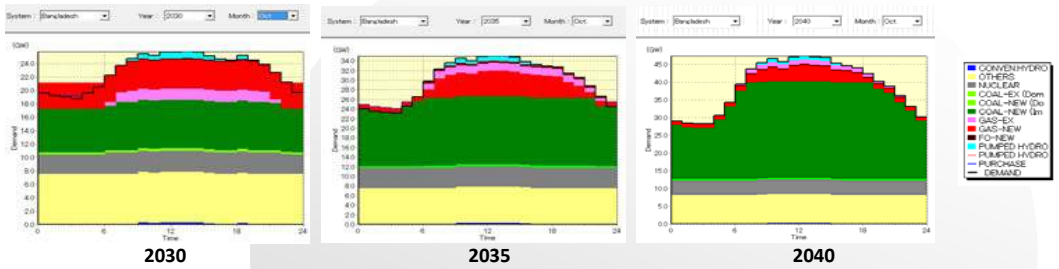


Scenario 1 (F6)

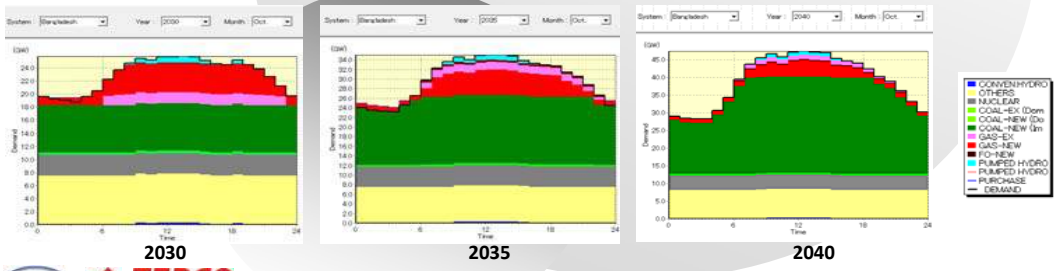


Economy index (PDP Scenarios)

Scenario 1 (F5)

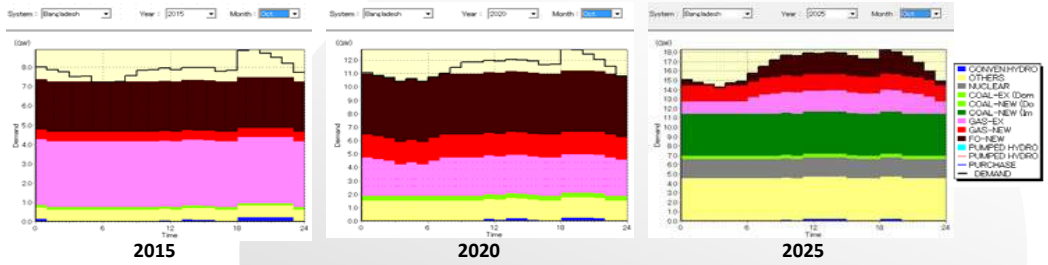


Scenario 1 (F6)

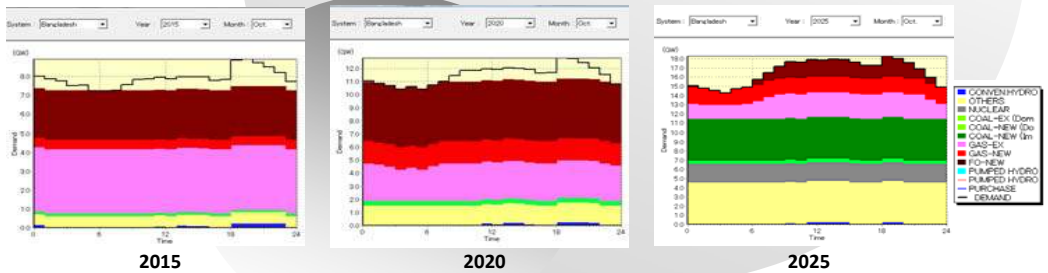


Economy index (PDP Scenarios)

Scenario 2 (F5)

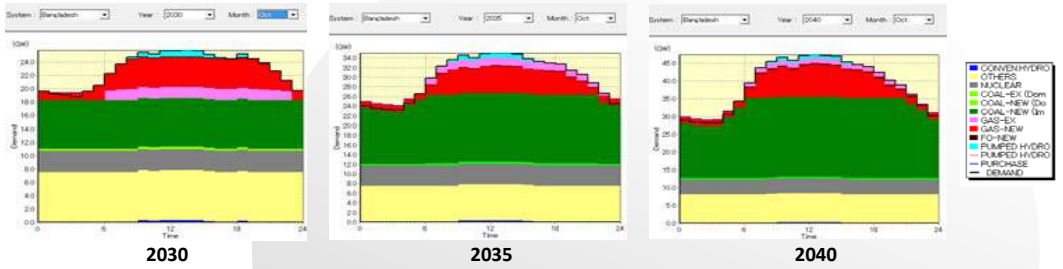


Scenario 2 (F6)



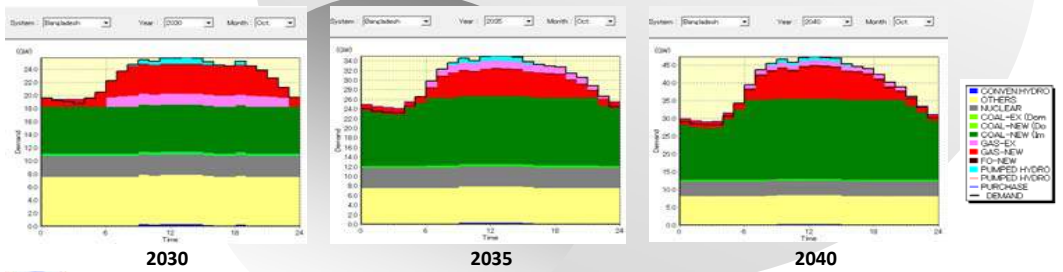
Economy index (PDP Scenarios)

Scenario 2 (F5)



2030 2035 2040

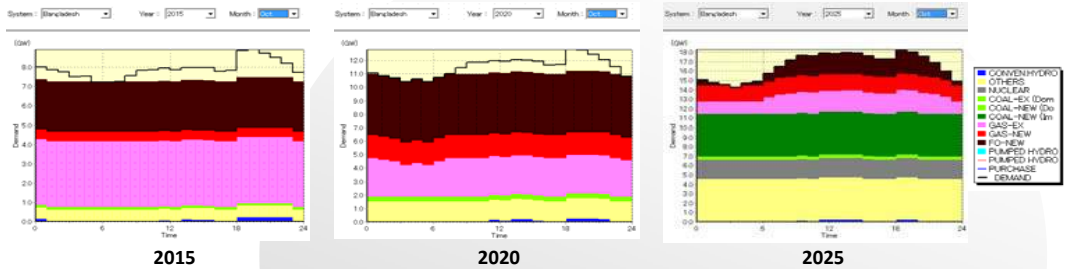
Scenario 2 (F6)



2030 2035 2040

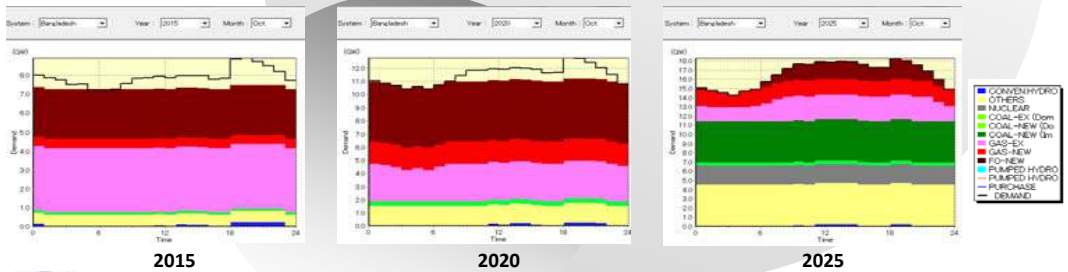
Economy index (PDP Scenarios)

Scenario 3 (F5)



2015 2020 2025

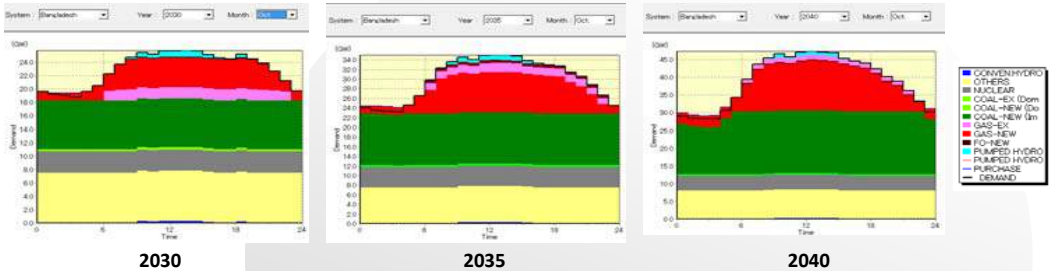
Scenario 3 (F6)



2015 2020 2025

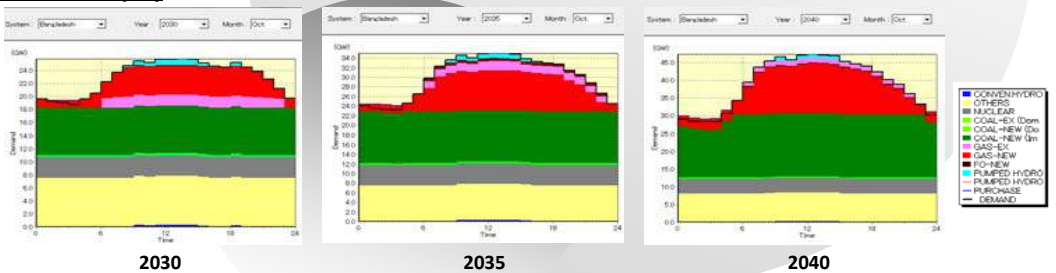
Economy index (PDP Scenarios)

Scenario 3 (F5)



2030 2035 2040

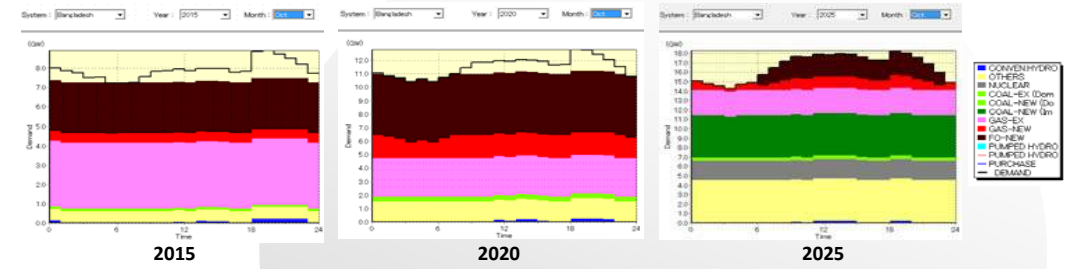
Scenario 3 (F6)



2030 2035 2040

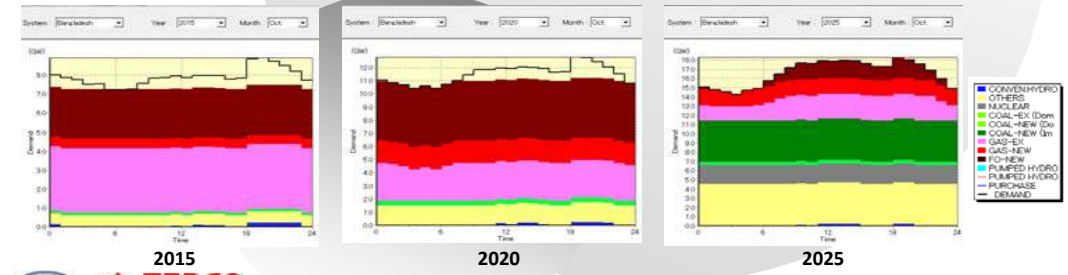
Economy index (PDP Scenarios)

Scenario 4 (F5)



2015 2020 2025

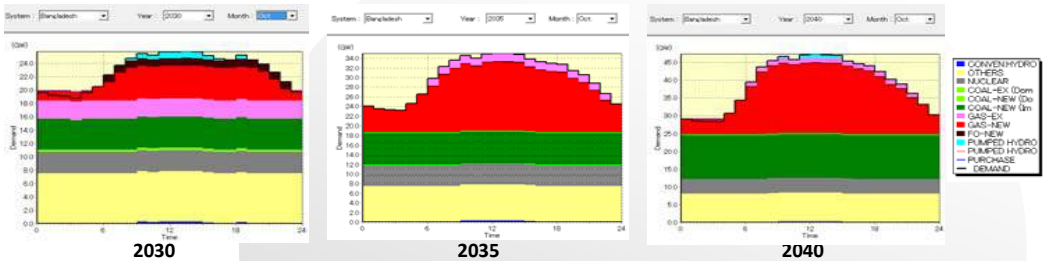
Scenario 4 (F6)



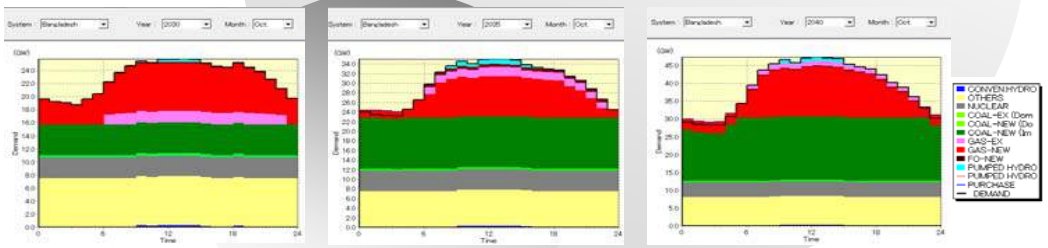
2015 2020 2025

Economy index (PDP Scenarios)

Scenario 4 (F5)

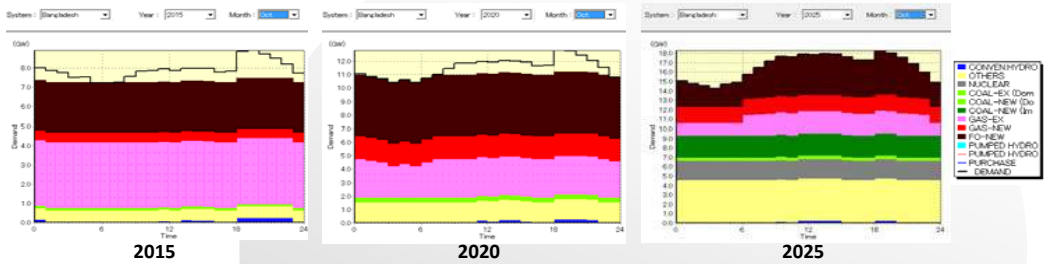


Scenario 4 (F6)

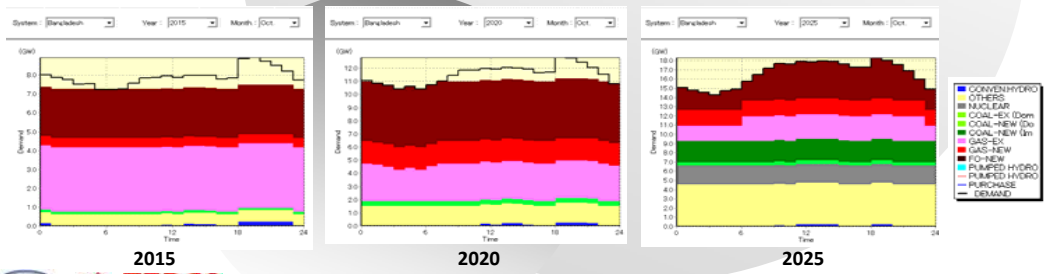


Economy index (PDP Scenarios)

Scenario 5 (F5)

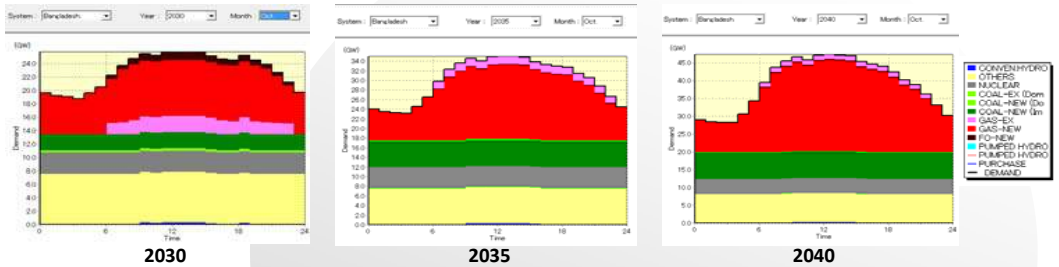


Scenario 5 (F6)

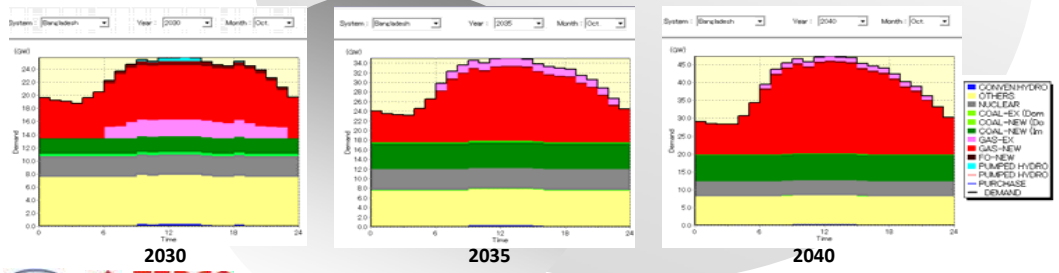


Economy index (PDP Scenarios)

Scenario 5 (F5)



Scenario 5 (F6)

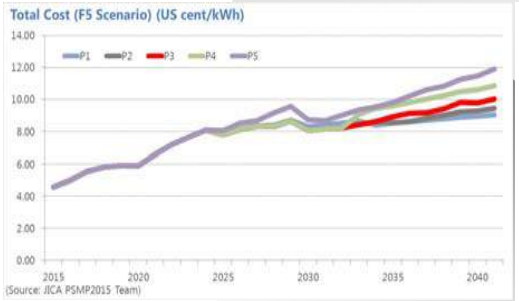


Economic Index

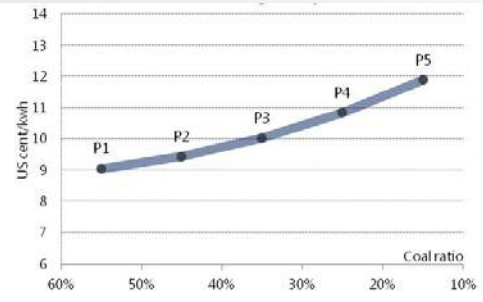
Economic Index
Generation cost (fixed price + fuel price) per electricity supply [US cent / kWh]

- The power generation cost is estimated at 9 to 12 US cents/kWh for 2040 under F5 scenario.
- Comparison of the power generation cost between the five scenarios for energy source ratio shows the power generation cost becomes higher as the ratio of coal to all the energy sources becomes smaller.

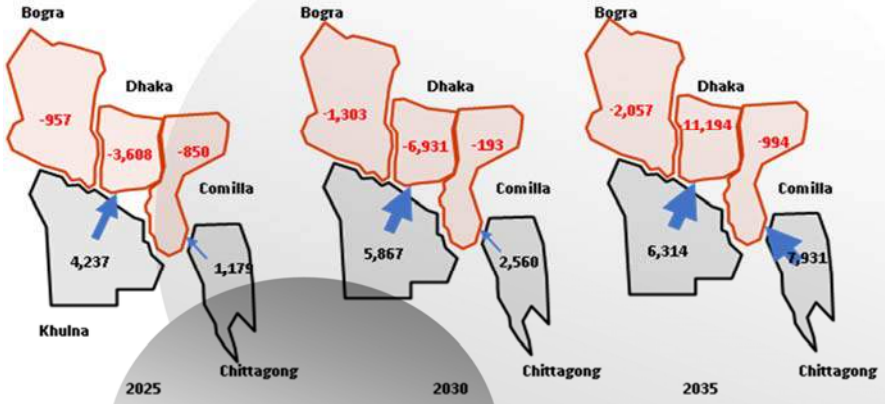
Power generation cost under each scenario for energy source ratio



Relationship between Coal ration and power generation cost



Regional Power Supply and Demand Balance



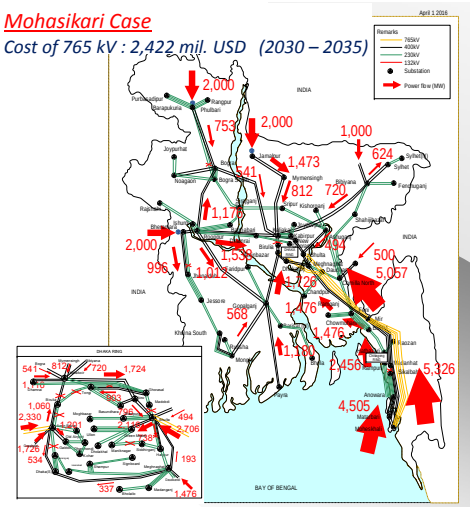
System Planning

Comparison between Mohasikali Case with Payra Case

- In the view point of the system planning, Payra Case is better, because of the following reason.
  - Cost of Mohasikali Case is larger than Payra Case.
  - Many lines must be constructed at the narrow point around Mir.

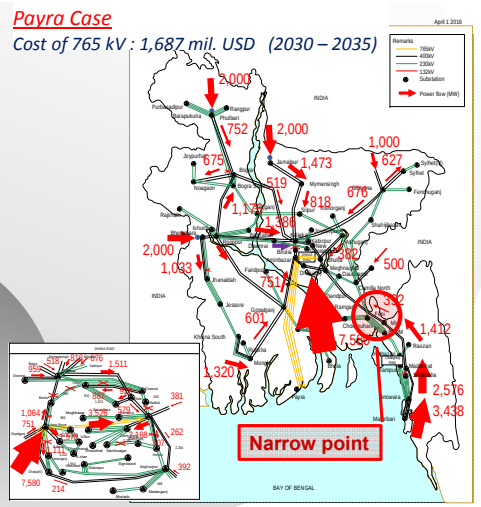
Mohasikari Case

Cost of 765 kV : 2,422 mil. USD (2030 – 2035)



Payra Case

Cost of 765 kV : 1,687 mil. USD (2030 – 2035)

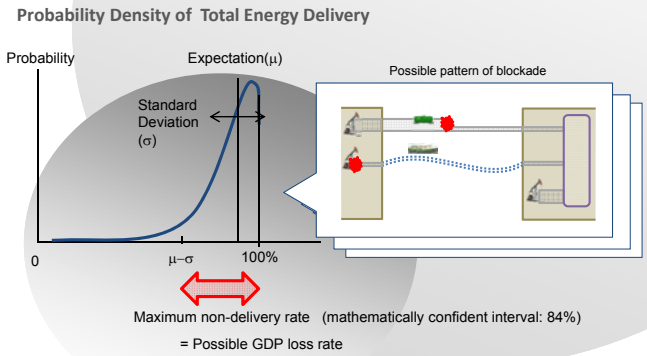


About Energy Security Index

Energy Security Index

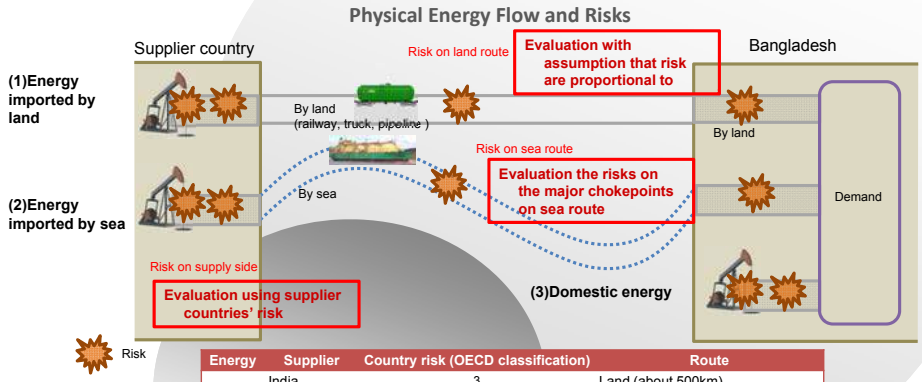
- Since every economic activities use energy, possible non-delivery rate can be considered as possible GDP rate.
- Energy security index expressed in monetary value:

Energy Security Index [$ / kWh]
= GDP[$] x Possible non-delivery rate [%] / Primary Energy Supply [toe] / Generation Efficiency [kWh/toe]



Security index: Evaluation of Risks

- Risk evaluation in this concept is to determine the assumed probability of blockade at each point.
- Quantifying energy security includes determining risk preference of policy makers. This means subjective (not objective) probability can sufficiently work instead of detailed risk analysis.



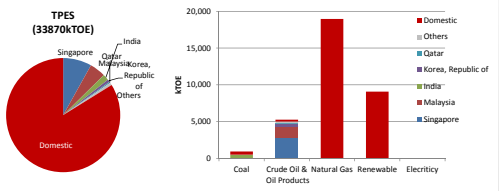
Energy	Supplier	Country risk (OECD classification)	Route
Coal	India	3	Land (about 500km)
	Indonesia	3	Sea (through the Malacca Straits)
	Australia	*	Sea (through the Malacca Straits)
Oil	UAE	2	Sea (through the Hormuz Straits)
	Saudi Arabia	2	Sea (through the Hormuz Straits)
Gas	India	3	Land (about 1500km)
	Qatar	3	Sea (through the Hormuz Straits)

Energy Security index: Energy Suppliers in 2013

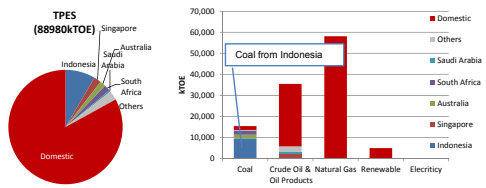
- From which countries will Bangladesh import energy in the future?

Current energy suppliers in Asian countries

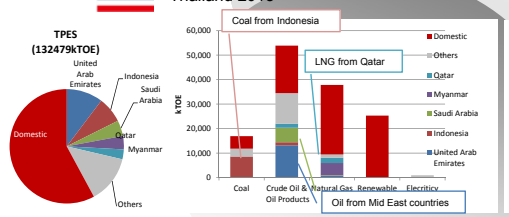
Bangladesh 2013



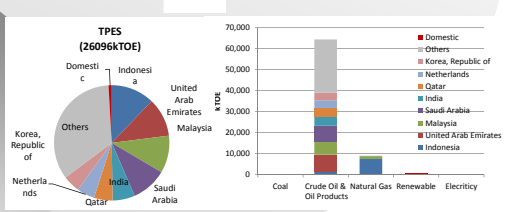
Malaysia 2013



Thailand 2013



Singapore 2013



Source) Energy Balances of Non-OECD Countries 2015, International trade statistics 2001-2015
Supplier countries composition of natural gas includes that of petroleum gas.

Energy Security index: Energy Suppliers in 2041

- Referring current energy suppliers to the Asian counties, we assumed energy suppliers to Bangladesh in 2041 as following:

Possible Energy Suppliers and their Potential (Assumption)

	Coal	Crude oil and oil products	Natural gas
Imported by land	India 5,000ktoe	—	India 9,500ktoe
Imported by sea	Indonesia: 50% of remains Australia: 50% of remains	UAE: 50% of remains Saudi Arabia: 50% of remains	Qatar: remains
Domestic	15,000ktoe	—	19,000ktoe

Energy Security index: Evaluation of Risks

- There are some studies related supplier countries' risk.

OECD Country Risk Classification

- Produced solely for the purpose of setting minimum premium rates for transactions according to the Arrangement on Export Credit
- Classifying countries into 7 grades (from 1(best) to 7(worst))

Other option: Classification based on Conflict set

- "Armed Conflict Dataset" prepared by Uppsala Conflict Data Program and International Peace Research Institute in Oslo
- Listing armed conflicts after 1946 and each location, length and type
- Intensity and locality of a conflict is not considered well

Example of classification

Energy	Supplier	Classification
Coal	India	3
	Indonesia	3
	Australia	*
Oil	UAE	2
	Saudi Arabia	2
Gas	India	3
	Qatar	3
Electricity	India	3

* High Income OECD Country not reviewed or classified

Number of numerated conflicts

Energy	Supplier	Number of numerated conflicts
Coal	India	15
	Indonesia	8
	Australia	1
Oil	UAE	0
	Saudi Arabia	1
Gas	India	15
	Qatar	0
Electricity	India	15

Example of Probability of route blockade

Classification	Probability (% of energy non-delivery)
*	0.1%
2	1%
3	5%

Energy Security index: Calculation

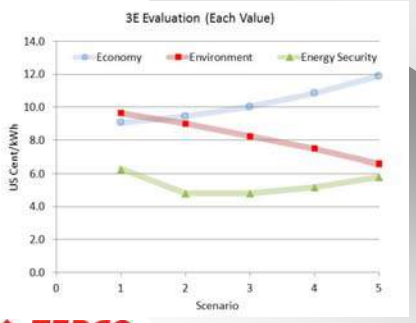
- Calculation Example: In Scenario 1

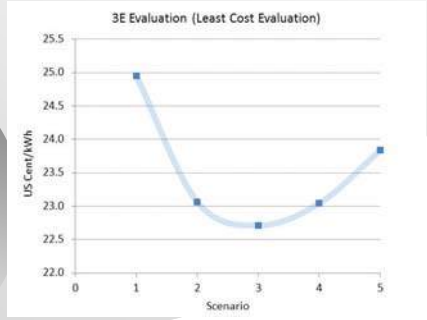
			Coal	Oil	Gas	Others	Total
Demand							
For Power		ktoe	38,019	46	14,253	9,255	
For Non-power (not taken into consideration)		ktoe	-	-	-	-	
Total		ktoe	38,019	46	14,253	9,255	**61,573**
Supply and probability of blockade							
Imported by land	India	kt	5,000 (5.48%)		0 (6.43%)		5,000
Imported by sea	Indonesia	kt	9,010 (9.75%)				9,010
	Australia	kt	9,010 (5.10%)				9,010
	UAE	kt		23 (5.95%)			23
	Saudi Arabia	kt		23 (5.95%)			23
	Qatar	kt			0 (9.75%)		0
Domestic		kt	15,000		14,253	9,255	38,508
Delivery rate							
Expectation(μ)		kt	36,408	43	14,253	9,255	
Variance(σ^2)		kt^2	965,724	1	0	0	
$\mu - \sigma$		kt	35,425	42	14,253	9,255	58,975
Possible GDP loss rate							**4.2%**
US cent / kWh (assuming $588 billion GDP (constant 2005))							**6.3**

Security index: Evaluation of Risks

- Three indices (Economy, Environment, Energy security) in 2041 are calculated and integrated as follows:

	Composition (MW base)	Economy [US cent/kWh]	Environment [US cent/kWh]	Energy Security [US cent/kWh]	Total [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	9.06	9.64	6.29	25.0
Scenario 2	Gas 25%, Coal 45%	9.45	9.00	4.82	23.1
Scenario 3	Gas 35%, Coal 35%	10.03	8.23	4.81	22.7
Scenario 4	Gas 45%, Coal 25%	10.84	7.48	5.18	23.0
Scenario 5	Gas 55%, Coal 15%	11.89	6.57	5.81	23.8





F-3 Power Quality

Power Quality

Fact Findings

Each utility has a strong initiative and accurate understanding to improve power:

1. Significant deficiency of power source including spinning reserve.
2. No application of automatic control such as LFC, free-governor operation. Instruction by telephone communication only.
3. Inadequate coordination of daily generation scheduling between NLDC and GenCos.
4. NLDC has less regulatory authority to make a balance between demand and supply.

Challenges in NLDC proves Bangladesh has enormous power system quality improvement potential.



Frequency chart of Free Governor mode operation test with Khulna gas turbine generator (158MW)

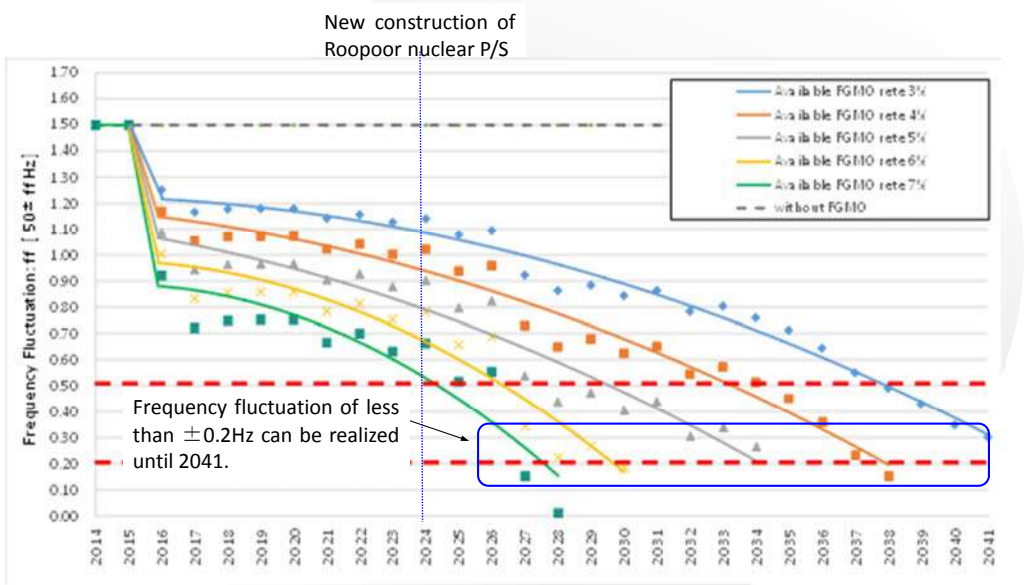
Power Quality/Frequency Control : Higher Value-Added Economy

Discussions and Proposals

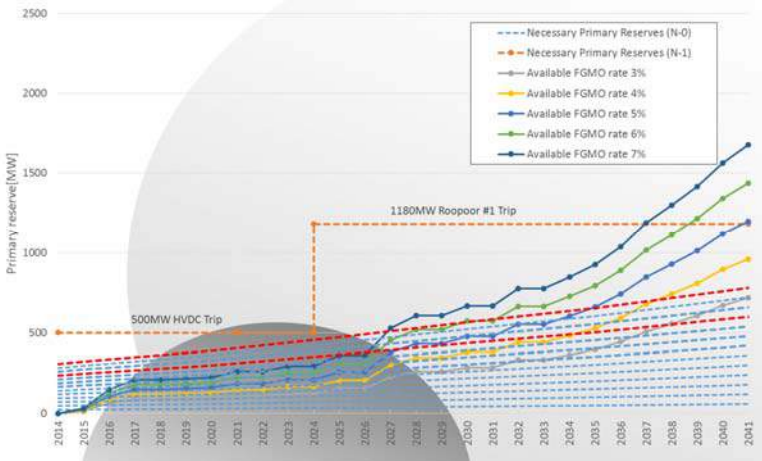
- There are high potential needs of frequency quality, in particular, from business sectors, in order to realize a higher value-added economy and more sophisticated industrial structure
- Frequency fluctuations could cause negative impacts as follows:

Industries	Effects by frequency fluctuations
Chemical fiber manufacturing	The change of winding speed could lead thread breakage and bad quality of thickness of the thread.
Paper	The change of winding speed could lead paper breakage and bad quality of thickness of the paper.
Oil	Bad pressure control for decomposition and desulfurization could lead to failure of impurity removal.
Iron and Steel Aluminum	Bad rolling process could cause uneven of thickness of products.
Motor vehicle	The change of weld time for automotive body panels could lead to bad effect for weld strength and quality of products appearance.

Power Quality/Frequency Control：Road Map toward 2041



Requirement of primary reserve



	2015	2020	2025	2030	2035	2040	2041
Power demand [MW]	8,920	12,949	19,191	27,434	36,634	49,034	52,034
Requirement for ±0.5Hz [MW]	248	299	364	436	503	582	600
Requirement for ±0.2Hz [MW]	323	389	474	566	654	757	780

Improvement of Power Quality

Fundamentals of Electricity Demand/supply Operation Process

Demand/supply Operation Planning

- Brief explanations of yearly, monthly, weekly and day-ahead plan

Real time Operation

- Brief explanations of economical load dispatching control (EDC), load frequency control (LFC), free governor mode operation (FGMO) and self-regulating characteristics of load

Present Status and Necessity of Improving Power Frequency Quality in Bangladesh

Electricity Demand-supply Operation in Bangladesh

- Observations of long-term planning and short-term planning
- The actual conditions of existing generation plants
- Necessary actions for improving demand/supply balance

The Actual Conditions of Power Frequency Quality

- The Actual Conditions of Power Frequency Control
- Necessity of Improving Power Frequency Quality

Scope of This Investigation

Improvement of Power Quality

Investigation of the Regulatory Framework for Electricity Business

Regulatory Framework for Power System Planning/Operation

- Overview of the case of Japan and Bangladesh

Regulation by the Electricity Acts

- Obligation of Electricity Supply and Voltage/Frequency Quality Assurance
- Obligation of Long-term Electricity Demand/supply Balance Planning/Amendment
- Restrictions on Electricity Consumption
- Penal regulations

Regulation by Independent Regulatory Organization

- Long-term demand-supply operation plan, short-term demand/supply operation plan

Summary

Improvement of Power Quality

Proposal for Frequency Quality Improvement Roadmap

Future Electricity Demand and Power Source in Bangladesh

Reserves for Power Frequency Control

- Trial Calculation of Availability for Reserves
- Trial Calculation of the Required Amount of Reserves
- Verification of Adequacy of Reserves
- Roadmap for Frequency Quality Improvement

Actual Condition of EMS/SCADA System in NLDC for Load Frequency Control (LFC)

Installed Functions in NLDC System

Logic Diagram of Load Frequency Control in CLDO System in TEPCO

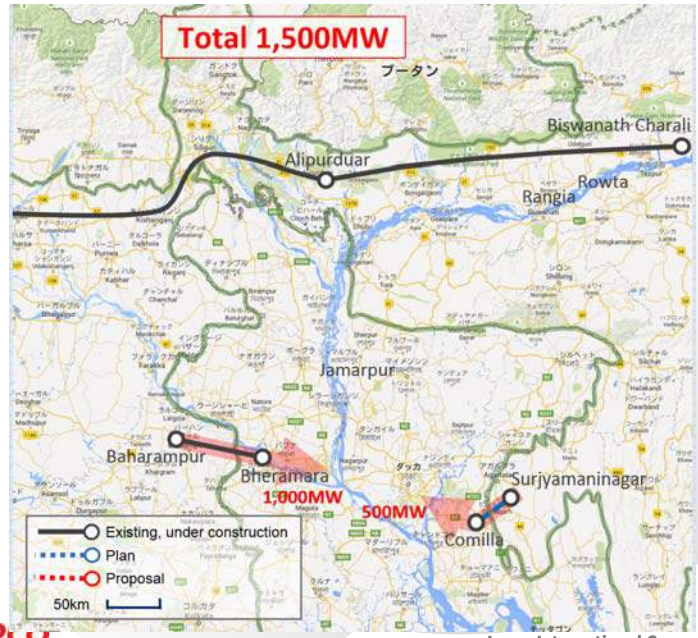
Early Applicableness of Load Frequency Control by NLDC System

Solution - Early Applicableness of FGMO

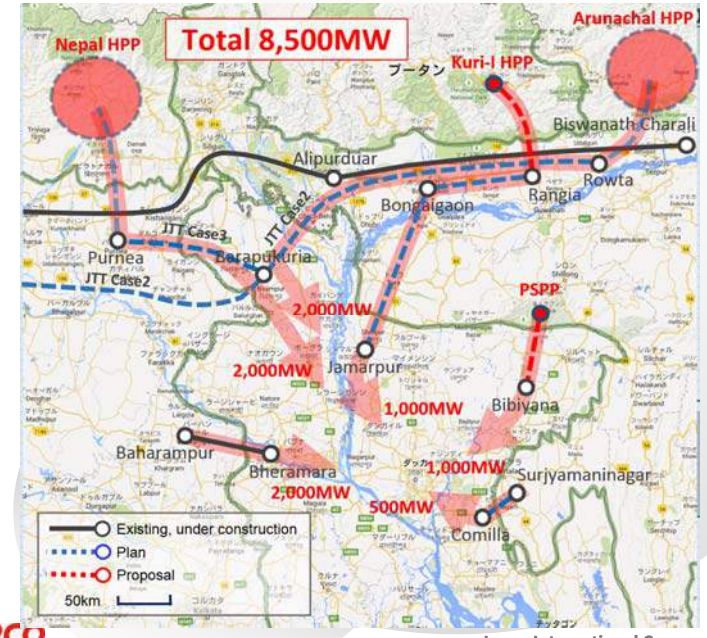
Go to additional N0.210+

F-4 Nuclear and Cross Border

Interconnection plan by 2020



Interconnection plan by 2030



F-5 Universal Access to Modern Energy and Renewable Energy

Universal Access to Modern Energy: Definitions?

World Trend of "Universal Access to Modern Energy"

- Sustainable Development Goal (SGD): Goal 7—Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All

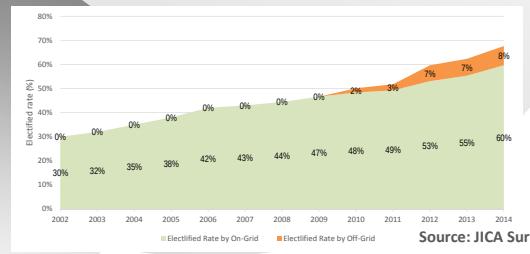
[Discussion and Proposal] Is this definition appropriate, comparing with the "int'l standard"?

GoB's Policy, Target and Definition

- "Electricity for All" by 2021 (Vision 2021)
- Bangladesh has "unique" definition of electrification rate

$$Access\ to\ Electricity\ (\%) = \frac{Number\ of\ \ Electrified\ Customer \times 7^{*1} + Number\ of\ \ SHS \times 4^{*2}}{Total\ \ Population}$$

- Under the definition, Bangladesh has achieved 68% of electrification (60% on-grid and 8% off-grid) as of 2014.



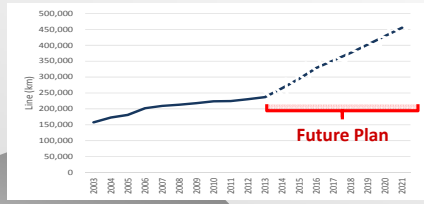
Source: JICA Survey Team

Universal Access to Modern Energy - Target vs. Reality

Approach to "100% Electrification by 2021"

- BREB (on-grid) +IDCOL (off-grid) = 100% electrification by 2021
- [Fact Finding] BREB has "aggressive" investment plan requiring twice faster implementation than in the past. IDCOL has achieved the world-fastest deployment of SHS.

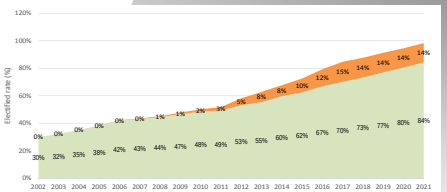
BREB's Past and Future Grid Extension Plan



Source: JICA Survey Team

[Discussion and Proposal] How GoB could achieve an aggressive investment plan?

- By 2021, the combined efforts of BREB and IDCOL is planned to achieve 100% electrification.



Source: JICA Survey Team

[Discussion and Proposal] How BREB and IDCOL ensure that their expansion plan complement to achieve electrification, not overwrap?

Universal Access to Modern Energy - Additional Demand

Future On-grid Electrification by 2031

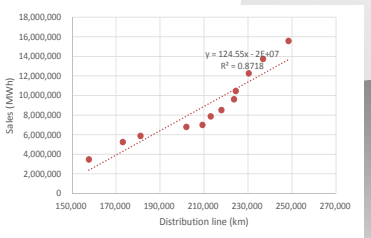
- [Fact Finding] From analysis of correlation between line extension and sales growth, future demand (MW) led by electrification is approx. 2400 MW:

  140,000 (km) x 124.55 (MWh/km) = 17,437 (GWh)

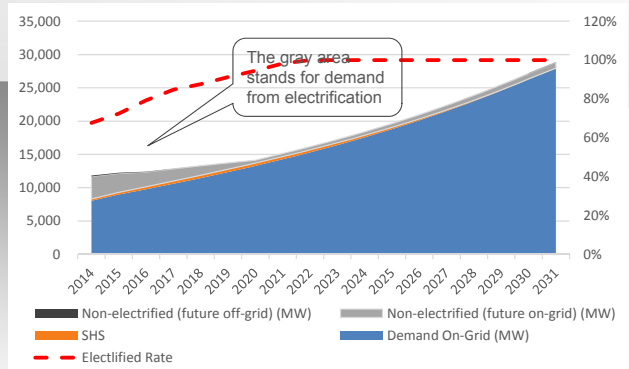
  17,437 (GWh) / 8760 (h) / 80% (LF) = 2,488 (MW)

  Data provided by REB: also derives approx. 2400 MW demand for electrification

Relation between Line Extension and Sales Grows



Source: JICA Survey Team

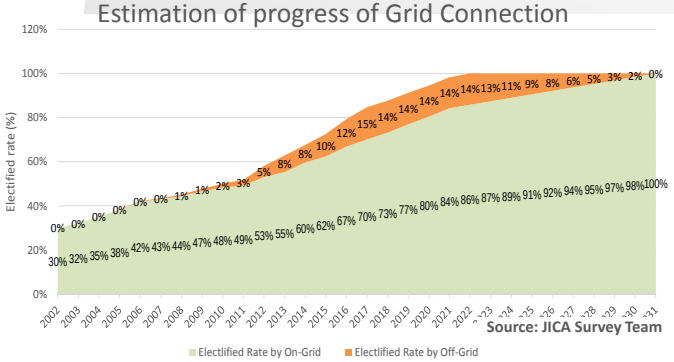


Universal Access to Modern Energy – After Completion?

Future On-grid Electrification by 2031

- After electrification 100% is reached in 2021, it is expected that the share of SHS will shrink, and millions of SHS batteries will be disposed.
- [Discussion and Proposal] The future battery disposal risks has been pointed out (e.g. lead, dilute sulfuric acid). Any proactive action has been taken by GoB?

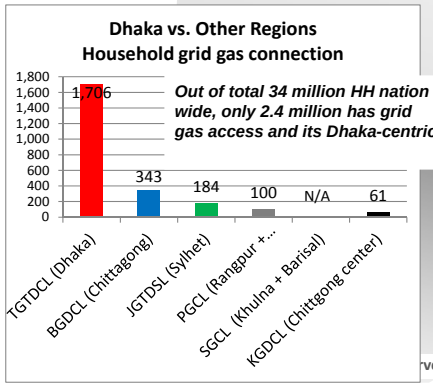
Estimation of progress of Grid Connection

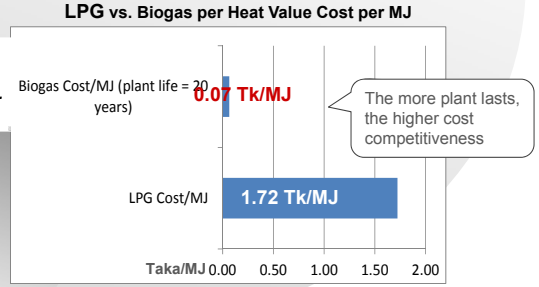


Universal Access to Modern Energy – Gas Access Gap

Household Gas Connection Gap between Urban and Rural

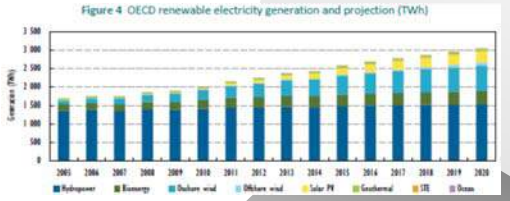
- Household gas connection is unevenly concentrated in Dhaka area.
- Rural households are exposed to respiration disease risks due to inefficient burning of solid fuels on an open fire or traditional stove indoors.
- [Discussion and Proposal] Bangladesh has a robust potential of biogas from poultry/dairy firms, suitable for household cooking use. Should biogas be promoted in rural areas, rather than expensive LPG?

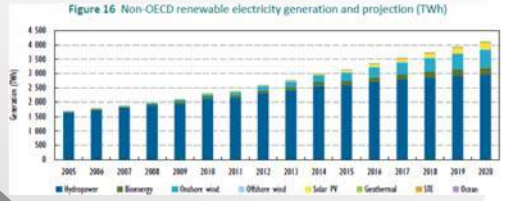


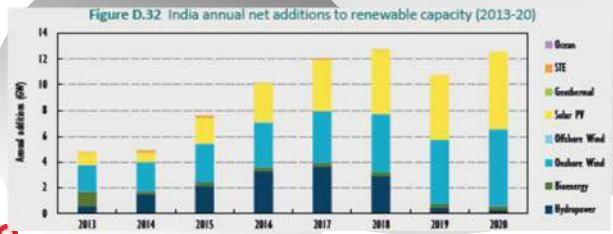


Renewable Energy World Trend

- [Fact Finding] Wind power accounts for nearly half of new renewable generation plans all over the world (for Non-OECD, non-hydro: 65%)
- India is no exception from Wind-dominated addition plan. Also an ambitious target to increase solar PV.
- Paris Agreement in COP21 will accelerate Parties to undertake renewables.



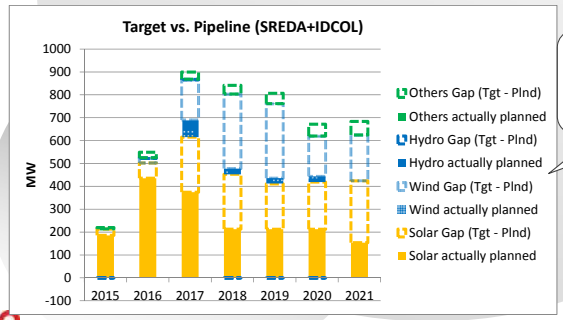




All Sources: IEA

Renewable Energy – Bangladesh's Policy and Target

- Renewable Energy Policy 2008: 5% of total supply by 2015 (650MW from RE), and 10% by 2020.
- [Fact Finding] SREDA target and the total deployment plans have a wide gap.
- [Fact Finding] GoB has stipulated "Solar park on non-agricultural/uncultivable land policy" caps the potential --- Solar Park up to 1400MW, Wind 600MW respectively.
- [Discussion and Proposal] Do institutions other than IDCOL (e.g. LGED, BPDB)have major RE deployment program? (BERB has approx. 4MW solar PV projects.)
- [Discussion and Proposal] Would SREDA re-define the Solar target accommodating the non-agricultural/uncultivable land use policy? Can any wind farm be invited w/o WRA?



Source: JICA Survey team based on SREDA

Renewable Energy – Potential and Issues

Solar PV: Out of more than 1200MW deployment plan, 700MW is assumed as private projects.

- [Fact Finding] Various financial incentives are to be provided for projects (e.g. tax & duty exemption, subsidy, equity requirements, GoB guarantee). FIT and Reverse auction are also being prepared by BERC.
- [Fact Finding] More than 2.0 ha land is required for 1MW solar PV. 700MW solar PV required at least 1400 ha. Land worth for more than 4000 farmers can be available? (average farm size: 0.3 ha.) → *GoB has stipulated "non-agricultural/uncultivable land policy" for solar park project permission.*
- [Discussion and Proposal] Will Grid Code or related technical regulations be prepared for grid-connected RE? (e.g. voltage, frequency, power factor) to connect RE generations to grid?

Wind:

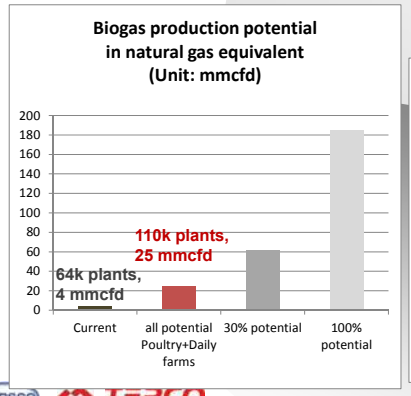
- [Fact Finding] Total 1370 MW is planned from 2015 to 2020 → Need to wait until the Wind Resource Assessment completion in 2018.

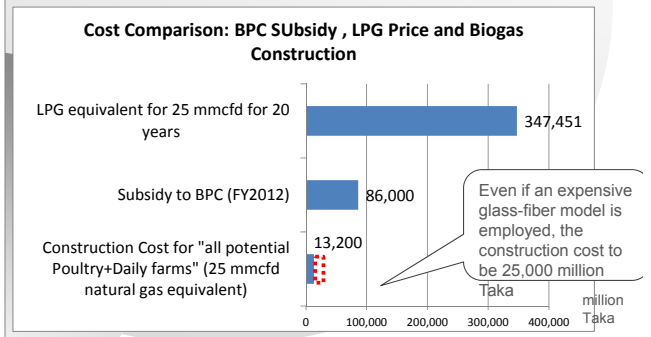
Hydro:

- [Fact Finding] In consideration of local sentiment, difficulty in investigation and project viability, hydropower development in Bangladesh may not have high priority in comparison with power import from neighbor countries.

Biogas Potential

- [Fact Finding] Bangladesh has a robust biogas potential of 9 million m^3/day. If the potential is fully developed, "185 mmcfd natural gas worth" biogas could be produced.
- [Fact Finding] Potential biogas supplier, poultry and daily farms 110 k for 25 mmcfd natural gas equivalent production capacity, if decent incentive & subsidy is provided.
- [Discussion & Proposal] Biogas is in fact "cost effective" as far as digester lasts, and carbon neutral solution to promote universal access of energy. GoB should pursue further promotion of biogas digester roll out, and remove impediments if any.





F-6 Operation and Maintenance (O & M)

Ascertaining actual conditions

Survey result

Item	Contents
Maintenance plan	Based on manual and experience
Feasibility of maintenance plan	Cannot proceed as scheduled
Reason to disturb maintenance	Waiting for budget approval, bidding and shutdown permission
Manufacture support for daily	None
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff and manufacture
Safety for staff	Only have BPDB guideline

Item	Contents
Fuel analysis	No analysis
Efficiency management	Nobody cares
Environmental regulation	No regulation
Report for Head office	Handwritten monthly report
Equipment issues	Does not reach rated output
Staff issues	Shortage of human resources
Training system	OJT Only theoretical lectures

Issues and countermeasure

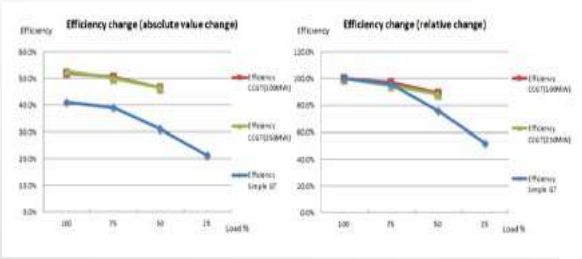
Focused on four categories and countermeasure to optimize O&M

Equipment and maintenance plan	*Budget approval and shutdown permission are delayed because there is no mid-long term maintenance information *Cannot repair because of shortage of power generation *Do not care about power plant efficiency *Does not reach rated output	→	**Equipment and maintenance plan**	Rehabilitation	Steam turbine rehabilitation
					Combined cycle power generation remodeling
Staff	*No effective training curriculum *Lack of technical skill		**Staff / Budget / Information**	Utilize the information effectively	Information management strategy
Budget	*No mid-long term maintenance plan			Human resource development	Training center
Information	*Lack of information strategy				

Rehabilitation

Merit of small size combined cycle power generation remodeling

Plant capacity	Hot start	Cold start	efficiency
400MW Class CCGT	1hour	6hours	50%
250MW Class CCGT	< 1hour	4hours	50%
100MW Class CCGT	0.5hour	2hours	50%
Simple GT	0.5hour		40%(new) 30%(old)



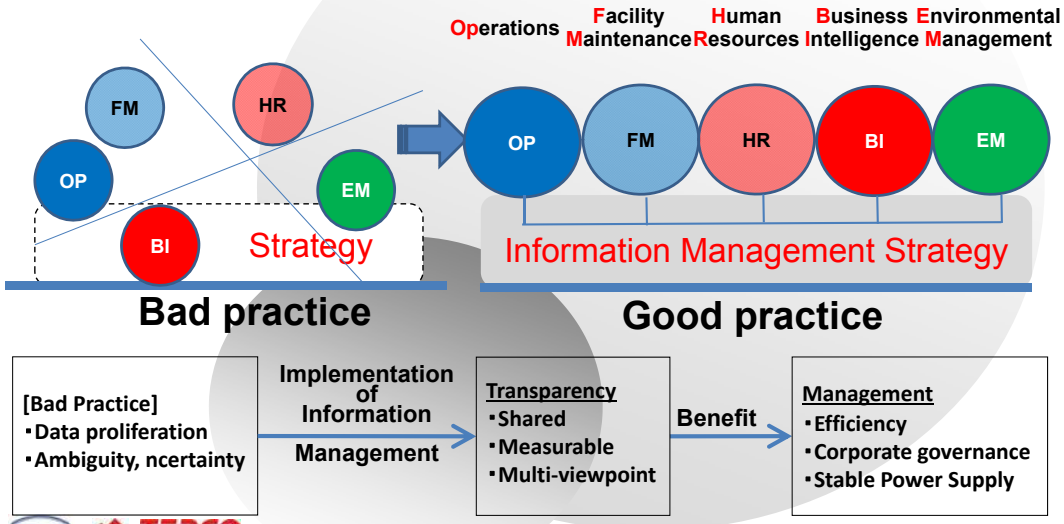
merit1 : short start time characteristics

merit2 : High efficiency under low load operation

	Site name	Target unit	COD	capacity condition: installed A	de-rated B	remarks C	New D	output increase D-C	Estimated Cost Mill dollar	Unit price mill dollar / MW	Efficiency after	Efficiency now	Manufacture support	Remaining plant life after rehabilitation (assumed plant life time 30years) years	year cost mill dollar / MW
Build and scrap (for CCGT)	Siddhigan)	Unit1	2004	210	150	110 (gas limitation)	150	40MW	200	5.0	50	33.8 (*1)	MHPS/Kawasaki	30	0.17
	Haripur	Unit1,2,3	1987	96	60	40(Unit 3 stopped)	100	60MW	150	2.5	50	21.2			0.08
	Tongi	Unit1	2005	105	105	105	150	45MW	200	4.4	50	25.9 (*2)			0.15

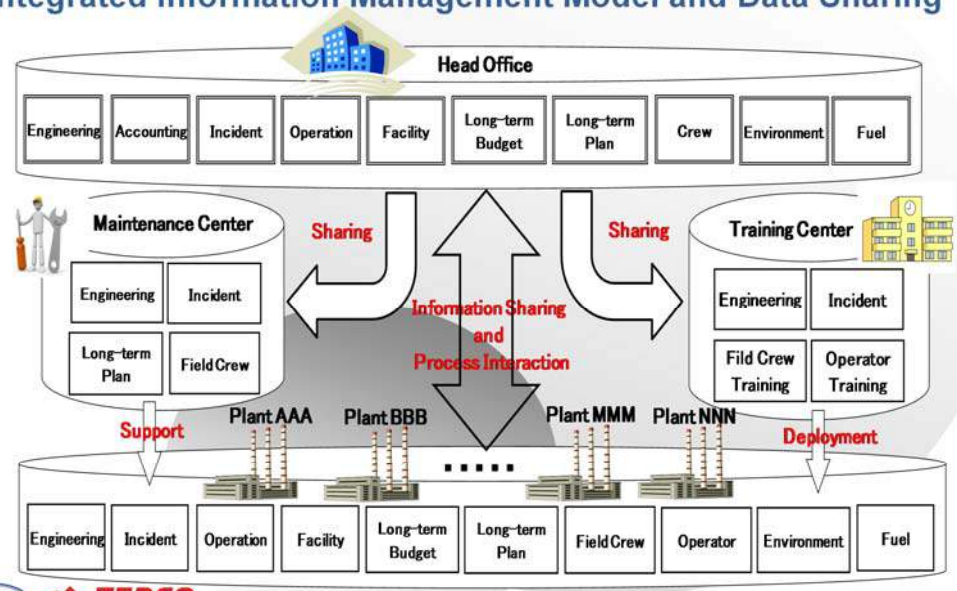
Information Management (1)

Strategic Approach to Integrated Information Management



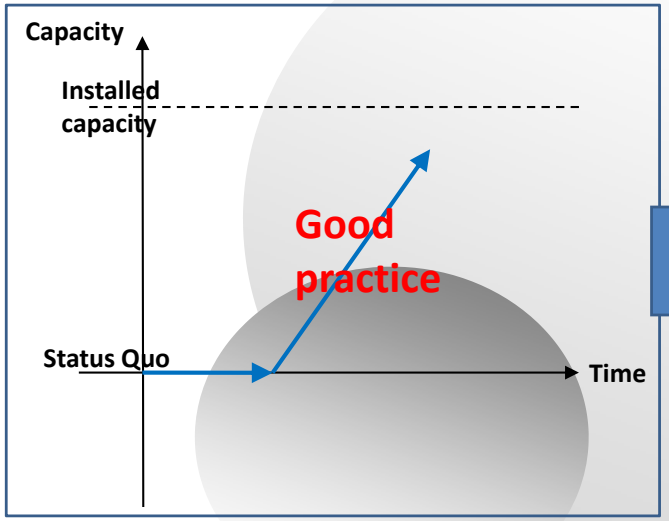
Information Management (2)

Integrated Information Management Model and Data Sharing



Information Management (3)

Operating at Constant Generation Level with High Quality



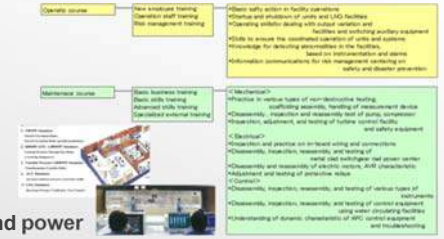
By applying proper maintenance, it is possible to bolster capacity.

By practicing planned maintenance, it is possible to mitigate shut-down impact on the grid.

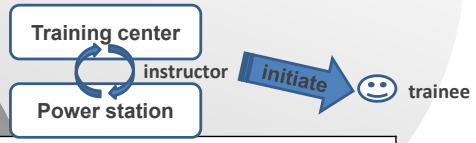
Training

Key item of human resource development

a. training curriculum
⇒ From a new face to a veteran, the maintenance of various curricula is necessary



b. Development of the instructor
⇒ rotation between the training center and power station
→ instructor getting site knowledge and feeding
→ back into the training content



c. Training facility

For operator	Operation simulator
For maintenance staff	Motor , pump , fan , instruments , Non Destructive Inspection/Test facilities, vibration analysis device …etc.,

F-7 O&M Legal Framework

Legal framework -1

O&M Problems and Solutions

① Problems
- MW Down (Output)
- η Down (Efficiency)
- Re Down (Reliability)

② Main Reasons
- Insufficient Maintenance
- Insufficient Inspection
- Insufficient η management

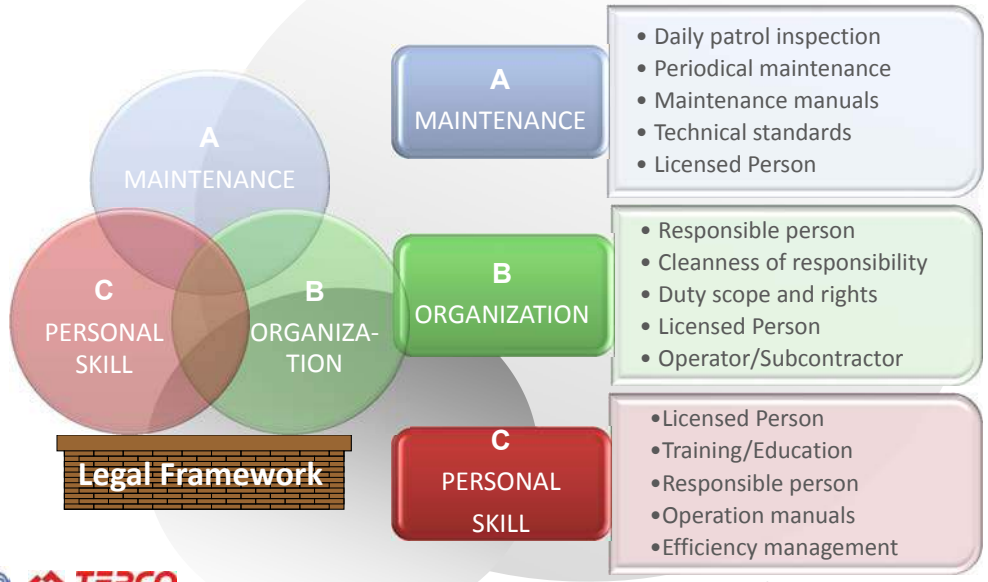
③ Why ?
- Lack of budget
- Lack of technical skill
- Lack of time
  - It is not easy to stop for maintenance due to power shortage.

④ O/M Solutions
- Operating efficiently
  - Efficiency management
  - Reduction of maintenance period
- Personal skill-up
  - Training, Education
- Efficient maintenance
  - CBM, Daily maintenance, Patrol inspection

⑤ Legal Framework Solutions
To build the mechanism for O/M legal solutions
- Formation of organization
- Clarification of responsibility
- Sustainability, PDCA
- Incentives and penalty

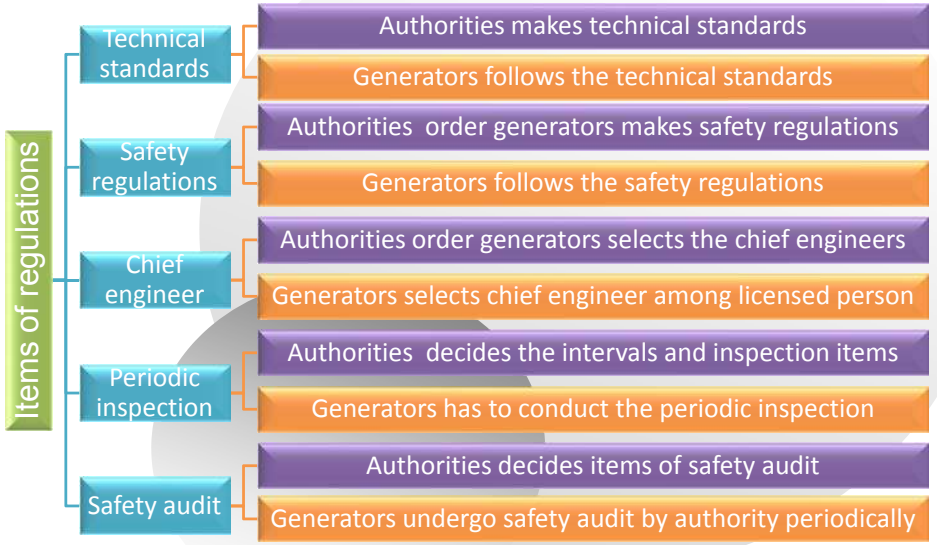
Legal framework -2

Legal framework should support key factors of O&M



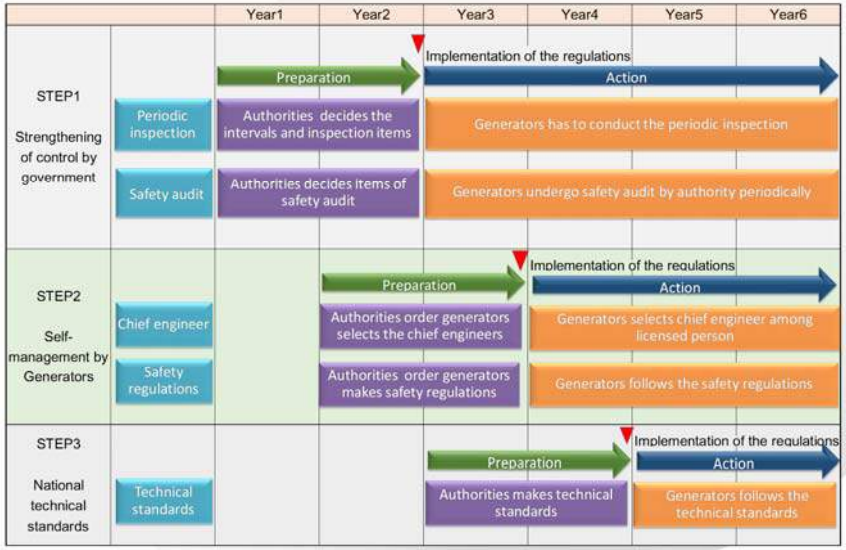
Legal framework -3

Recommended items of regulations for Bangladesh



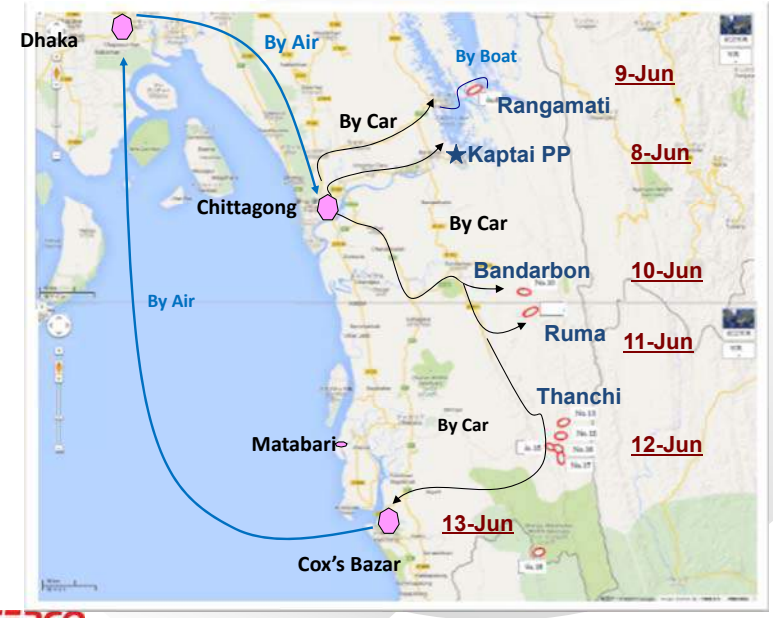
Legal framework -4

Recommended schedule of regulations for Bangladesh

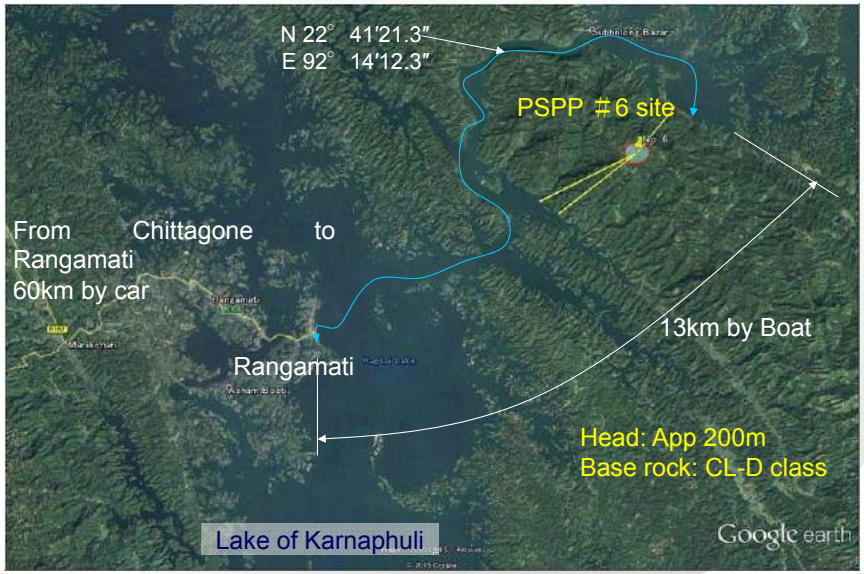


F-8 Hydropower Development

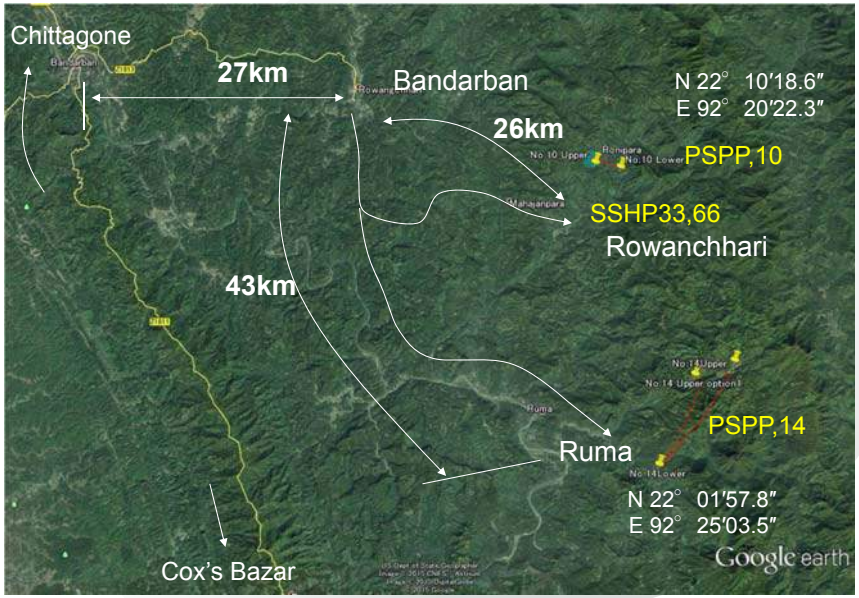
Actual route of survey



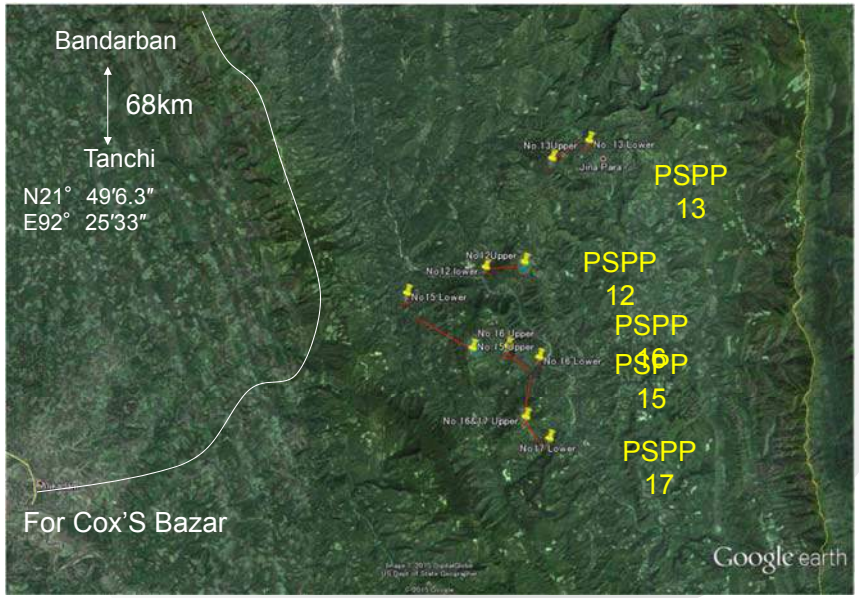
PSPP #6 (Rangamati Area)



PSPP #10, 14 (Bandarbon Area)



PSPP # 12,13,15,16,17(Tanchi Area)



Travel to Chittagong Hill Tracts



Security Guards during the Site Survey



Police Check Post



Boat used for the Site Survey



Survey Team on the Boat

Travel to Chittagong Hill Tracts



Commute to school by boat



Main Street of Rowanchhari



Main Street of Luma



Market in Thanchi

Chittagong Hill Tracts Development Plan

- Implementing Agencies:
  - Ministry of Chittagong Hilltracts,
  - Chittagong Hill Tracts Development Board(CHTDB).
- Mission:
  - Development of rural road and infrastructure.
  - Poverty reduction though Socio-economic Rehabilitation.
  - Introduction of sustainable land use technology.
  - Welfare of mother and children.
  - Human resource development.
- Vision:
  - Developed road communication.
  - Education institution within the reach of children.
  - Developed agricultural infrastructure.
  - Poverty reduction of poor jumia families though rubber and mixed fruit gardening.
  - Capacity building and empowerment of local communities.
  - Adequate facilities for sports cultural activities.
  - Developed tourism area that generates income for local communities.

Chittagong Hill Tracts Projects and Program and HPP projects

Mission	Consistency Hpp projects
Development of rural road and infrastructure.	(+) New access roads construction (+) Rural electrification as compensation
Poverty reduction though Socio-economic Rehabilitation.	(+) Increasing job opportunity
Introduction of sustainable land use technology.	
Welfare of mother and children.	
Human resource development.	

Planning maps can not be confirmed.

Natural Environment along the Road

- Most of the land along the road is utilized for agricultural land and/or afforestation.
- Soil erosion caused by cultivation at steep slope was observed.
- Wild life was few observed along the road.

- The river water has not been seriously polluted by organic substance.
- The river bank is naturally remained.

No strategic preservation plans are introduced.



Washing in the river in Rowanchhari

Social Environment along the Road

- Social Environment along the Road
  - Land utilization is mainly for Banana and pineapple plantation, Dry Rice, and Timber forest.
  - Local people enjoy fishery in the river.
  - Tourism facilities such as accommodations, fruits shops, and viewpoints exist for Bangladesh tourists.
  - Several road construction, bridge building are on-going.
  - Signboards of UNICEF、UNDP、EU、USAid for assistance for education and health care were observed.

Support looks like at random.

There is no sustainable and strategic land use plan.



Buddhist temples in Rowanchhari

Electrification in Chittagong Hill Tracts

- Distribution line: Ruma and Bandarban
- House solar panels: Some part of the area (they will expand in the near future)
- Un-electrified: The other area (unknown)

No electrification maps of current condition and plan.



A Lady who is working at a drapery shop in Thanchi

Environment and Social Risk

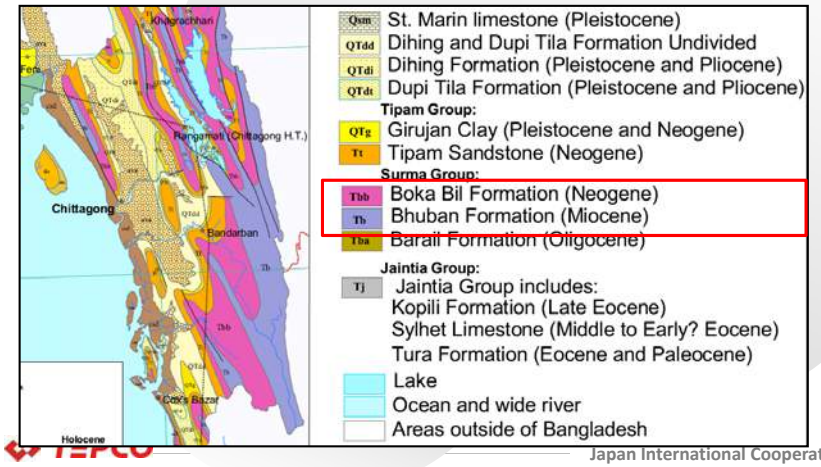
- Discontent for not fully implemented Chittagong Hill Tracts Accord
- Negative feeling for the word “hydropower”

↓

- Igniting new conflicts by land acquisition and resettlement
- Interruption of study and construction
- Acceleration deforestation and un-sustainable land use

Geology

- Boka Bil Formation (Neogene) or Bhuban Formation (Miocene), which consists of sand stone, mad stone and those alternate layer
  - > Relatively low concreteness, but possible to construct PSPP,
  - > No active fault near the project site areas.



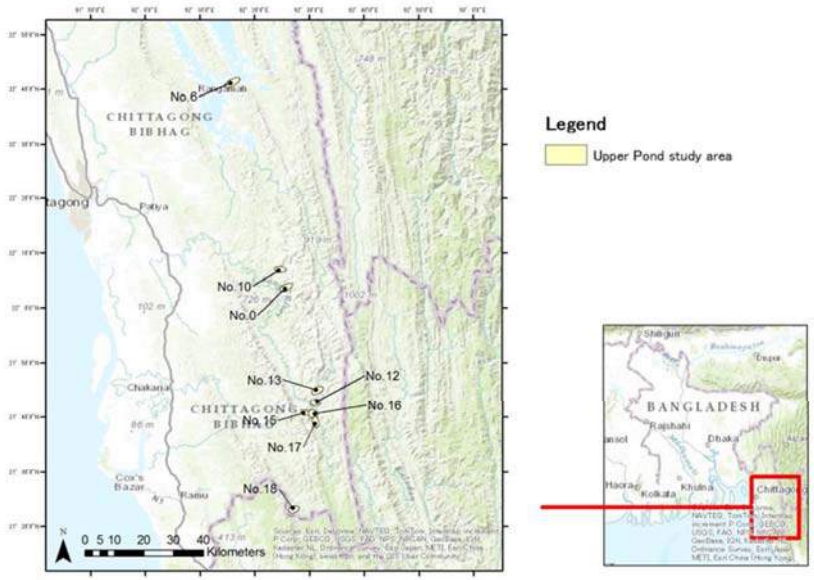
Geology of Chittagong Hill Tracts





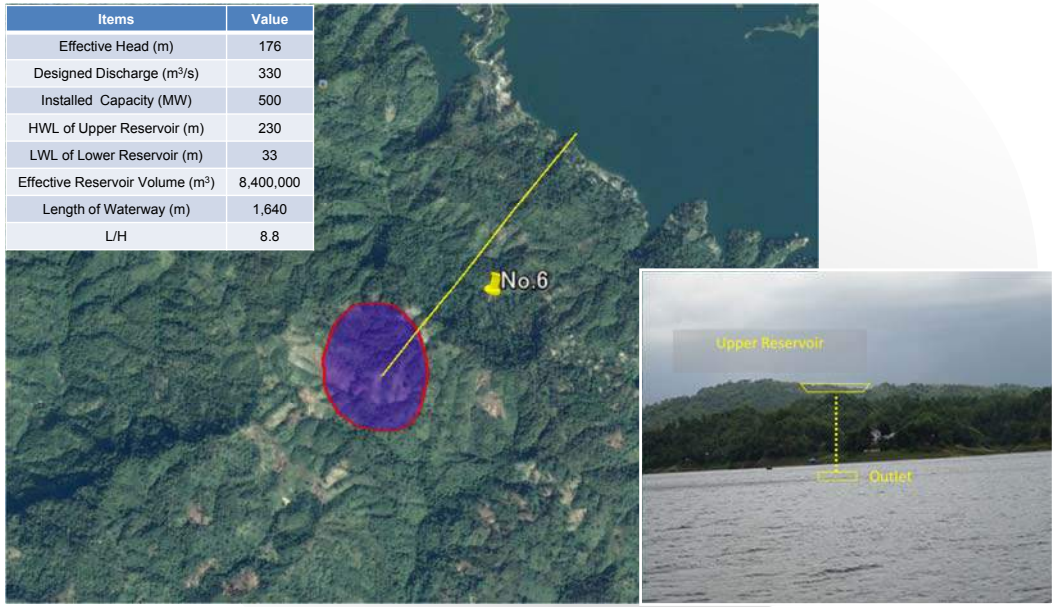
Typical alternate layer of sand stone and mad stone

Location of PSPP Potential Sites



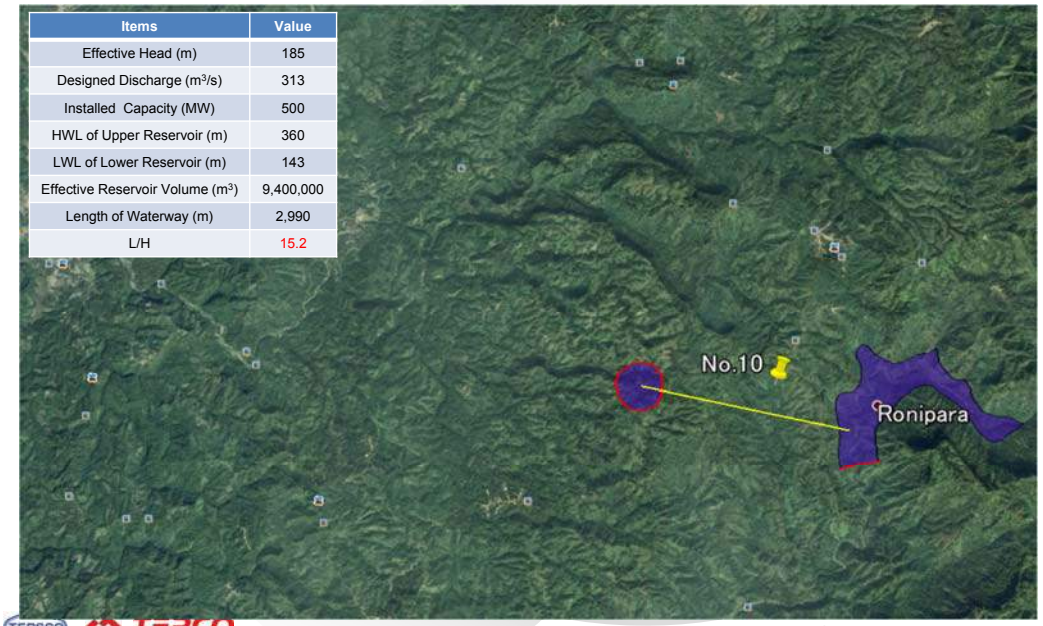
#6

Items	Value
Effective Head (m)	176
Designed Discharge (m^3/s)	330
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	230
LWL of Lower Reservoir (m)	33
Effective Reservoir Volume (m^3)	8,400,000
Length of Waterway (m)	1,640
L/H	8.8



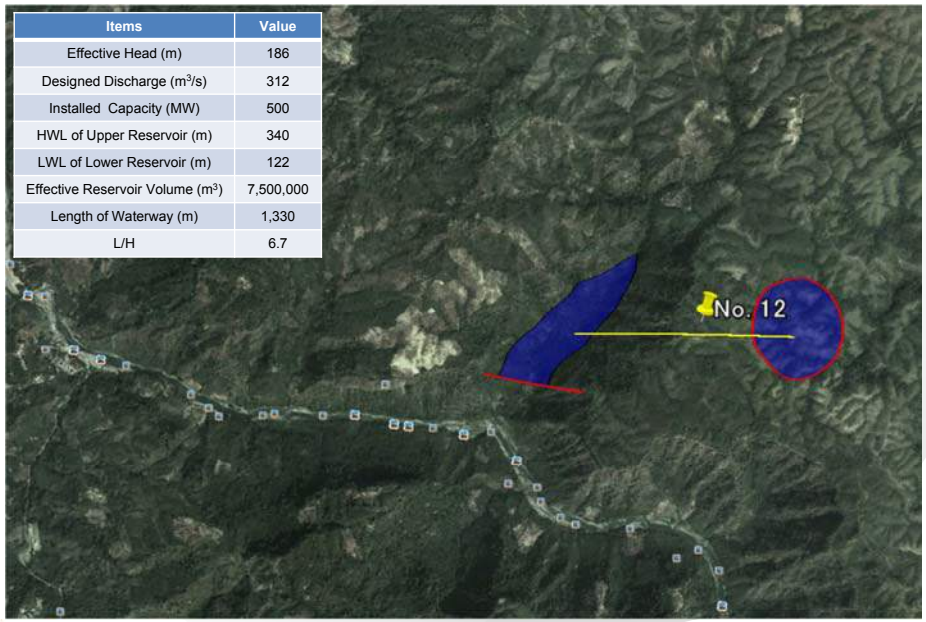
#10

Items	Value
Effective Head (m)	185
Designed Discharge (m³/s)	313
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	360
LWL of Lower Reservoir (m)	143
Effective Reservoir Volume (m³)	9,400,000
Length of Waterway (m)	2,990
L/H	15.2



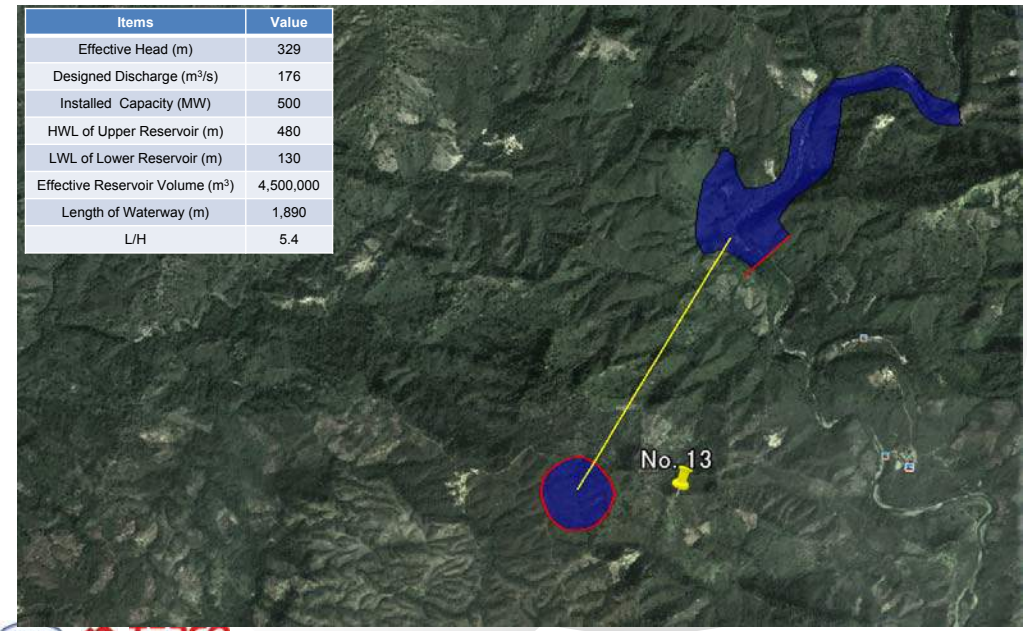
#12

Items	Value
Effective Head (m)	186
Designed Discharge (m³/s)	312
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	340
LWL of Lower Reservoir (m)	122
Effective Reservoir Volume (m³)	7,500,000
Length of Waterway (m)	1,330
L/H	6.7



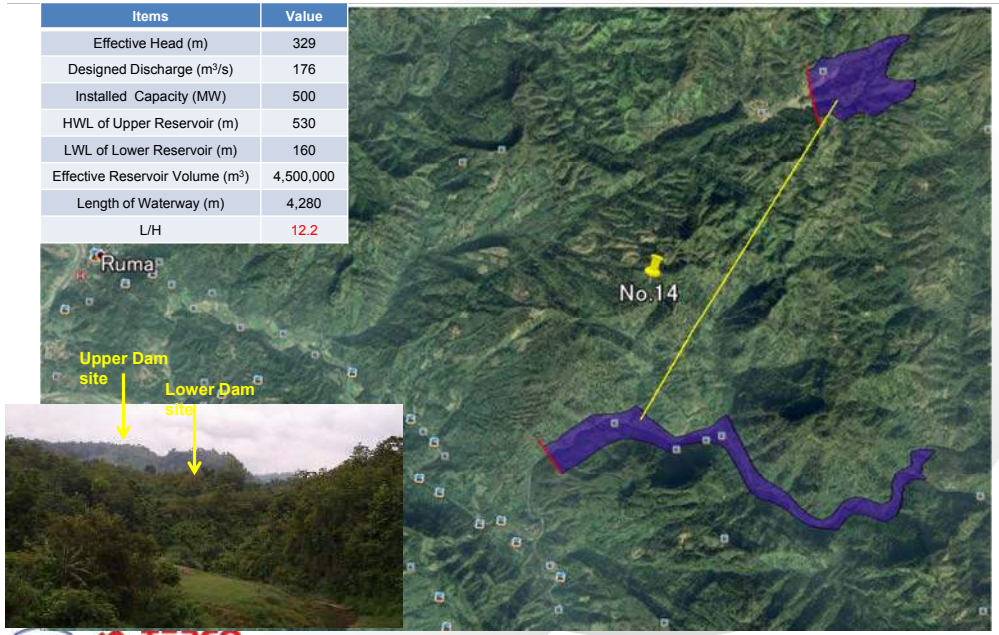
#13

Items	Value
Effective Head (m)	329
Designed Discharge (m³/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	480
LWL of Lower Reservoir (m)	130
Effective Reservoir Volume (m³)	4,500,000
Length of Waterway (m)	1,890
L/H	5.4



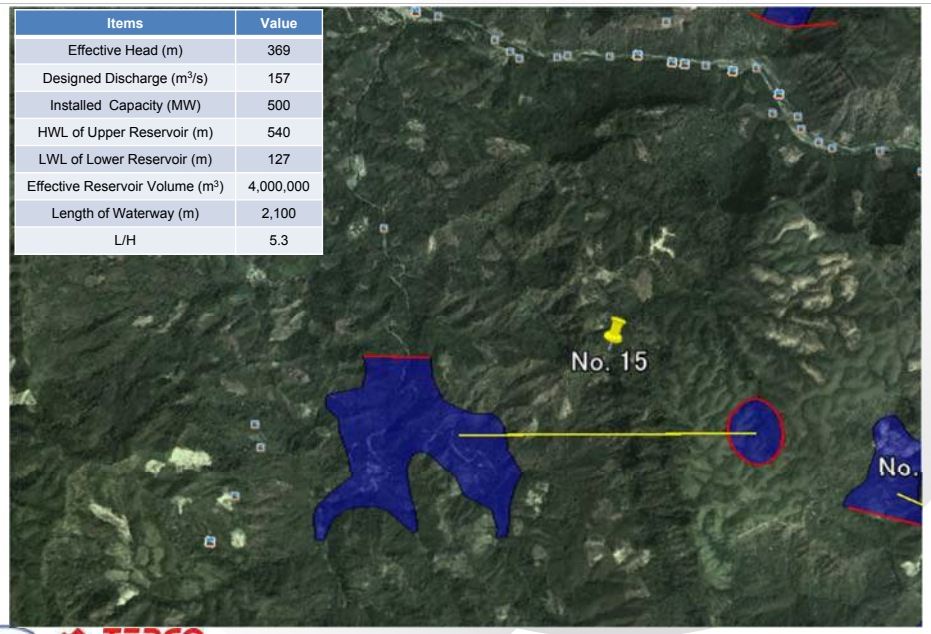
#14

Items	Value
Effective Head (m)	329
Designed Discharge (m³/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	530
LWL of Lower Reservoir (m)	160
Effective Reservoir Volume (m³)	4,500,000
Length of Waterway (m)	4,280
L/H	12.2

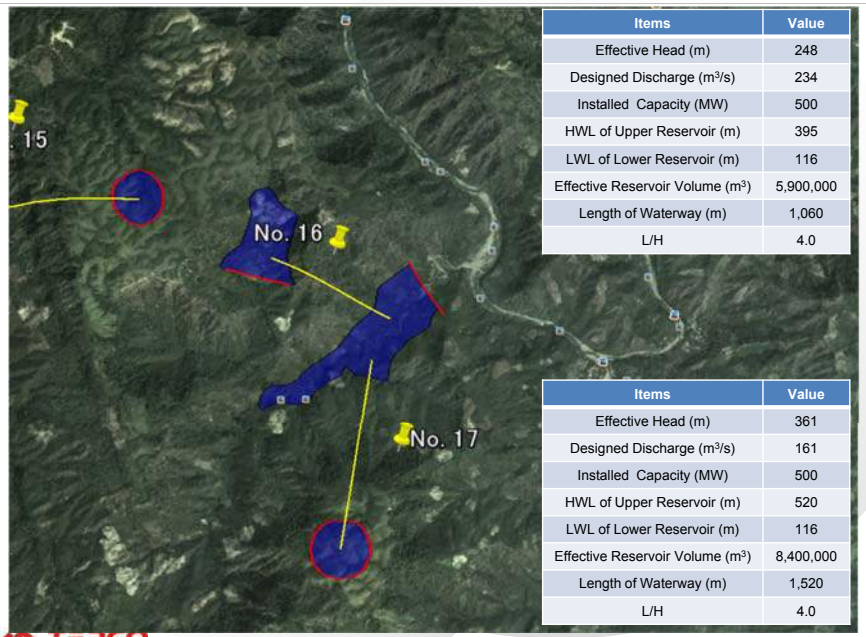


#15

Items	Value
Effective Head (m)	369
Designed Discharge (m³/s)	157
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	540
LWL of Lower Reservoir (m)	127
Effective Reservoir Volume (m³)	4,000,000
Length of Waterway (m)	2,100
L/H	5.3



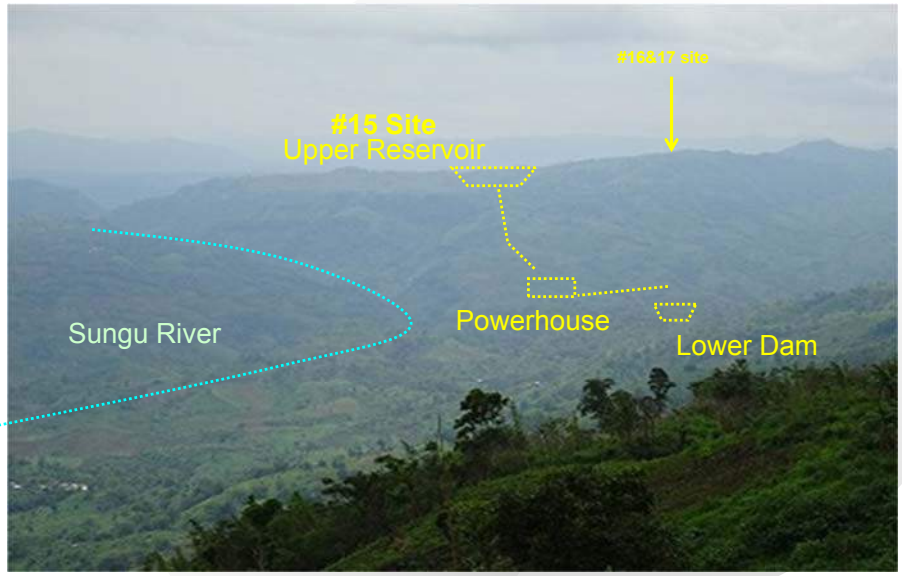
#16 & 17



Items	Value
Effective Head (m)	248
Designed Discharge (m³/s)	234
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	395
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m³)	5,900,000
Length of Waterway (m)	1,060
L/H	4.0

Items	Value
Effective Head (m)	361
Designed Discharge (m³/s)	161
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	520
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m³)	8,400,000
Length of Waterway (m)	1,520
L/H	4.0

PSPP # 15,16,17(Tanchi Area)



Comparison of PSPP Potential Sites

Site No.		No.6	No. 10	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18
Upper Reservoir	Type	Artificial Pond	Artificial Pond	Artificial Pond	Artificial Pond	Ordinary	Artificial Pond	Ordinary	Artificial Pond	Ordenary
	Dam Height							80		80
	HWL	230	360	340	480	530	540	395	520	405
	NWL	220	350	330	470	520	530	390	510	395
	LWL	190	320	300	440	500	500	365	480	375
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Lower Reservoir	Type									
	Dam Height	-	70	80	70	70	60	70	70	70
	HWL	33	173	152	160	190	157	146	146	170
	NWL	33	153	132	120	170	137	126	126	130
	LWL	33	143	122	130	160	127	116	116	140
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Waterway	Length (L)	1640	2990	1330	1890	4280	2100	1060	1520	1580
	Diameter	8.4	8.2	8.1	6.1	6.1	5.8	7.0	5.8	7.0
	Length X Diameter	13,724	24,378	10,816	11,561	26,180	12,122	7,406	8,876	11,107
Gross Head	(H)	187.0	197.0	198.0	350.0	350.0	393.0	264.0	384.0	265.0
L/H		8.8	15.2	6.7	5.4	12.2	5.3	4.0	4.0	6.0
Net Head		175.8	185.2	186.1	329.0	329.0	369.4	248.2	361.0	249.1
Discharge		330	313	312	176	176	157	234	161	233
Installed Capacity	(Efficiency=88%)	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
Social Aspects	Resettlement	Several HH Local Sentimental	None	None	None	None	Several Ten HH	None	None	None
Natural Environmental Aspects	Pretected Area	-	-	-	-	-	-	-	-	Shangu-Matamuhuri Wildlife Sanctuary
Access to the Site		52km	24km	18km	30km	29km	15km	21km	21km	
Others		-	-	Too small CA	Expansion Possibility	-	-	No Expansion	Expansion Possibility	Small CA
Comprehensive Evaluation		E	E	D	B	E	D	C	A	E

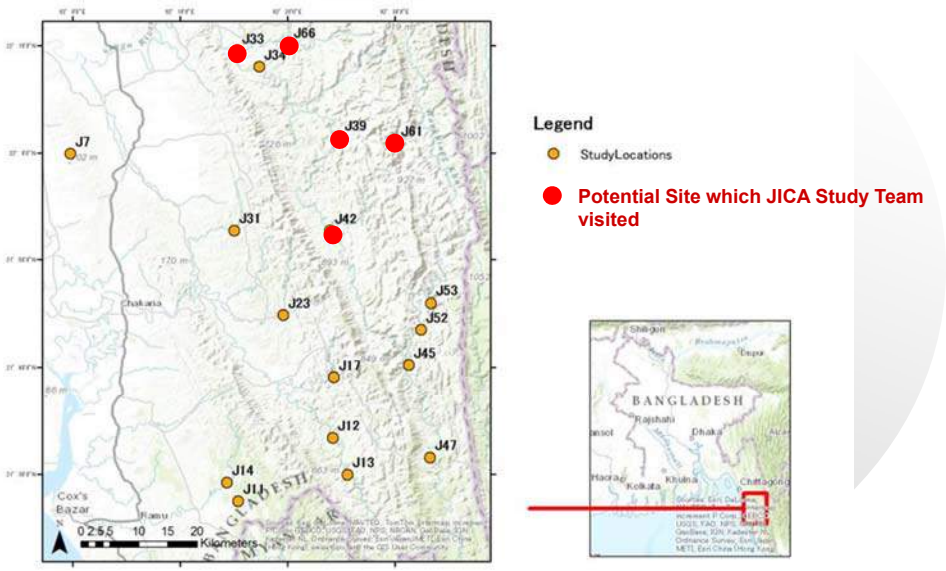
*CA:Catchment Area

Evaluation Items

Summary on PSPP

- Physical possibility of PSPP Development
  - PSPP potential sites such as # 17 an # 13 near Thanchi can be physically developed at the scale of 500MW to 1,000MW
- Difficulty for the further steps:
  - Difficult access to the project sites,
  - Limitation of maps available (only 1/50,000 maps with 100m contour lines),
  - Sensitive sentiment of local people against hydropower Development , but depending on areas.
  - Difficulty in land acquisition and compensation
  - Peace and order issue in the CHT during F/S, D/D and construction stages

Location of Ordinary HPP



J33, J39, J42



J33 Site (view from down stream)



Upstream of J42 Site

Site No.	Head (m)	Discharge (m3/s)	Power (MW)	Energy (MWh/year)	Percentage of Time
J33	12	268	23.5	37,648	18.3
J39	70	200	102.5	144,000	16.0
J42	60	156	156	96,676	16.1

Source: Study on Prospective Hydroelectricity Generation in Southeast Bangladesh, 2014, Streams Tech, Inc., USA

J33, J39, J42

- The projects of J33, J39, 42 are planned to hold back water on the Sangu main river by dams.
- Since many local people are living along the Sangu river, even a small dam may causes large scale of resettlement.



Houses along the Sangu river



Houses along the Sangu river



Upstream of J66 site



Downstream of J61 site

Site No.	Head (m)	Discharge (m3/s)	Power (MW)	Energy (MWh/year)	Percentage of Time
J61	40	9	2.6	3,296	14.6
J66	20	31	4.6	6,426	16.0

Source: Study on Prospective Hydroelectricity Generation in Southeast Bangladesh, 2014, Streams Tech. Inc., USA

- Too small water flow in the dry season in comparison with the planned discharge.
- J66 site is located at the center of Rowanchhari.
- No houses were observed at downstream of J61 site.

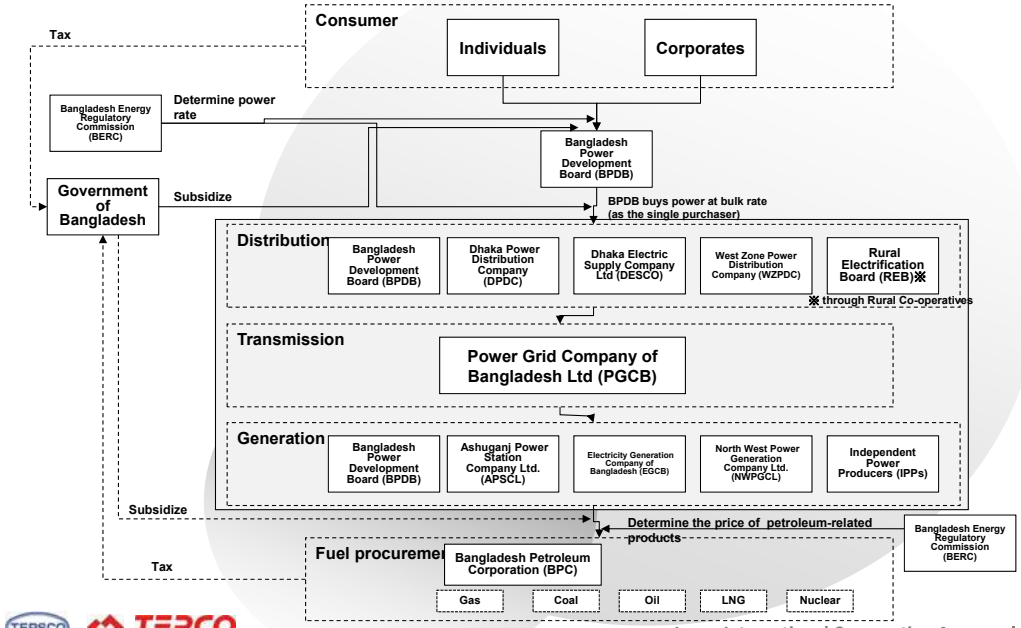
- Tentative Conclusion
  - In consideration of local sentiment, difficulty in investigation and project viability, hydropower development in Bangladesh may not have high priority in comparison with power import from neighbor countries.
- Next Steps
  - To get detailed information related to the development plan of CHT,
  - To compare benefits from PSPP projects with power import.

G Energy and Power Tariff Strategy

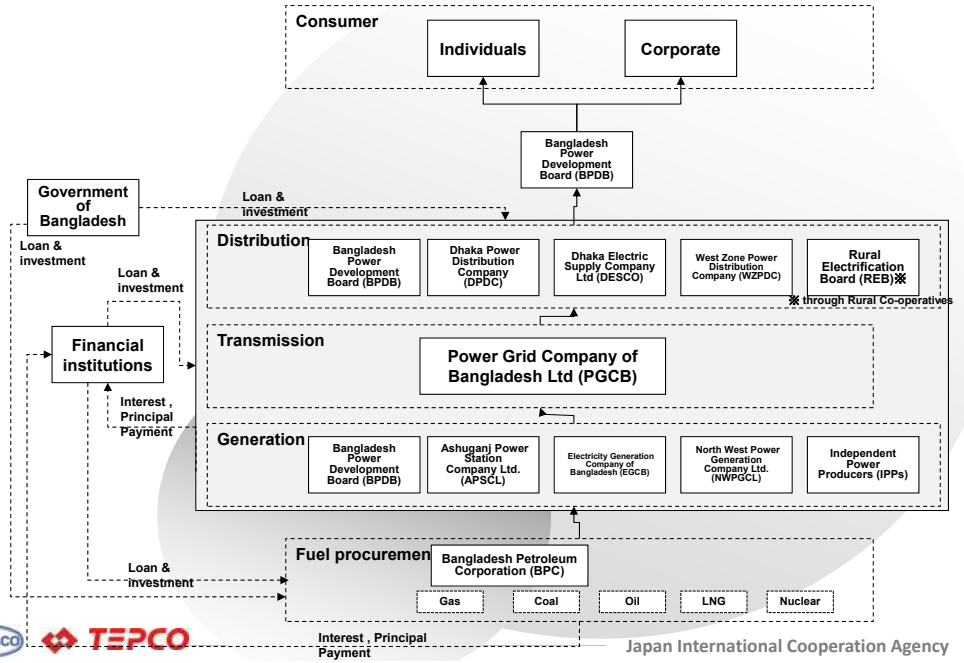
G-1 Tariff Policy and Impact on National Economy

Cash Flow in Power Sector (OPEX)

Go to additional N0.269



Cash Flow in Power Sector (CAPEX)

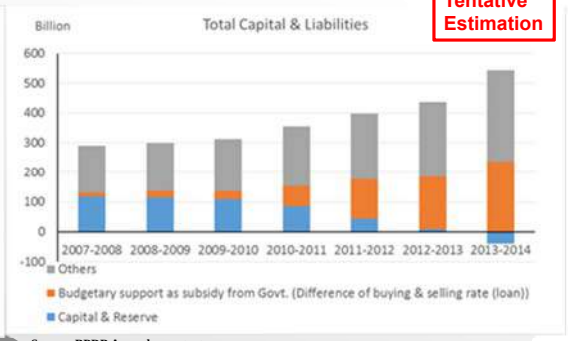


Total Capital & Liabilities of BPDB



Tentative Estimation

Source: BPDB Annual report, etc.



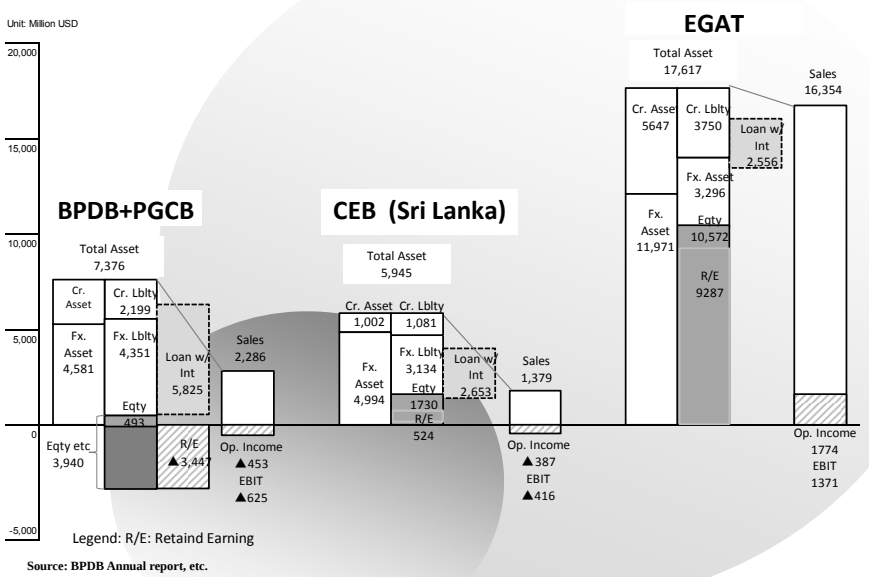
Tentative Estimation

Source: BPDB Annual report, etc.

Impact of Energy Tariff Increase on National Economy

- Balance sheet of BPDB is in serious situation.
- Debt equity swap (debt equity conversion) is discussed but it is only temporary solution.

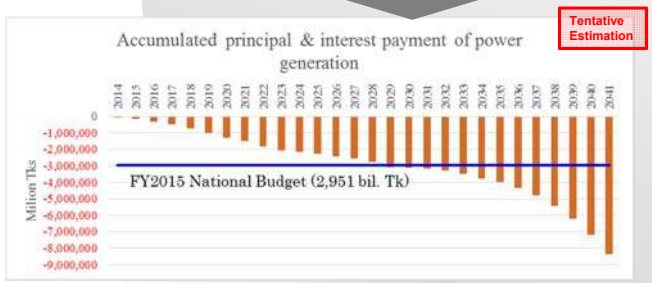
Total Capital & Liabilities of BPDB



Source: BPDB Annual report, etc.

Bulk rate should be increased



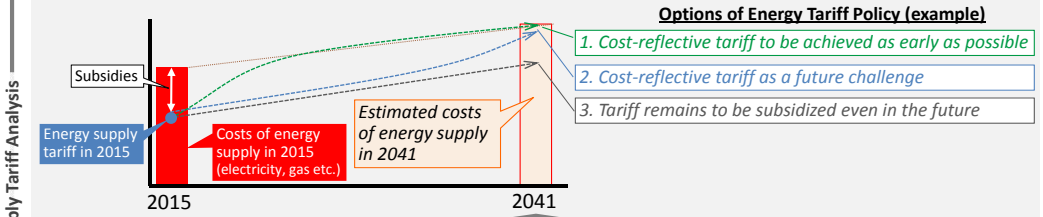


By FY2041, the accumulated payment rises up to 8,359 million Tk, or equivalent to 2.8 times of Bangladesh national budget in FY2015.

Energy and Power Tariff Strategy

Projection of Costs of Energy Supply and Tariff Policy

- The energy tariff in Bangladesh needs to be adjusted to be cost-reflective with the progress of economic development



Impact of Energy Tariff Increase on National Economy

- For avoiding a negative effect of rapid tariff increase on national economy in Bangladesh, policy tools for mitigation may be justified
- However, priority of distributing the limited financial resources (subsidies) among sectors also needs to be considered
- Policy options of energy tariff are analyzed using GTAP model

তোমাকে ধন্যবাদ

Additional Slides

MDGs and SDGs

After N0.72-001

- The Millennium Development Goals (MDGs)
  - Adopted in 2000
  - 8 categories of quantifiable targets to be achieved by 2015
  - Aimed to tackle issues that included slashing poverty, hunger, disease, gender inequality, and access to water and sanitation
- Sustainable Development Goals (SDGs)
  - Adopted in 2015
  - 17 categories of targets, but the three core elements are: Economic growth, Social inclusion and Environmental protection
  - **More influence and implication on energy and power sectors**

MDGs



SDGs



SDGs' Implication to Bangladesh's Energy and Power Sectors

After N0.72-002

- **Goal 7: Affordable and Clean Energy**: Ensure access to affordable, reliable, sustainable and modern energy for all
  - This is not only focusing on electricity, but "modern energy" – e.g. LPG and modern bio energy.
  - Affordability, reliability and sustainability should be considered in an orchestrated manner – Heavy subsidy helps affordability but not sustainable. "Targeted care" works better for poor households.
  - As Bangladesh will increase coal usage, "Clean Coal Technology" could be an option like India.
  - If fossil fuel consumption increases (e.g. Diesel for Transport), huge impact on air pollution can raise. GoB should protect its precious asset – people and their health.
- **Goal 9: Industry, innovation, infrastructure**: Build resilient infrastructure, promote sustainable industrialization and foster innovation
  - Domestic natural gas exploration has much room to employ innovation and research.
  - Developing resilient infrastructure for fuel import (e.g. port, terminal, pipeline) is critical for stable energy supply.
  - Further energy efficiency, as well as innovative operation and maintenance in power generation is the key to manage energy demand increase.
  - Demand Side Management saves energy consumption and fosters industrial innovation.
- **Goal 13: Climate action**: Take urgent action to combat climate change and its impacts
  - Low-lying, river-rich Bangladesh is one of the most vulnerable countries to the climate change.
  - Taking all actions above in an integrated manner mitigates the climate change risks

Review of Power demand Forecasts

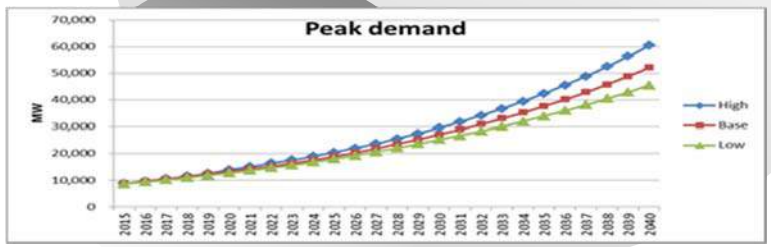
After N0.13-001

Power demand by case

(1) Peak demand

	Unit	2014	2015	2020	2025	2030	2035	2040	2041
Base	MW	8,000	8,920	12,800	18,300	25,800	35,000	47,400	50,400
High	MW	8,000	8,920	13,000	19,100	27,600	39,500	56,200	60,300
Low	MW	8,000	8,920	12,600	17,700	24,100	31,200	40,300	42,400
	Unit		2015/10	2020/15	2025/20	2030/25	2035/30	2040/35	2041/15
Base	%		7.3	7.5	7.4	7.1	6.3	6.3	6.9
High	%		7.3	7.8	8.0	7.6	7.4	7.3	7.6
Low	%		7.3	7.2	7.0	6.4	5.3	5.3	6.2

Note: The demand are potential data, Source : JICA Study team

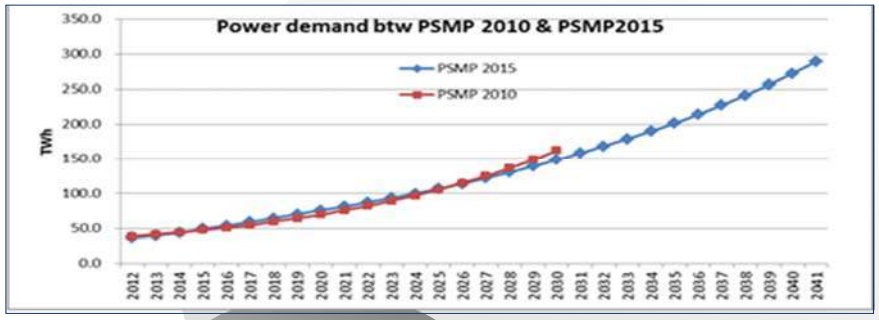


279

Comparison

Comparison between PSMP 2010 and PSMP2015 (Base case)

After N0.13-002



- The GDP growth rate of PSMP2010 is 7% from 2010 to 2030 and PSMP 2015 is 6.3 % from 2015 to 2041.
- In PSMP2015, energy consumption intensities to GDP and Power ratios are increased.
- The power demands are calculated by the expressions with "Intensity × GDP" or "Intensity × income per capita"

280

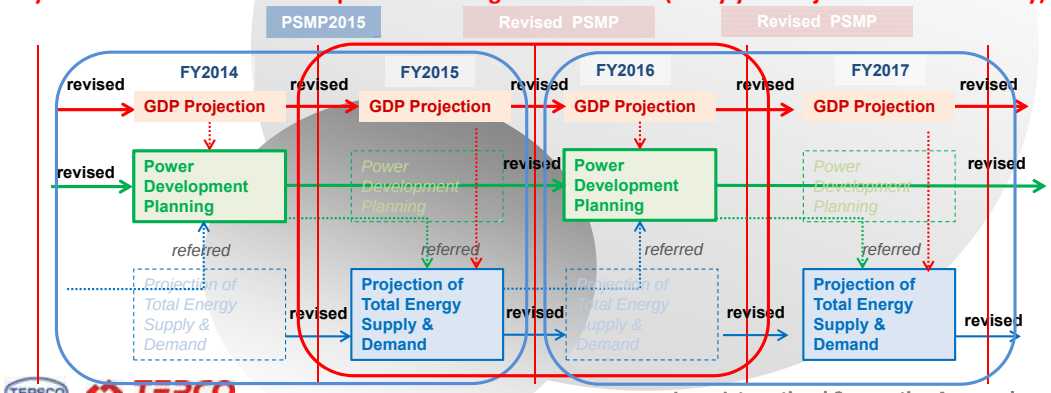
Energy Supply & Demand Balances

After N0.158

Cycles of Energy Master Plan = ROLLING PLAN (yearly adjustment)

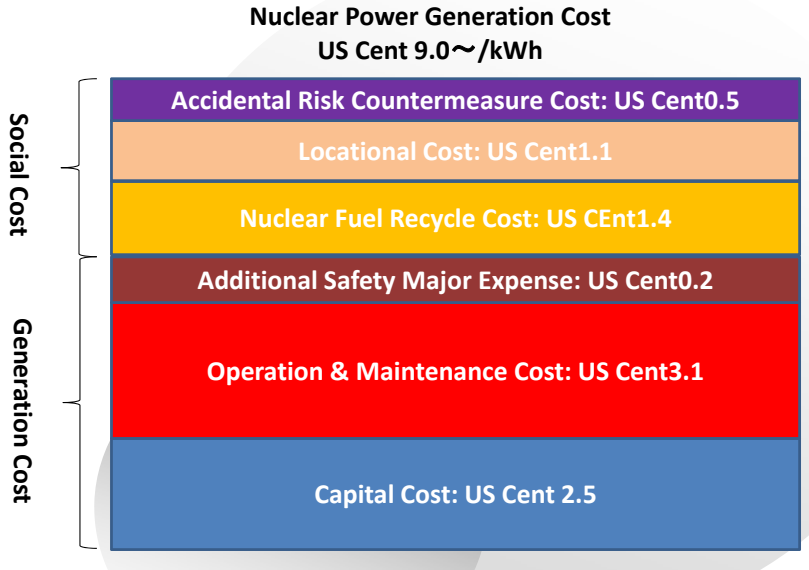
- Because the power demand planning and the projection of total energy supply & demand are interdependent on each other, i.e. power demand projection affects total energy demand and vice versa, the work of power development planning takes a cyclic process so that:
  - Power develop plan is formulated referring to the latest forecast of energy demand and national economy; and
  - Projection of total energy supply & demand is formulated referring to the latest plan of power development and national economy;
- Though a time lag may exist between these two works, the difference caused by this time lag is adjusted appropriately.

Cyclic Process of Power Development Planning ROLLING PLAN (Every year Adjustment is Necessary)



Nuclear Power Generation Cost by Cost Verification Committee (2011)

After N0.210-001

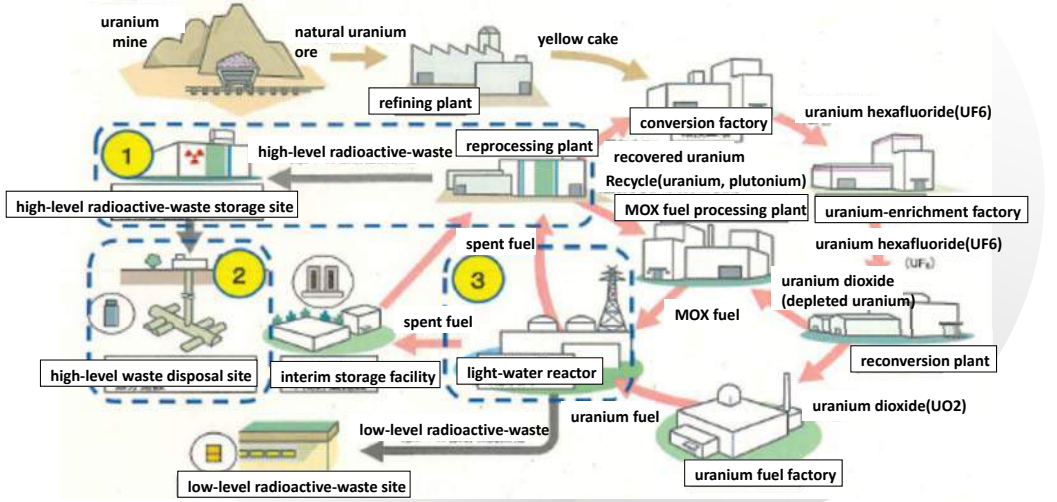


Source: 3rd Working Group for verification of power generation cost, Advisory Committee for Natural Resources and Energy

Overview of Nuclear Back End Cost

After N0.210-002

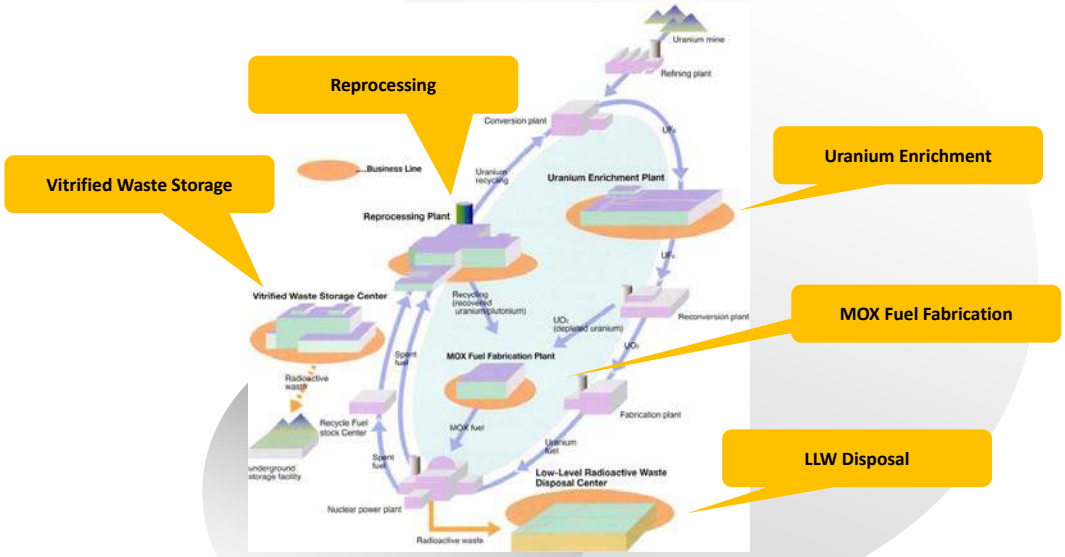
(1) Spent Fuel Reprocessing Cost
(2) Designated Radioactive Waste Disposal Cost
(3) Decommissioning of Nuclear Power Stations



Source: Nuclear, Energy Drawing 2012 7-2-1

Nuclear Fuel Cycle Outlook

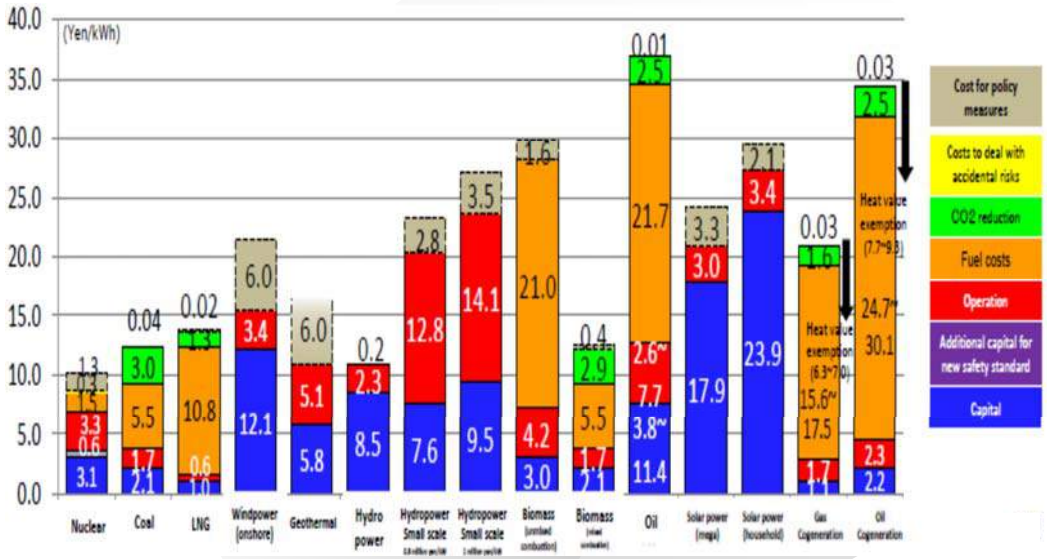
After N0.210-003



Source: Japan Nuclear Fuel Limited

Power Generation Cost of Each Power Source in Japan (2014)

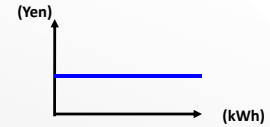
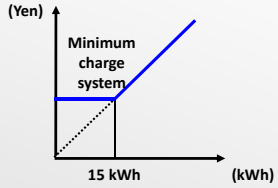
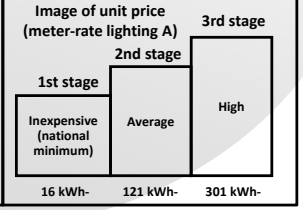
After N0.269-001



Source: Power Generation Cost Analysis Working Group, METI, Japan

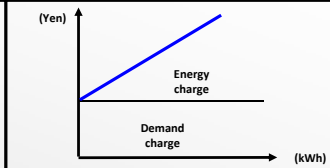
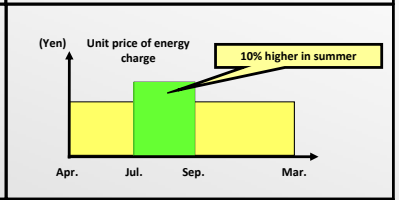
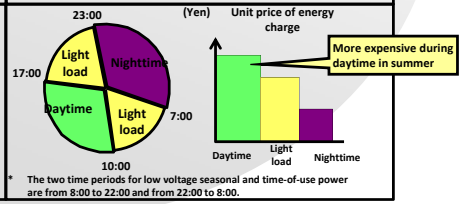
Types of Electricity Rate Systems (1)

After N0.269-002

	Outline	Image of electricity rates
Flat-rate system	▪ The amount of monthly electricity rate remains constant, regardless of the amount of electricity used. ▪ Applied to small customers whose forms of electricity usage are almost equal, and installation of measuring instruments is not cost efficient. (Flat-rate lighting, Public street lighting A, etc.)	
Meter-rate system	▪ The amount of electricity rate is decided by multiplying electricity usage by the unit price of electric energy. ▪ If electricity usage is zero, the electricity rate is also zero, making it impossible to recover the supply cost. Usually, therefore, the minimum amount to be paid is specified in the case where electricity usage is below a certain level. (Meter-rate lighting A and Public street lighting B)	
3-stage rate system	▪ Against the background of upward trend of cost and from the viewpoints of achievement of high-level welfare society and energy conservation: - 1st stage: relatively inexpensive (necessaries of life) - 2nd stage: nearly average - 3rd stage: slightly high (upward trend of cost is reflected) * Introduced in 1974 in the wake of oil crisis (Meter-rate lighting A, B and time-of-use lighting)	

Types of Electricity Rate Systems (2)

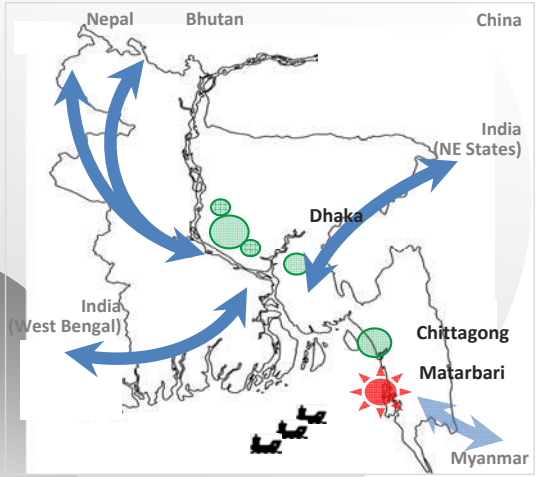
After N0.269-003

	Outline	Image of electricity rates
Demand charge system (2-stage rate system)	Electricity rate is decided in the following two stages: ▪ Fixed rate in proportion to contract demand (kW) and contract capacity (kVA) ▪ Energy charge in proportion to electricity usage (Meter-rate lighting B, time-of-use lighting, HAPI-e Time, Low voltage power, etc.)	
Seasonal rate system	▪ As for the energy charge in summer (from July through September) when power supply and demand balance becomes tight, higher rates than the rates in other seasons (from October through June), which reflect the supply cost, are applied. ▪ The rates in summer is 10% higher than the rates in other seasons. (Low voltage power and Low voltage integration use contracts)	
Seasonal and time-of-use rate system	A system that reflects the difference in supply costs to cope with changes in seasonal and time-of-use load curves ▪ Peak hours (daytime): relatively expensive ▪ Light load hours (nighttime and living hours): relatively inexpensive (HAPI-e Time and 'Low voltage seasonal and time-of-use power')	 * The two time periods for low voltage seasonal and time-of-use power are from 8:00 to 22:00 and from 22:00 to 8:00.

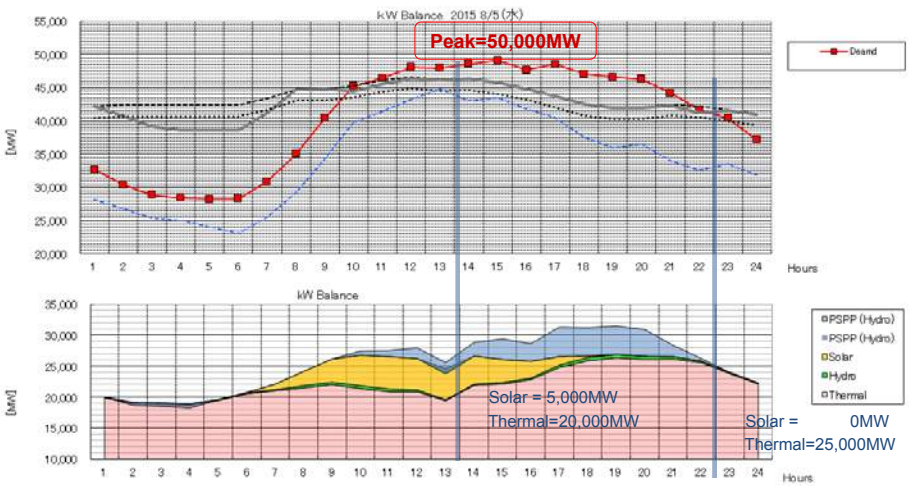
BIG-B Initiative (The Bay of Bengal Industrial Growth Belt)

Accelerating industrial agglomeration in Dhaka–Matarbari belt and beyond to shape a value chain hub for South Asia and Southeast Asia

Energy & Power	Supplying reliable energy & power for industries
Trans-port	Fostering connectivity as a regional node and hub
Invest-ment Climate	Promoting domestic & foreign direct investment
Others	Enhancing sustainable socioeconomic development



Function of Renewable Energy



23.6 4th Seminar (4th Steering Committee)

- Date: 18 June 2016
- Venue: Bijoy Hall, Bidyut Bhaban, Power Division, MoPEMR
- Discussion Point: Explain for Draft Final Report
  - ✓ Economic Development
  - ✓ Primary Energy Balance
  - ✓ Power Balance
  - ✓ Cost and Tariff Balance





- Participants

Participants are shown below table.

No.	Name	Designation	Organization
1	Ali Kausar M. Firoz	Project Officer Energy	ADB
2	Len George	Energy Specialist	ADB
3	Sherine Ibrahim	Senior Project Management Specialist	ADB
4	A.M.M. Sazzadur Rahman	Managing Director	APSCL
5	Dr. Aminul Huq	Consultant (Energy)	Asian Development Bank
6	Kamal Ahmed	Reporter	Bangladesh Betar
7	Ismail Ali	Member	BEA
8	Sontosh Kumar Sadhukhan	Director, Power	BERC
9	Paban Chowdhury	Executive Chairman (Secretary)	BEZA, PMO
10	Latif Khan	President	BIPPA
11	Abdul Halim	Secretary General	BIPPA
12	Mahmud Reza Khan	Chairman	BPC
13	Khaled Mahmood	Member Generation	BPDB
14	Md. Nurul Islam Bhuiyan	Member (Planning & Development)	BPDB
15	Muhammad Belal Hossain	Executive Engineer, System Planning	BPDB
16	Md. Mahbubur Rahman	Director	BPDB
17	Lokman Hossain Miah	Member (Admin)	BPDB
18	Md. Aslam Uddin	Deputy Secretary (Planning & Development)	BPDB
19	Jorifa Khatun	Executive Engineer, System Planning	BPDB

No.	Name	Designation	Organization
20	Md. Shamsul Hassan Miah	Chairman	BPDB
21	Engr. Ashutosh Roy	Chief Staff Officer (CSO)	BPDB
22	Md. Azizul Islam	Member (Finance)	BPDB
23	A. K. Mahmud	Director, System Planning	BPDB
24	Minhajuddin Ahmed	Member, Company	BPDB
25	Bikash Dewan	Chief Engineer, P&D	BPDB
26	Md. Asadullah	Consultant (Tech.)	BPDB- RPCL Power Generation
27	Prof. Dr. Md. Sayeed Salam	Chairperson, EEE Dept.	BRAC University
28	Mizanur Rahman Khan	Member (Distribution & Operation)	BREB
29	Syed Mahbubur Rahman	Director (PP)	BREB
30	Mazharul Anwar Khan	Senior Reporter	BSS
31	Binu	Reporter	BTV
32	Irtiza Nasim Shourov	Reporter	Channel 24
33	Md. Abul Quasem	Managing Director	Coal Power Generation Co. Ltd. (CPGCBL)
34	ANM Obaidullah	Superintending Engineer (Planning)	CPGCBL
35	Birg. Gen. Shahid Sarwar (Rtd.)	Managing Director	DESCO
36	Engr. Jagodish Chandra Mandol	Executive Director (Engg.)	DESCO
37	Md. Ali Ahsan	Sub-Divisional Engineer	DESCO
38	Md. Mafizul Islam Bhuiyan	Chief Engineer (P&D)	DESCO
39	Dr. Sultan Ahmed	Director (NRM & Research)	DOE
40	Brig. Gen (Retd.) Md. Nazrul Hasan	Managing Director	DPDC
41	Md. Ramizuddin Sarker	Executive Director (Engg.)	DPDC
42	Md. Mehedi Hasan	Sub Divisional Engineer	DPDC
43	ATM Harunur Rashid	Executive Director (Operation)	DPDC
44	G.M.A. Afzal	Managing Director	E.R.L
45	Monoranjan Biswas	Joint Secretary (Japan 2)	Economic Relations Division
46	Prof. Dr. Taifur Ahmed Choudhury	Head of the Depertment, EEE	EEE Dept. BUET
47	ATM Zahirul Islam Majumder	Managing Director	EGCB
48	Ibrahim Ahmed Shafi Al Mahtab	Superintending Engineer	EGCB
49	M.A. Hasnat	Executive Director (Engineering)	EGCB
50	Falguni Rashid	Reporter	Ekattor TV
51	Kazi Zebunnessa Begum	Joint Secretary	EMRD
52	Md. Abu Yousuf Miah	Deputy Chief	EMRD
53	Mohiuddin Miah	Reporter	Energy and Power
54	Md. Zakir Hossain	Additional Secretary	Energy Division
55	Md. Altab Hossain	Secretary	EPRC
56	Muhammad Alkama Siddique	Additional Secretary	ERD

No.	Name	Designation	Organization
57	Syed Mahamudur Rahman	Photographer	Focus Bangla News.
58	Dr. Md. Nehal Uddin	Director General	Geological Survey of Bangladesh
59	S.M Zahid Hasan	Senior Adviser	GIZ
60	Ashoke Kumar Biswas	Manager (Central Load Dispatch)	GTCL
61	Md. Ishaque Uddin	Director (OP)	GTCL
62	A.S.M. Manjurul Quader	Director	Hydrocarbon Unit
63	Md. Harun-or-Rashid Khan	Director General	Hydrocarbon unit
64	Tanvir A. Siddiqui	Vice President	IDCOL
65	Md. Ibrahim Khalilullah	Reporter	Jamuna TV
66	Arfin Ara Begum	Additional Secretary, Finance Division	Ministry of Finance
67	Md. Rakib Hossain	Additional Secretary	Ministry of Public Administration
68	Md. Anwar Hossain	Additional Secretary	Ministry of Science and Technology
69	A.M Khurshedul Alam	Managing Director	NWPGCL
70	Md. Lutfar Rahman	General Manager	Petrobangla
71	Jameel A. Aleem	Director (Ops & Mines)	Petrobangla
72	Md. Maqbul-E-Elahi	For Director	Petrobangla
73	Istiaque Ahmad	Chairman	Petrobangla
74	Masum-Al-Beruni	Managing Director	PGCB
75	Chowdhury Alamgir Hossain	Executive Director (P&D)	PGCB
76	Arun Kumar Saha	Chief Engineer (P&D)	PGCB
77	Dr. Selina Akhter	Joint Chief	Planning Commission
78	Md. Abdur Rouf Miah	Director	Power Cell
79	C F K Mussaddeq Ahmed	Director (Private Power)	Power Cell
80	M. Amzad Hossain	Director	Power Cell
81	Mohammad Hossain	Director General	Power Cell
82	A.T.M. Mostafa Kamal	Deputy Secretary	Power Division
83	AKM Aminur Rahman	Deputy Secretary	Power Division
84	Md. Nazmul Abedin	Deputy Secretary	Power Division
85	Md. Humayan Kabir	Programmer	Power Division
86	Md. Showkat Ali	Deputy Secretary	Power Division
87	Mohammad Mofijur Rahman	Deputy Secretary	Power Division
88	Surayya A. Jahan	Deputy Secretary	Power Division
89	Tahmina Yeasmin	Deputy Secretary	Power Division
90	Zillur Rahman	Senior Assistant Secretary	Power Division
91	Abdul Halim	Joint Secretary	Power Division
92	A.K.M. Humayun Kabir	Joint Secretary	Power Division
93	Mohammad Alauddin	Joint Secretary	Power Division

No.	Name	Designation	Organization
94	Md. Khurshad Alam	Assistant Secretary	Power Division
95	S.M. Ayubar Rahman	Assistant Secretary	Power Division
96	Hossain Momtaz	Assistant Programmer	Power Division
97	SK Md. Abdul Ahad	Joint Chief	Power Division
98	Md. Shohelur Rahman Khan	Senior Assistant Chief	Power Division
99	Kazi Rowshan Akhter	Additional Secretary	Power Division
100	Md. Mahbub-ul-Alam	Additional Secretary (Planning)	Power Division
101	Dr. Ahmad Kaikius	Additional Secretary	Power Division
102	Sheikh Faizul Amin	Joint Secretary, Development	Power Division
103	Mir Mohammad Aslam Uddin	Senior Information Officer	Power Division
104	Muktadir Aziz	APS to Energy Adviser	Prime Minister's Office
105	S.M Tarikul Islam	Director (Deputy Secretary)	Prime Minister's Office
106	Maj. Gen. Moin Uddin	Chairman	REB
107	Md. Salim Bhuiyan	Executive Director (Engg.).	RPCL
108	Debashish Roy	Reporter	Somoy TV
109	Md. Anwarul Islam Sikder ndc	Chairman	SREDA
110	Prof. Dr. S.M.Lutful Kalim	Professor (on leave) BUET, Professor & Dean,	UIU
111	Md. Fayyaz Khan	Professor, EEE	UIU
112	Md. Shafique Uddin	Managing Director	WZPDCL
113	Md. Aminur Rahman	Assistant Engineer	WZPDCL
114	Engr. Md. Saifuzzaman	Superintending Engineer (P&D)	WZPDCL
115	A.B.M. Ruhul Amin	PS to Chairman Standing Committee	
116	Md. Jahid Hossain	APS to Chairman Standing Committee	

(Alphabetical order)

■ Presentation materials

Presentation materials are as next pages.

PSMP2016
Final Steering Committee

JICA PSMP2016 Team

June 2016

Tokyo Electric Power Services Co., Ltd.
Tokyo Electric Power Company Holdings, Inc.

SUMMARY PART

PSMP2016 Summary

PSMP2016 Key Discussion Points

A Economic Development
A-1 Economic Development

B Primary Energy Balance
B-1 Primary Energy Demand
B-2 Domestic Gas Supply
B-3 LNG Supply
B-4 Coal Supply
B-5 Oil Supply

C Power Balance
C-1 Power Demand Forecast
C-2 Power Development Plan
C-3 Renewable Energy
C-4 Power Imports
C-5 Transmission Analysis
C-6 Rural Electrification (Distribution)
C-7 Power Quality
C-8 Operations and Maintenance

D Cost and Tariff Balance
D-1 Tariff Policy

A Economic Development

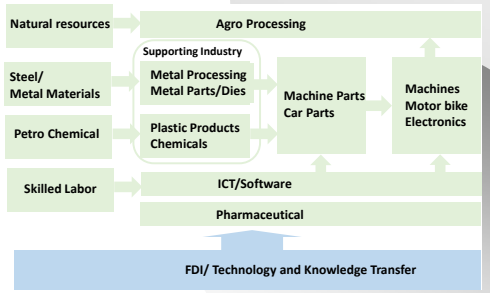
PSMP2016 Summary

A-1 Economic Development

Current Status and Issues

- Bangladesh economy has been growing rapidly, especially since 1990s when garment (RMG) emerged as a major export industry.
- For further economic growth on a long-term basis, the country's industrial structure should shift from labour-intensive industries to **more value-added industries** (e.g. machinery, electronics, ICT, pharmaceutical).

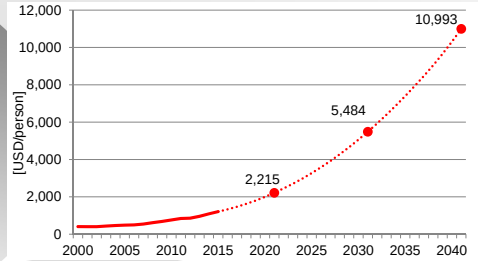
Image of Industrial Structure as of 2041



Future Goals

- GDP per capita in 2041 is expected to reach World Bank's criteria of **"high-income countries"**.
- To achieve this, appropriate policy measures for promoting the diversification and modernization of the industry, such as:
  - Short and medium term: incentives for foreign direct investment; various infrastructure development (e.g. industrial parks like SEZ, ports, roads, railways, power plants)
  - Medium and long term: construction of industrial parks; facilitation of infrastructure development; industrial human resource development; promotion of deregulation and economic liberalization

Projection of GDP per Capita (Nominal)



B Primary Energy Demand

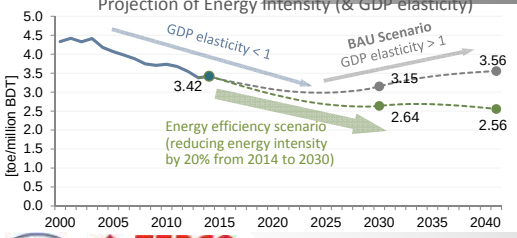
PSMP2016 Summary

B-1 Primary Energy Demand

Current Status and Issues

- With the high growth of economy, **energy demand is also expected to increase rapidly**.
- Energy intensity is expected to turn upward (i.e. GDP elasticity of energy consumption > 1) from mid-2020s in BAU scenario. This is due to the energy consumption in industrial and transport sectors that will increase higher than GDP.
- In order to achieve the target of "reducing energy intensity by 20% from 2014 to 2030", energy efficiency measures need to be implemented, such as mandatory reporting for large (industrial) customers, appliance labelling, energy-saving building code, etc.

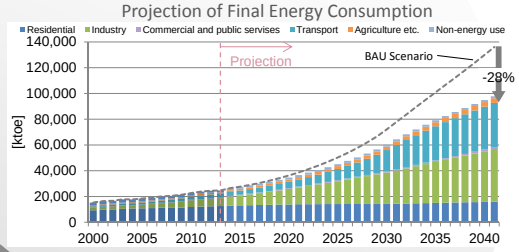
Projection of Energy Intensity (& GDP elasticity)



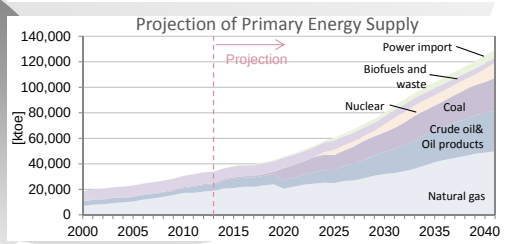
Future Goals

- **Energy efficiency measures** will be implemented proactively so that the energy consumption will be reduced by 28% in 2041 from BAU scenario.

Projection of Final Energy Consumption



Projection of Primary Energy Supply



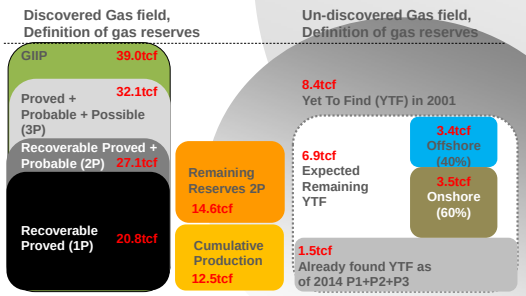
PSMP2016 Summary

B-2 Domestic Gas Supply

Current Status and Issues

- Gas Supply from current domestic gas field will **peak out in 2017-2018, and decline thereafter.**
- Recoverable proven reserve of natural gas is 20.8TCF. 12.5 TCF has been produced and consumed by 2014. Remaining gas reserve will be **8.3 TCF** (Reserve to Production ratio is **9.5 years**).
- Current gas development performance is not satisfactory.
- **New gas fields** need to be explored and developed in an **efficient** manner.

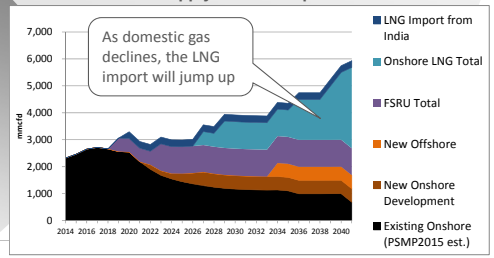
GIIP and YTF 2015 Update



Future Goals

- Domestic gas 2,000 mmcfd should be produced in 2041.
  - Current **PSC** should be reviewed to attract IOCs. Technologically advanced and financially sound **IOCs** should be invited to onshore/offshore field development under revised PSC.
  - **Strategic partnership** between IOCs and domestic production companies should be considered.
  - **Role of BAPEX** should be revised and include acquisition of energy resources in **overseas**.
  - The **efficiency of gas use** to save indigenous gas resources should be improved. **Legal framework** needs to be introduced to discourage inefficient use.

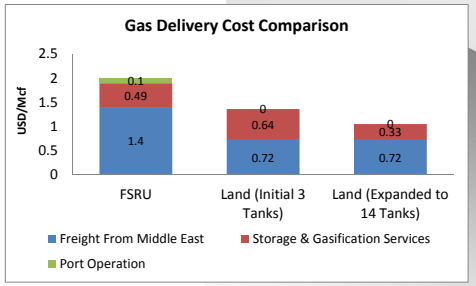
Gas Supply Scenario up to 2041



B-3 LNG Supply

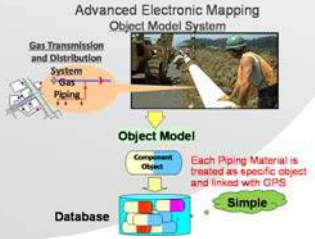
Current Status and Issues

- LNG will be a major source of gas energy in near future. Over **70%** of gas supply will be sourced by imported LNG in 2041.
- LNG should be imported effectively based on a **comprehensive study** to cover **short term** and **long term** issues.
- Use of **FSRU** will be a **short term solution**, and **land-based LNG terminal** must be a **long term solution**.



Future Goals

- LNG 4,000 mmcfd should be imported in 2041.
  - **LNG Procurement Strategy** need to be set to minimize the price risk by traditional long term "take or pay" contract. Joint infrastructure projects with neighboring countries can be considered.
  - **Operation mode** is changing from gas allocation to customer demand base. **Advanced operation system** need to be introduced.
  - **Integrity of gas transmission infrastructure** should be secured.
  - Introduction of **electronic mapping** for gas infrastructure to support the **advanced operation**, **preventive maintenance**, **operation safety** and **emergency transaction**.



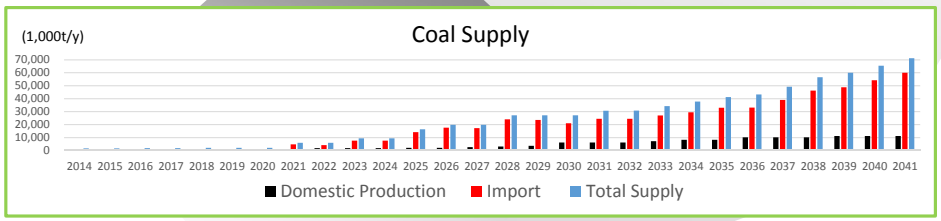
B-4 Coal Supply

Current Status and Issues

- As for the quantity of import coal in 2041, **60milion tons** is expected.
- On the other hand, the coal-fired power stations in Southern Asia surrounding Bangladesh increase rapidly. As a result, the supply, the quality and the price of import coal will **become very unstable in future**.
- There are two critical issues in Bangladesh, **Infrastructures for Import Coal** and **Domestic Coal Development**

Future Goals

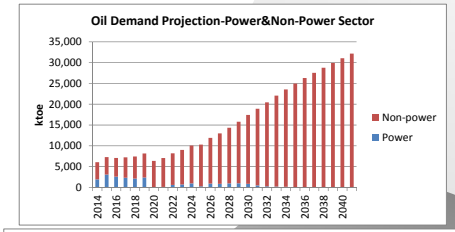
- For Infrastructures for Import Coal,
  1) **Implementation of F/S** of the import coal infrastructure
  2) Construction based on the F/S
- For Domestic coal development
  1) **Technology acquisition** in the coal mine for Bangladesh
  2) Carrying out a **pilot operation of an open cut mining** technology in the Barapukuria coal mine.
  3) **Development permission** of Digipara coal mine and Karaspir coal mine
  4) Approval of **small scale open cut mining** at Phulbari after getting the result of the pilot operation at Barapukuria coal mine

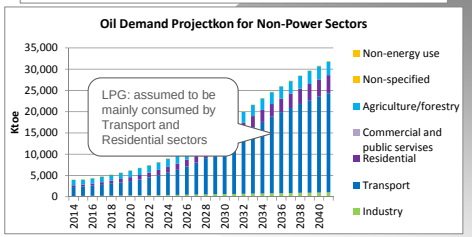


B-5 Oil Supply

Current Status and Issues

- Total oil demand (Power + Non-Power) in 2041 will become **6-fold** from 2015 (5.2% p.a.).
- Oil demand in **Non-power sector** in 2040 will become **8-hold** from 2015 (7.4% p.a.). This growth is mainly led by **Transport sector** demand growth (11-fold).





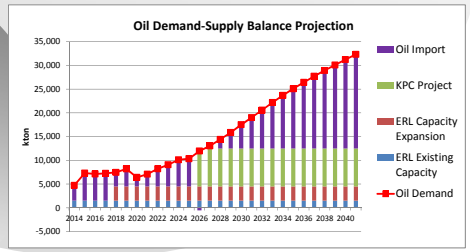
Future Goals

- **Comprehensive analysis** including economic, market and energy security on oil products should be implemented.
- Based on the analysis, a decision should be made on **whether domestic refinery construction or oil product import is more economically viable**.

Advantages of Constructing a Refinery against Product Import

Advantages	Disadvantages
● More oil product procurement option (diversification of oil product procurement)	● Large upfront capital expenditures & long-term loan repayment
● Lower freight cost	● Risk of low utilization depending on domestic and export demand
● Lower price volatility	● Risk of low refining margin for a long period of time
● Oil product control	

- **Exit strategy on oil subsidy** should be developed and implemented in order to avoid huge pressure to the national coffer.



C Power Balance

C-1 Power Demand Forecast

Current Status and Issues

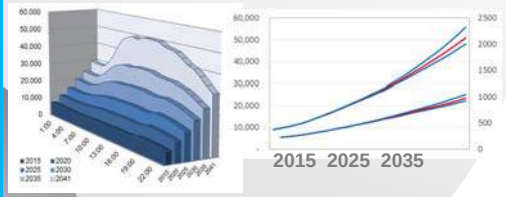
- The peak demand **continuously increases with a rapid economic development from around 9,000MW to 51,000MW in 2041.**
- Peak demand is examined, considering economic growth scenario or **GDP and energy-GDP elasticity with effect of energy conservation.**

FY	Simplified Model									
	GDP growth rate	Elastisty	Electricity growth rate	Demand without EE&C	Captive power to Grid	Demand without EE&C with captive power	Effect of EE&C	Demand with EE&C	Captive power to Grid	Peak Demand w/(EE&C+ Captive)
2015	6.5%	1.27	8.3%	8,920	-	8,920	0.0%	8,920	-	8,920
2020	8.0%	1.27	10.2%	14,009	149	14,157	6.7%	13,075	149	13,223
2025	6.9%	1.27	8.8%	21,903	891	22,795	13.3%	18,983	891	19,874
2030	5.9%	1.27	7.5%	32,198	1,634	33,833	20.0%	25,759	1,634	27,393
2035	4.8%	1.27	6.1%	44,483	1,634	46,117	20.0%	35,587	1,634	37,221
2040	4.3%	1.27	5.5%	58,486	1,634	60,120	20.0%	46,789	1,634	48,423
2041	4.3%	1.27	5.5%	61,681	1,634	63,315	20.0%	49,345	1,634	50,979

Average 6.1%

Future Goals

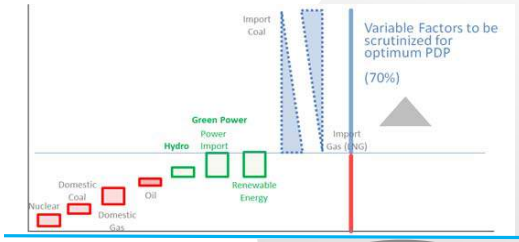
- Power Demand **without EE&C: 63,000MW**
- Power Demand **with EE&C: 50,000MW**
- Power demand is estimated by multiplying estimated maximum power and estimated daily load curve from 2015 to 2041.
- Estimated power demand forecast from 2015 to 2041 shows a change of daily load curve **shifting** from **evening peak to daytime peak** and increasing peak demand **between 2030 and 2035**.

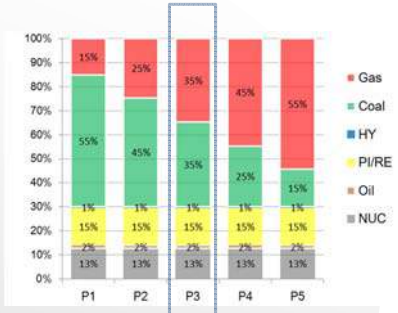


C-2 Power Development Plan

Current Status and Issues

- Seeking an optimum energy scenario is examined based on fixed factors such as **Nuclear, Power Imports/Renewable Energy, Hydropower, Oil,** and **variable factors of Gas and Coal.**
- Five scenarios with variable shares of coal and gas as of 2041 changed from **Scenario 1 (coal max) to Scenario 5 (gas max)** are examined.

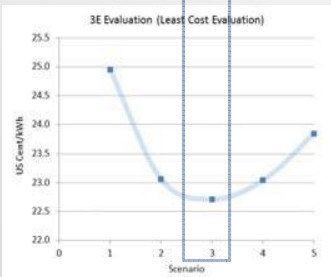




Future Goals

- Three "E" conditions **(3E),** which stand for **Economic, Environment and Energy security values,** are numerically calculated.
- **Scenario 3, Coal 35% and Gas 35% (MW basis) is a least cost option.**

	Composition (MW base)	Economy [US cent/kWh]	Environment [US cent/kWh]	Energy Security [US cent/kWh]	Total [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	9.06	9.64	6.29	25.0
Scenario 2	Gas 25%, Coal 45%	9.45	9.00	4.82	23.1
Scenario 3	Gas 35%, Coal 35%	10.03	8.23	4.81	22.7
Scenario 4	Gas 45%, Coal 25%	10.84	7.48	5.18	23.0
Scenario 5	Gas 55%, Coal 15%	11.89	6.57	5.81	23.8

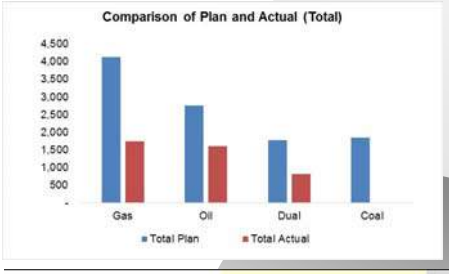


C-2 Power Development Plan

Current Status and Issues

● PSMP2010 Review

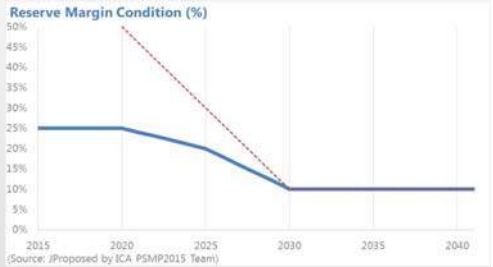
Gap between in the planed capacity in PSMP2010, and the actual installation/COD from 2010 to 2015.
Coal : 0%
Gas/Oil/Dual: 50%



Fuel-wise			Gas	Oil	Dual	Coal	Total
Total	[MW]	Plan	4,126	2,743	1,767	1,850	10,486
		Actual	1,739	1,598	807	-	4,144
	[%]		42%	58%	46%	0%	40%
Average	[%]			49%		0%	

● Reserve Margin (RM)

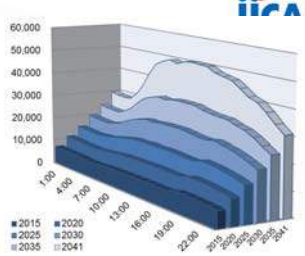
Ideal reserve margin and its with consideration of uncertainty of investment/ construction delay risks.

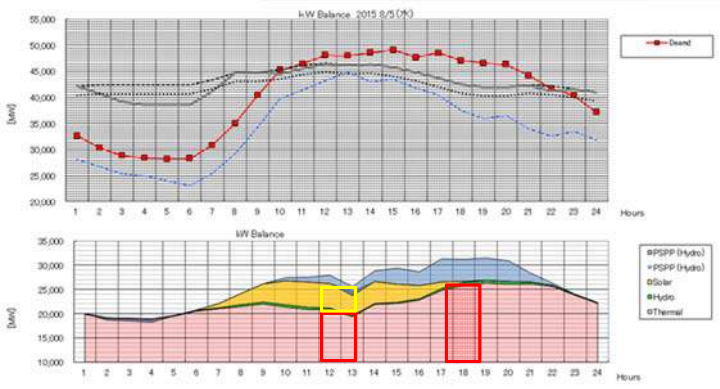


C-2 Power Development Plan

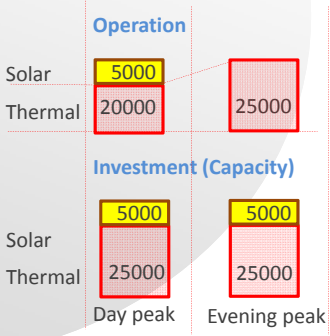
Challenging for Expansion of Renewable, Importance of Green Energy

The introduction of a **5,000 MW solar** power plant has created a time in a day when 5,000 MW of the installed capacity of a thermal power plant remains unused, or a **total of 30,000 MW of installed capacity,** and 5,000 MW solar and **25,000 MW thermal** power plants, respectively, are required for meeting the daytime peak demand of 25,000 MW.





Shifting evening peak to daytime peak between **2030 and 2035**



C-3 Renewable Energy

Current Status and Issues

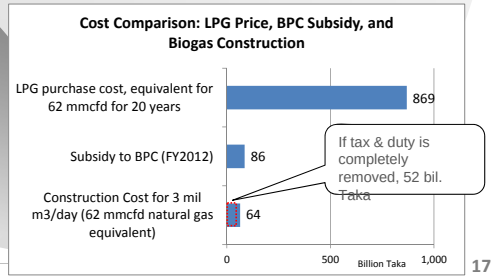
- Bangladesh has vast **solar PV potential**. However the **land availability** for solar park is quite limited, if the non-agricultural land use policy is properly complied.
- **Potential of wind** , waste to energy and micro/mini grids are yet confirmed and further studies are required.
- Currently only limited number of utility-scale RE generations exist, but several utility-scale solar PV projects are in progress.
- Bangladesh has **vast biogas potential**. However, several barriers such as poor quality of digester result in only 4 mmcfd "natural gas worth" biogas production per day.

Technology	Capacity (MW) WITH land limitation	Capacity (MW) WITHOUT land limitation
Solar Park	1400	18,978
Wind Park	637*	1,033*
Solar Rooftop	635	635
Solar Home Systems (SHS)	100	100
Solar Irrigation	545	545
Biomass Generation	275	275
Biogas Generation	10	10
Waste to Energy	1**	1**
Small hydro power plants	60	60
Mini-grid, Micro-grid	3**	3**
Total	3,666 or more	21,640

Note: * The potential might be revised upwardly based on the USAID-supporting Wind Resource Assessment to be completed in 2017.
** Capacity of waste to energy and mini-grid, micro-grid are based on the existing plans, not on the actual potential. For waste to energy, the actual technical potential estimation requires established waste delivery procedures to a power station.

Future Goals

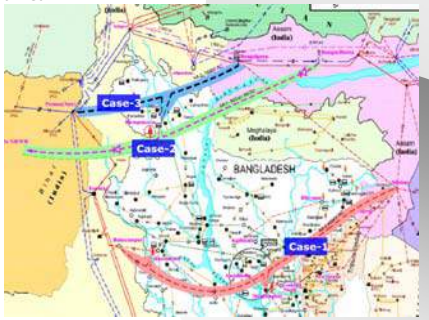
- Additional **3,700 MW or more** RE power generation should be developed by 2041.
  - Transparent and competitive bidding process
  - FIT and auction system
  - Technical standards and regulation/rules for RE grid-connection
- Additional 3 million m³/day **biogas** (= **62 mmcfd**) should be produced by 2041. It is equal to **27% of Residential gas demand in 2041**.
  - Removal of import duty and levy on high-quality glass-fiber biogas digester → **Achieved**
  - Nurture of domestic glass-fiber biogas digester manufactures and dealers



C-4 Power Import

Current status and issues

- **Import Powers**, mainly from hydropower, can contributes **improvement of the quality of the power supply**, such as stabilization of network voltage and frequency, is a prerequisite.
- There is abundant **water power resource** potential in the countries surrounding Bangladesh, namely **Bhutan, Nepal, Myanmar**, and the **Indian** States of the North East and West Bengal.
- **Transmitting hydropower from Bhutan and Nepal** to Bangladesh is impossible without the consent of India, which is geographically located between Bangladesh and these countries. In order to tackle this problem, three new cases of inter-connection have begun to be planned



Possibility of International power trading in Bangladesh

Future goals

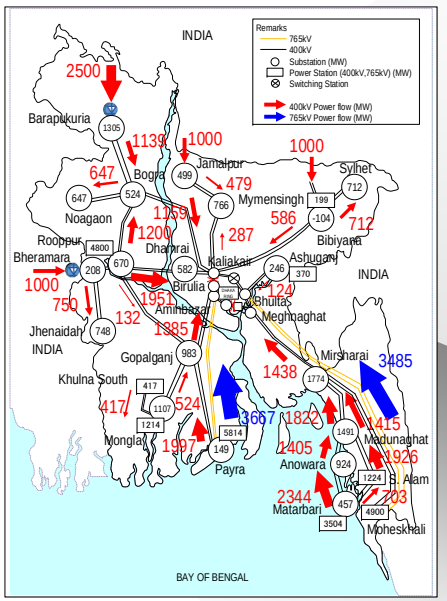
- It is expected that Bangladesh imports electricity out of such **hydropower generation via power interconnections** with such neighboring countries for **stable base load supply, energy fuel diversification**, and **climate change mitigation**.

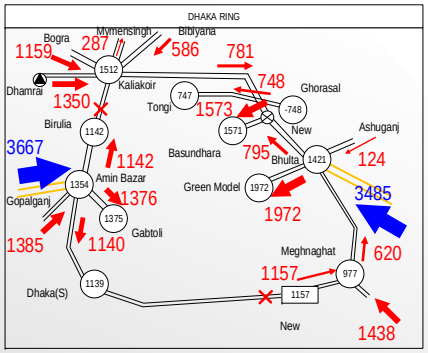


Power supply and demand situation in 2041

C-5 Transmission Analysis

Future Goals



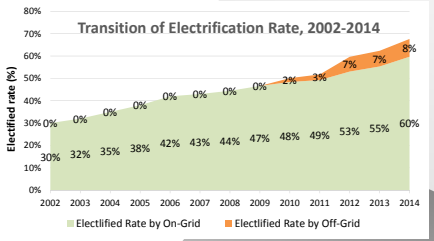


- **The locations of gas-fired power stations should be identified** by considering location of LNG receiving points as well as GAS infrastructure and transmission line.
- In case of Matabari and Payra where LNG import facility is planned, **765kV transmission lines are required from power center to load center.**

C-6 Rural Electrification (Distribution)

Current Status and Issues

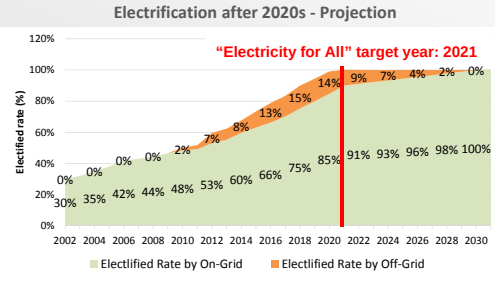
- In total **68%** Bangladesh population were electrified in 2014 (60% by on-grid, 8% by off-grid).
- The explosive increase of **SHS** contributes to the electrification.



- **Another 140,000 km** line is required for on-grid electrification. BREB has already plans to add 120,000km.
- About **14,000 km** to cover non-electrified areas have technical difficulties for grid extension (e.g. far from PGCB line, population scarce, river-crossing). **If** electrification is met only by the **grid-extension**, it would take **until 2030s**.
- After the on-grid electrification is completed, millions of **SHS wastes** would occur.

Future Goals

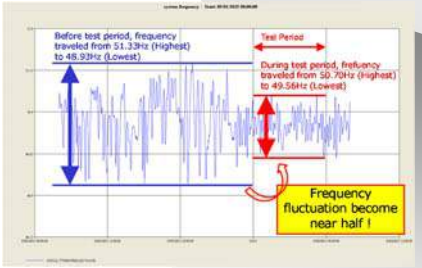
- A **good communication** and coordination between **BREB** and **IDCOL** is required to **complement** electrification projects, and **achieve "Electricity for All" by 2021**.
- Only one **definition of electrification rate** should be selected and adopted to keep its integrity (currently there are three in Bangladesh).
- **SHS waste** will increase after early 2020s. The current recycling process should prove effective and scalable.



C-7 Power Quality

Current Status and Issues

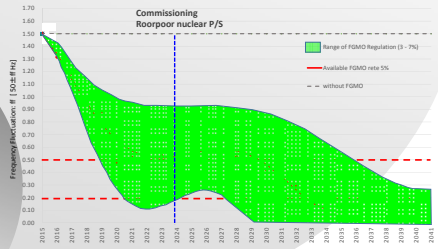
- Significant deficiency of power source including spinning reserve. Therefore the **load shedding operation was frequently performed before 2015**.
- **No application of automatic control** such as **LFC** and **Free-Governor Mode Operation**. Instruction by telephone communication only.
- **Currently frequency fluctuation is ± 1.5 Hz**. It causes **negative impacts to industry.**
- Inadequate coordination of daily generation scheduling between NLDC and GenCos.
- NLDC has less regulatory authority to make a balance between demand and supply.



Frequency Fluctuation Record during Test Operation in Khulna P/S

Future Goals

- **Sufficient reserves for FGMO** should be prepared in planned way enough to improve frequency fluctuation **within ± 0.5 [Hz]** (1/3 of present fluctuation)**before the commissioning of Roopoor nuclear power plants in 2024 and 2025.**
  Then frequency fluctuation level will reach **within ± 0.2 [Hz] as world's top quality in 2041.**
- **Improvement of Electricity Act and Grid Code Framework**.
  Add the provisions of various obligations for improvement of power quality in Electricity Act.
  Provisions for securing reserves in Grid Code should be enhanced

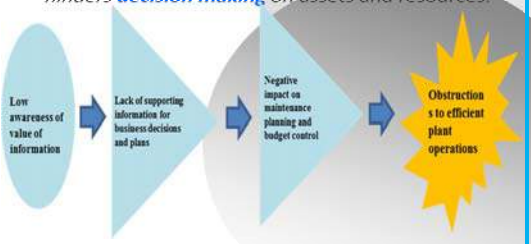


Trend of power frequency quality improvement

C-8 Thermal Power Plant O&M

Current Status and Issues

- The absence of **government supervision** allows low awareness of significance of maintenance.
- The lack of planning/budgeting undermines **preemptive maintenance** and scheduled shutdown.
- Insufficient training facilities with conventional training styles lead to scarcity of **qualified crew members.**
- The lack of supporting data and information hinders **decision making** on assets and resources.

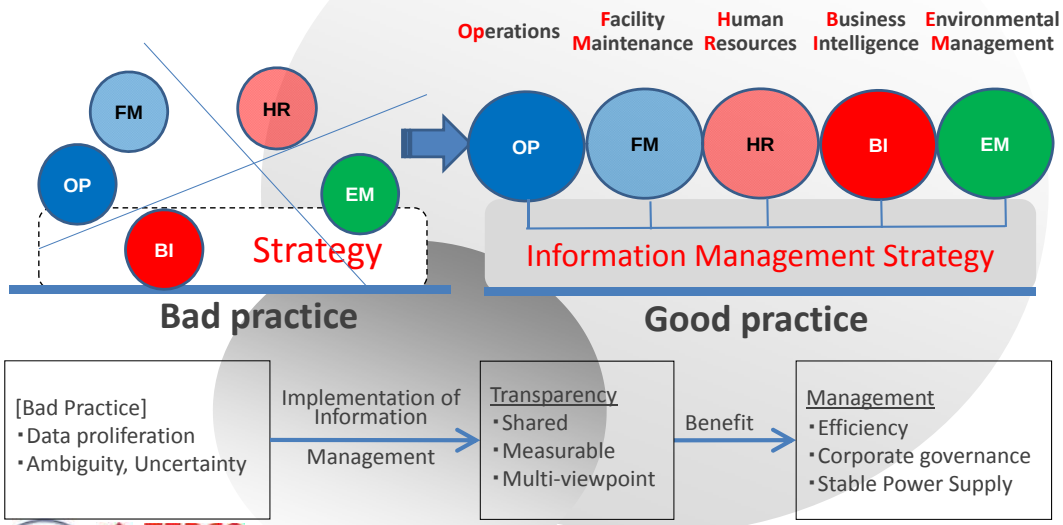


Future Goals

- Unit rehabilitation/conversion to combined cycle for the immediate needs for capacity enhancement is proposed.
- **Training facilities** with sophisticated training systems are prepared.
- Facility maintenance policies equipped with an **enforceable legal framework** and technological standards are made.
- An integrated information/data management platform is introduced to support asset/resource management for **higher efficiency and lowered shutdown impact.**

C-8 Thermal Power Plant O&M

Strategic Approach to Integrated Information Management



D Cost and Tariff Balance

D-1 Tariff Policy : (a) Natural Gas Price

Current Status and Issues

- Increment of natural gas price is indispensable in order to avoid serious financial deficit of Bangladesh Government.
- However, the result of GTAP showed that rapid annual increase of gas price gives huge negative impact on Bangladesh economy.

Future Goals

- **Progressive increase of domestic tariff (e.g. 10-20%/year increase until 2031 and 1.5%/year from 2032, or about 10%/year until 2041).**

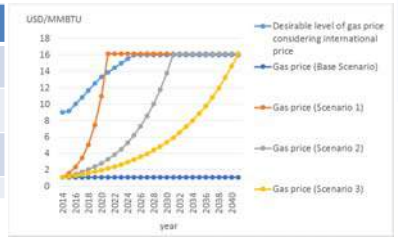
Result of GTAP analysis

Single year analysis

Scenarios	Average Gas Tariff Increase in USD
(a)	50%
(b)	100%

Time-series analysis

Scenario	Annual Increase of Gas Price in USD
Base Scenario	0%
1	47.2%/year until 2021 0%/year from 2022
2	17.3%/year until 2031 0%/year from 2032
3	10.6%/year until 2041



	(a) 50% Increase	(b) 100% Increase
Impact on real GDP (%)	-1.26	-2.47
Impact on real export (%)	-0.72	-1.35
Impact on real import (%)	-1.36	-2.70

Impact on real GDP (%)

	2014	2021	2031	2041
Scenario 1	-0.33	-5.13	0.52	0.18
Scenario 2	-0.02	-0.43	-2.82	0.09
Scenario 3	0.04	0.19	-1.08	-0.32

D-1 Tariff Policy : (b) Electricity Tariff

Current Status and Issues

- Increment of electricity tariff is indispensable for solving serious financial deficit of BPDB.
- However, the result of GTAP showed that rapid annual increase of tariff gives huge negative impact on Bangladesh economy.

Future Goals

- **Progressive increase of electricity tariff (e.g. 2.6%/year increase until 2031 and 1.5%/year from 2032).**

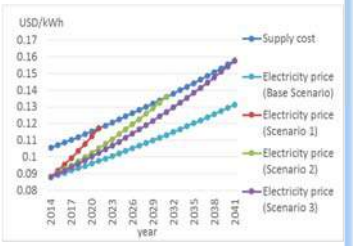
Result of GTAP analysis

Single year analysis

Scenarios	Average Electricity Tariff Increase in USD
(a)	10%
(b)	20%
(c)	30%

Time-series analysis

Scenario	Annual Electricity Tariff Increase in USD
Base Scenario	1.5%/year
1	4.2%/year until 2021 1.5%/year from 2022
2	2.6%/year until 2031 1.5%/year from 2032
3	2.2%/year until 2041



	(a) 10% Increase	(b) 20% Increase	(c) 30% Increase
Impact on real GDP(%)	-0.72	-1.45	-2.17
Impact on real export (%)	-0.28	-0.56	-0.83
Impact on real import(%)	-0.27	-0.55	-0.82

[Assumption] Supply cost increase 1.5%/year until 2041

Impact on real GDP (%)

	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.06	-0.06
Scenario 2	-0.07	-0.09	-0.17	-0.06
Scenario 3	-0.04	-0.06	-0.1	-0.15





TECHINICAL PART

PSMP2016 Key Discussion Points

A Economic Development
A-1 Economic Development

B Primary Energy Balance
B-1 Primary Energy Demand
B-2 Domestic Gas Supply
B-3 LNG Supply
B-4 Coal Supply
B-5 Oil Supply

C Power Balance
C-1 Power Demand Forecast
C-2 Power Development Plan
C-3 Renewable Energy
C-4 Power Imports
C-5 Transmission Analysis
C-6 Distribution
(Rural Electrification)
C-7 Power Quality
C-8 Operations and Maintenance

D Cost and Tariff Balance
D-1 Tariff Policy

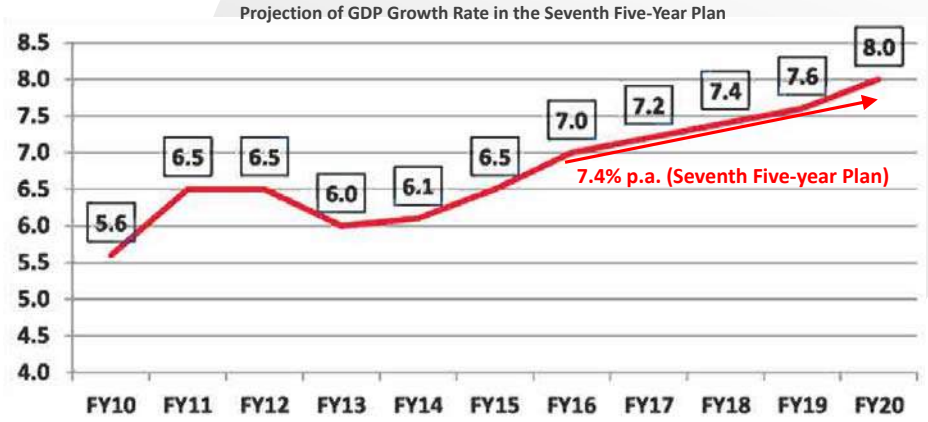
A Economic Development

A-1 Economic Development

GDP Projection

GoB's Seventh Five-Year Plan

- The Seventh Five-Year Plan of the Government of Bangladesh (Planning Commission) sets the country's GDP growth target to be 7.4% p.a. during the five-year period (FY2016-FY2020).
- The growth rate is expected to increase steadily from 6.5% in FY2015 to 8.0% in FY2020.
- The government sees that the upward trend of GDP growth rate since FY2013 is expected to continue.

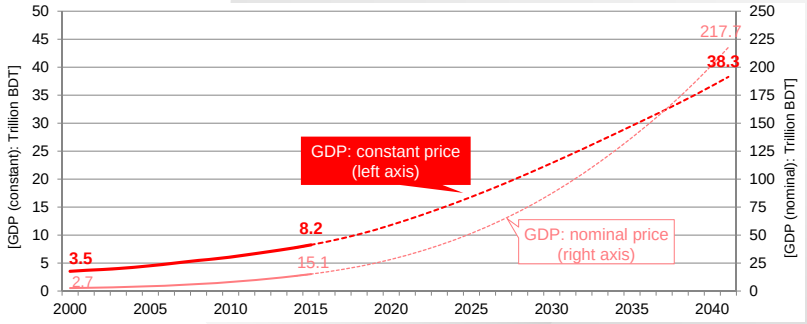


Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

Projection in PSMP 2015

- The study team considers that the 7.4% p.a. growth from 2016 to 2020 might be overstretching and that the growth rate between 6.5 and 7.0%, as projected by international organizations, may be more realistic.
- However, considering the consistency with the economic development plan officially made public by GoB, this study follows the GoB's economic growth target, i.e. 7.4% p.a. from 2016 to 2020, assuming that all the necessary policy measures to achieve this target will be optimally in place.
- Real GDP (constant at 2005 price) as of 2041 is estimated to reach 38 trillion BDT, about 4.6 times of the current level (8.2 trillion BDT). The average growth rate from 2016 to 2041 is 6.1% p.a.
- Nominal GDP (current price) is estimated to become about 220 trillion BDT in 2041.

GDP Projection Up to 2041



Average growth rate (real GDP)	
2011-2015	6.3%
2016-2020	7.4%
2021-2025	7.4%
2026-2030	6.3%
2031-2035	5.3%
2036-2041	4.4%
2016-2041	6.1%

Source: Prepared by the Study Team

Summary Tables of GDP Projection

- This study's projection of GDP (real, nominal, and PPP) up to 2041 is summarized as follows.
  - In projecting nominal GDP, inflation rate is expected to become gradually moderate, down to 3.2% in 2041.

Real GDP Projection (constant at 2005 price)

	2015	2020	2025	2030	2035	2041
GDP(million USD)	126,630	181,282	258,598	351,109	453,642	587,665
GDP(billion BDT)	8,245	11,804	16,838	22,862	29,538	38,265
Growth rate (USD, BDT)		7.4% p.a.	7.4% p.a.	6.3% p.a.	5.3% p.a.	4.4% p.a.
Exchange rate	65.1	65.1	65.1	65.1	65.1	65.1
Per Capita (USD)	787	1,063	1,444	1,883	2,357	2,970
Per Capita (BDT)	51,215	69,245	94,035	122,611	153,446	193,361

Nominal GDP Projection (current price)

	2015	2020	2025	2030	2035	2041
GDP(million USD)	194,300	340,576	585,615	943,451	1,423,643	2,175,520
GDP(billion BDT)	15,136	28,320	51,559	87,237	137,132	217,738
Growth rate (USD)		11.9% p.a.	11.4% p.a.	10.0% p.a.	8.6% p.a.	7.3% p.a.
Growth rate (BDT)		13.3% p.a.	12.7% p.a.	11.1% p.a.	9.5% p.a.	8.0% p.a.
Exchange rate	77.9	83.2	88.0	92.5	96.3	100.1
GDP deflator	5.8%	5.3%	4.8%	4.3%	3.8%	3.2%
Per Capita (USD)	1,207	1,998	3,270	5,060	7,396	10,993
Per Capita (BDT)	94,015	166,131	287,938	467,860	712,373	1,100,271

GDP Projection (PPP, constant at 2011 price)

	2015	2020	2025	2030	2035	2041
GDP(million USD)	504,770	722,625	1,030,822	1,399,588	1,808,308	2,342,549
Per Capita (USD)	3,135	4,239	5,757	7,506	9,394	11,837

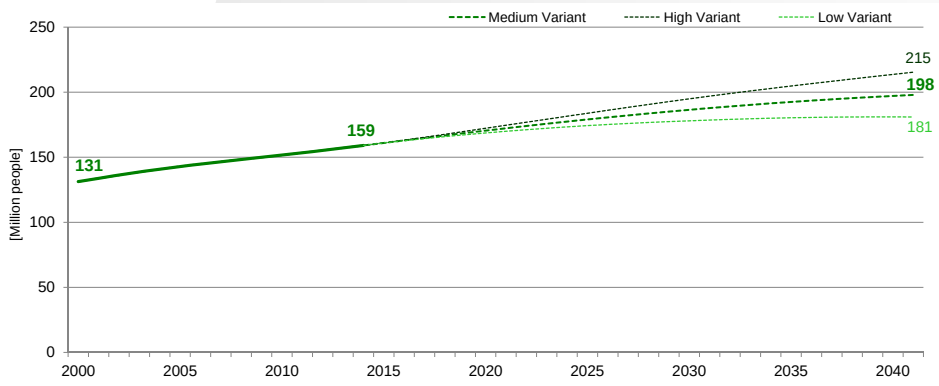
Source: Prepared by the Study Team

Economic Growth Scenario

Population Projection

- Population projection refers to United Nations' "World Population Prospects 2015". In the "Medium Variant" scenario (adopted for GDP projection), the population as of 2041 is expected to reach 198 million, i.e. 0.8% p.a. growth from 2014.
  - The growth rate is expected to decline from 1.2% to 0.4%.
- In the "Low Variant" scenario, the total population starts decreasing from 2039.

Population Projection Up to 2041

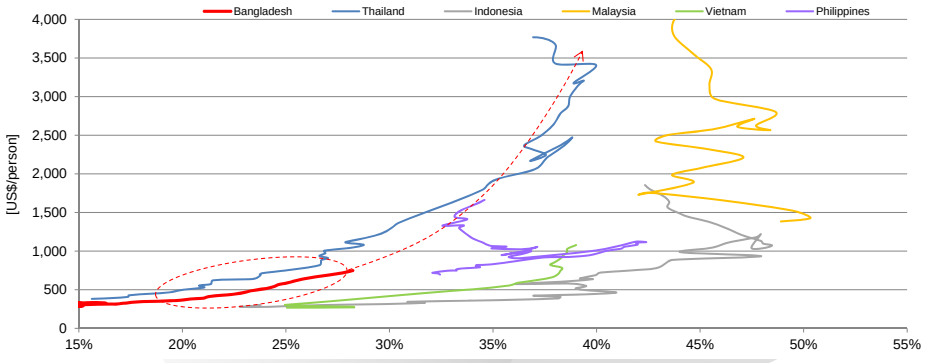


Source: United Nations "World Population Prospects 2015"

Economic Development Scenario for Bangladesh

- The following figure plots the relation between the share of industrial sector in GDP (horizontal axis) and the GDP per capita of Bangladesh and five ASEAN countries since 1960.
- As a general trend, the industrial sector's share in GDP increases up to a certain level along with the growth of GDP per capita.
- Bangladesh's GDP capita started increasing rapidly when the industrial sector's share exceeded 20%. Recently the trend curve has been taking a similar track to what Thailand experienced before.

Industrial Sector's Share in GDP and GDP per Capita (real GDP) of Bangladesh and ASEAN Countries (1960-2014)

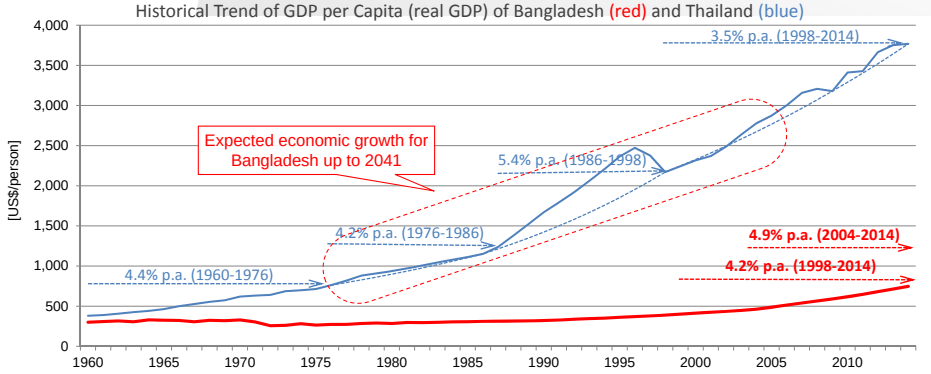


Source: Prepared by the Study Team using World Bank database

Economic Development Scenario for Bangladesh (continued)

- Bangladesh's GDP per capita as of 2014 (747 USD) was almost equivalent to that of Thailand around 1976.
- Bangladesh saw a 4.2% p.a. growth of GDP per capita from 1998 to 2014 (16 years). This can be compared with Thailand's growth rate (4.4% p.a.) from 1960 to 1976 (16 years).
- Assuming that Bangladesh follows the track of Thailand's economic growth in the past, the accelerated growth is expected to continue.
- In addition, considering the follower advantage for Bangladesh (4.9% p.a. growth for the past 10 years), the growth rate of GDP per capita can be still higher than the past track of Thailand.

Historical Trend of GDP per Capita (real GDP) of Bangladesh (red) and Thailand (blue)

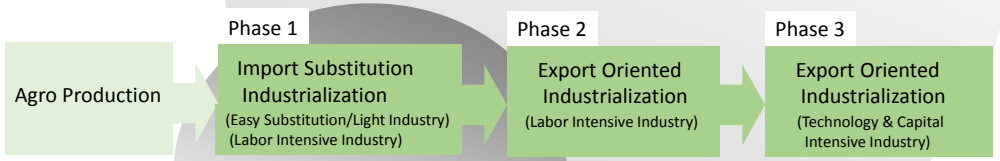


Source: Prepared by the Study Team using World Bank database

Policy Measures for Promoting Industrial Development

Process of Industrialization

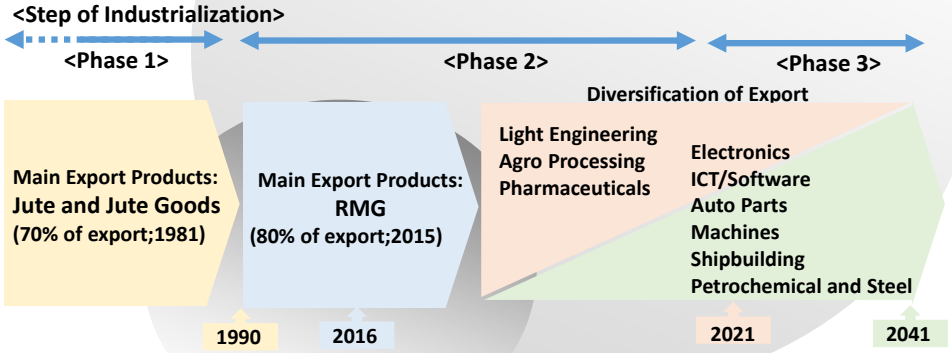
- Manufacturing is the driver of industrial growth, and the main driver of manufacturing growth is the export market as mentioned in 7th FIVE YEARS Plan.
- According to the academic researches, it is found that there are 3 phases for industrialization in Asian developing countries.
  - Phase1: Import Substitution Industrialization by labor intensive and light industries under infant industry protection policies.
  - Phase2: Export Oriented Industrialization by labor intensive industries like textile and footwear industry under export industry development policies.
  - Phase3: Export Oriented Industrialization by technology and capital intensive industries like metal parts and machine industry.



Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

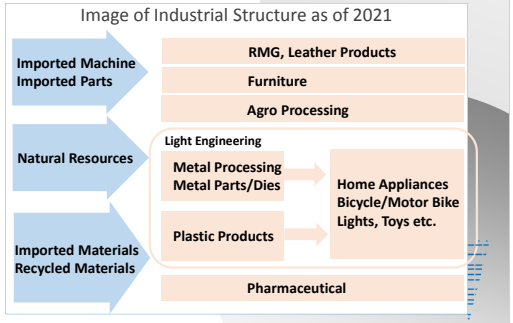
Future Image of Industrial Development in Bangladesh

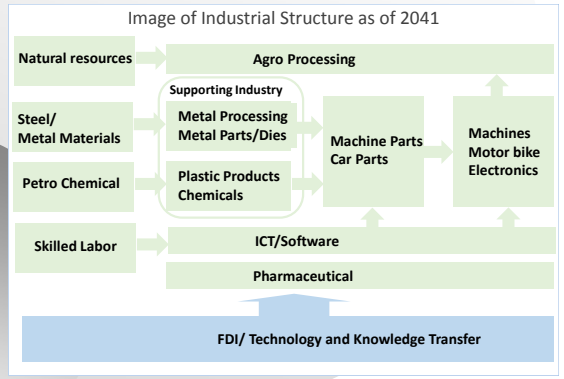
- Jute and Jute goods were main export products at the beginning of 1980s in Bangladesh.
- It is said that Bangladesh proceeded from Phase1 to Phase2 around 1990 and now Bangladesh is in the Phase2 whereas Thailand proceeded from Phase1 to Phase2 around 1971 and entered into Phase 3 in the middle of 1980s.
- Until 2021, although the Bangladesh economy will remain depending much on traditional industries, RMG, Jute and Leather etc., new industries will expand gradually and the export products will be diversified during the same period and from 2021 this tendency will be accelerated.



Future Image of Industrial Structure in Bangladesh

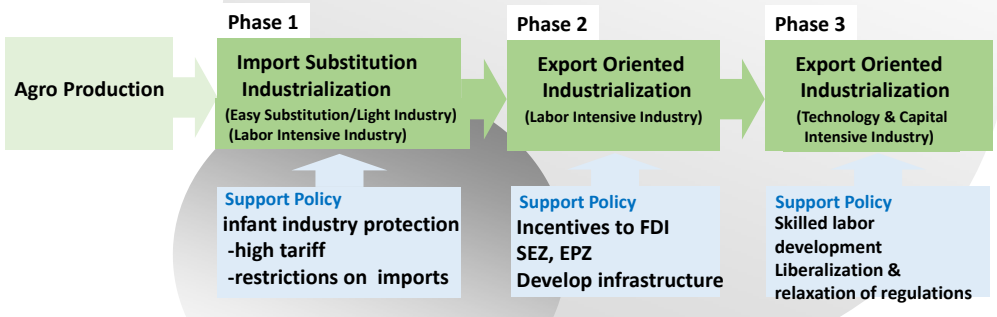
- Until 2021, Bangladesh Industry will depend on natural resources, imported materials and imported parts & machines and will diversify gradually including Light Engineering and Pharmaceutical.
- After 2021 towards 2041, Bangladesh Industry will be able to provide row materials and machines for itself and will be a high value added industry by introducing FDIs and taking advanced technologies and knowledges.
- Agro industry is always important because it can absorb huge labor force and can secure food supply. Furthermore Agro industry can be high value added industry by agro processing. We can see a good example of agro processing in present Thailand.





Measures Needed for Industrialization in Bangladesh

- For Import Substitution Industrialization, policies for infant industry protection may be necessary (ex. High tariff, restriction on imports).
- For Export Oriented Industrialization, policies on provision of incentives to FDI, construction of Industrial zone like SEZ for foreign enterprises and development of various infrastructures like port ,road, railway, power supply are needed.
- In the stage of Phase3, in addition to the above mentioned policies in Phase2, skilled labor development and liberalization & relaxation of regulations are needed for realizing the industrialization among international competition.



B Primary Energy Balance

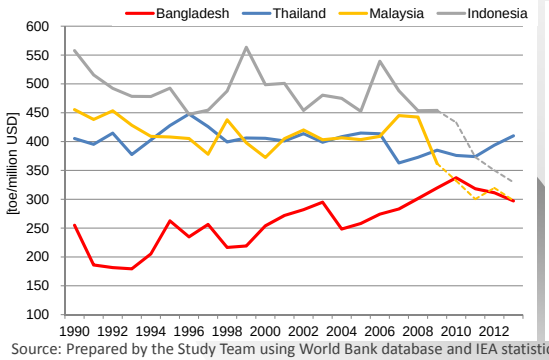
B-1 Primary Energy Demand

Industrial Sector Energy Demand

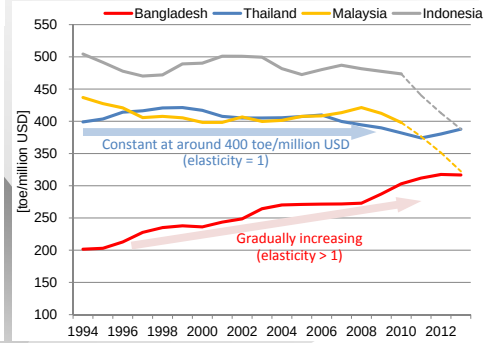
GDP Elasticity of Industrial Sector's Energy Consumption

- This study analyzed the industrial sector's energy intensity, i.e. energy consumption divided by the sectorial valued added (= GDP) of manufacturing (not the total GDP), which indicates how much energy (toe) is consumed for the industrial sector to yield a value of 1 million USD.
  - If this ratio is constant, GDP elasticity of energy consumption is 1.
  - If this ratio increases/decreases from the previous year, GDP elasticity is higher/lower than 1.
- Whereas this ratio is relatively constant in Thailand, Malaysia and Indonesia, Bangladesh has seen a gradually increasing trend.

Industrial Sector's Energy Consumption per Sectorial Value Added



(5-year moving average)

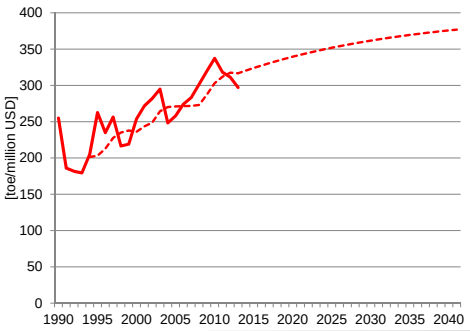


Source: Prepared by the Study Team using World Bank database and IEA statistics
Note: Declining trend of energy consumption in Malaysia and Indonesia from 2010 is considered a statistical error

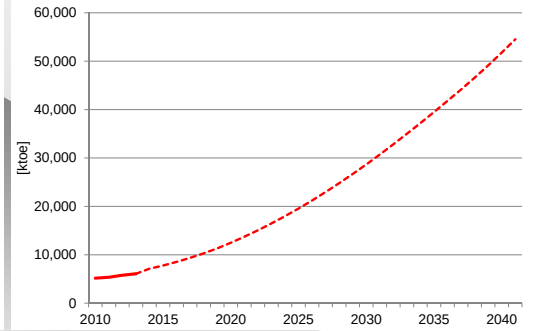
Projection of Industrial Sector Energy Consumption

- The main reason why the ratio of industrial sector's energy consumption to sectorial GDP is creeping up (GDP elasticity higher than 1) in Bangladesh is that the economic development is still at an early stage and that a shift from labour-intensive industries to energy-consuming industries is still in process.
- This study projects that this trend is expected to continue and the energy consumption of the industrial sector will be about 54,500 ktoe, about nine times increase from 2013.

Energy Consumption per Sectorial Value Added (projection)



Sectorial Energy Consumption (projection)

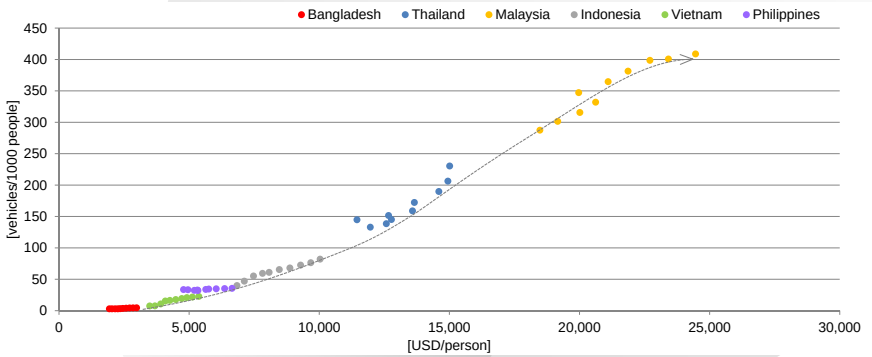


Transport Sector Energy Demand

General Trend of Motorization

- The following figure shows a correlation between GDP per capita and motorization rate in ASEAN countries.
- When the economic development comes to a certain level, motorization rate increases rapidly.
- The motorization rate of Bangladesh is expected to follow those of ASEAN countries.

Historical Trend of GDP per Capita (PPP) and Motorization Rate

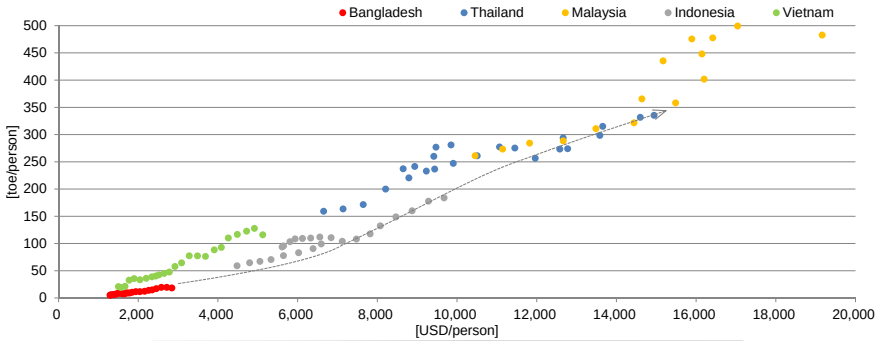


Source: Prepared by the Study Team using World Bank database and OICA statistics

General Trend of Energy Consumption

- The growth of transport sector's energy consumption is expected to take a S-shaped curve so that:
  - Energy consumption increases acceleratedly when the economic development comes to a certain level and the car ownership (motorization) increases rapidly;
  - The growth rate of energy consumption becomes moderate when the economic development reaches a certain level of maturity and the transport with private vehicles is taken over by the advanced public transport system especially in the urban area.
- The following figure shows that the historical trend of transport sector energy consumption in ASEAN countries is tracing a S-shaped curve.

Historical Trend of GDP per Capita (PPP) and Transport Sector's Energy Consumption per Capita

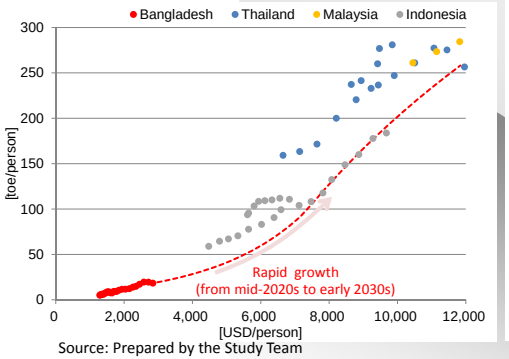


Source: Prepared by the Study Team using World Bank database and IEA energy balances

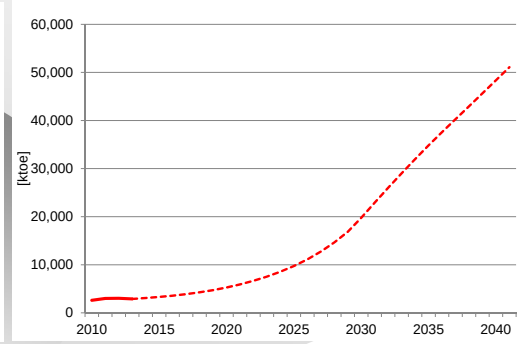
Projection of Transport Sector Energy Consumption

- Referring to the historical trend of Indonesia and Thailand that the transport sector's energy consumption per capital starts growing steeply when GDP capita reached around 5,000-6,000 USD and the growth becomes moderate when it exceeds 8,000 USD, this study considers that the car ownership increases rapidly during that period.
- Bangladesh is expected to follow this track, i.e. the transport sector energy consumption, driven by car ownership, will increase rapidly from mid-2020s to early 2030s.
- The sector's energy consumption will reach around 51,000 ktoe in 2041.

Sectorial Energy Consumption per Capita (projection)



Sectorial Energy Consumption (projection)



Source: Prepared by the Study Team

Civilian Sector Energy Demand (Residential & Commercial)

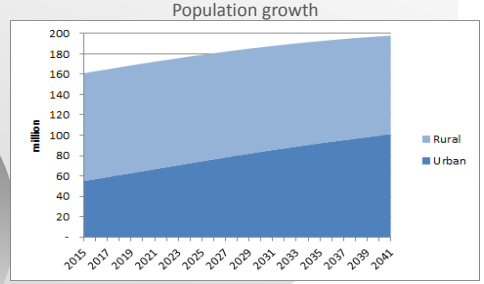
Residential Sector: Assumptions

Key Assumptions

		2014		2031		2041
		Urban	Rural	Urban	Rural	Urban/Rural
Population (thousands)		159,078		187,779		197,134
Urban population (% of total)		34%		46%		51%
Rate of electrification (%)		74%		100%		100%
Energy source	Air conditioner	Electricity (Fans,ACs)	Electricity (SHS) (Fans)	Electricity (ACs)	Electricity (SHS) (Fans, ACs)	Electricity (ACs)
	Cooking (fridge/refridge)	Electricity	-	Electricity	Electricity (SHS)	Electricity
	Cooking (heating), Heating water	Natural gas	Biomass, Natural gas	Natural gas	Biomass, LPG	LPG, Natural gas, Biomass
	Lighting	Electricity(fluorescent light)	Kerosene, Electricity (SHS)	Electricity(LED)	Electricity(LED)	Electricity(LED)

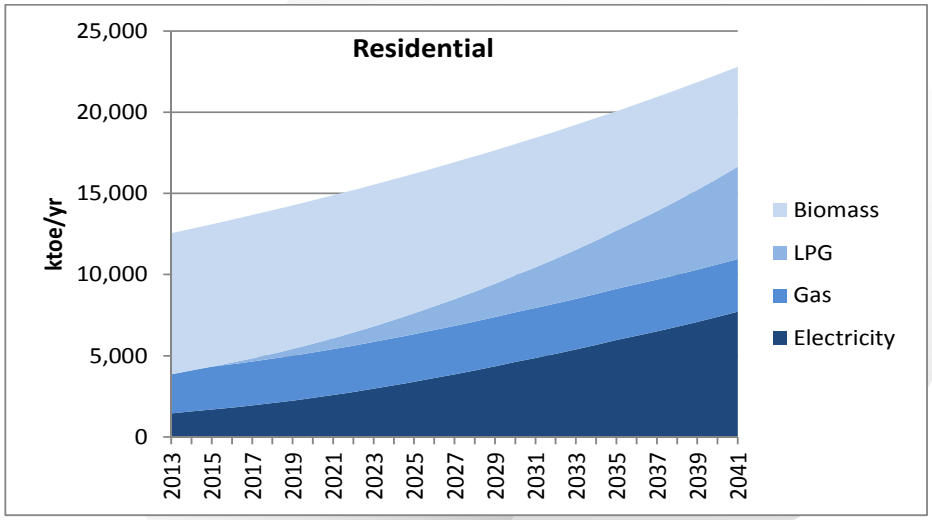
- Population will steadily grow with half of them residing in urban areas by 2041.
- 100% electrification will be achieved by 2021.
- Replacement of biomass and natural gas with LPG for cooking purpose will be encouraged.
- Energy efficient home appliances such as ACs, refrigerators, fans and LEDs will be promoted. Policies will promote improved (more efficient) cook stoves (70% of biomass , 40% of gas cook stoves' market share).

Population growth

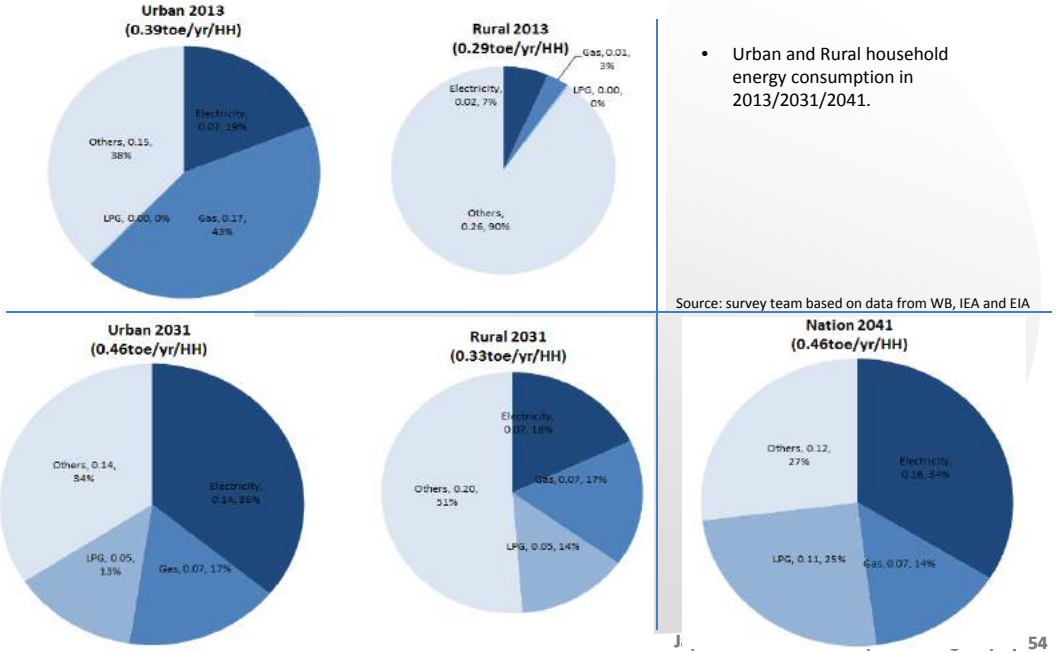


Source: UN" World Population Prospects 2014,2015"

Residential Sector: Energy Demand Forecast



Residential Sector: Forecast (snapshots)



- Urban and Rural household energy consumption in 2013/2031/2041.

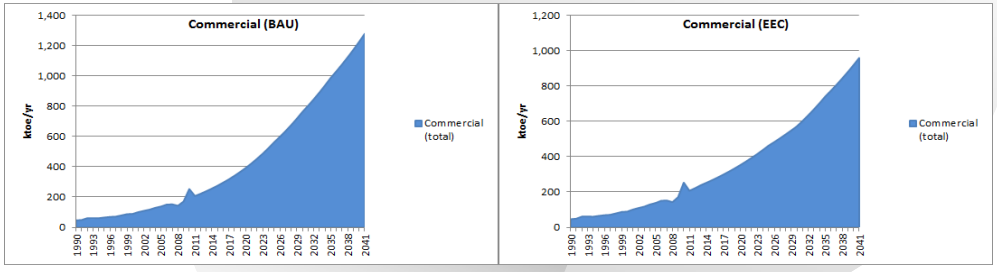
Source: survey team based on data from WB, IEA and EIA

Commercial Sector: Assumptions and Energy Demand Forecast

Key Assumptions

- The commercial sector will continue to grow.
- Various policies and programs will be implemented, therefore energy efficiency in buildings will be improved, achieving 25% energy reduction compared to Business as Usual by 2030.

Energy Demand Forecast



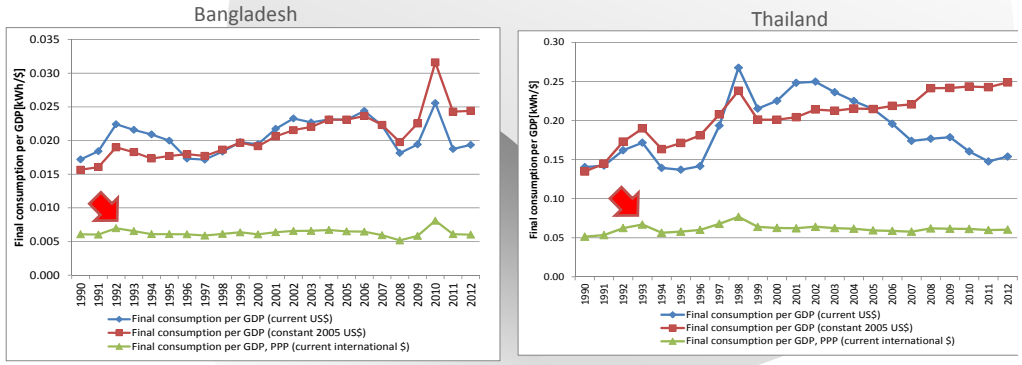
Commercial Sector: Current status and Forecast

Current Data

- IEA data for total energy consumption in commercial sector.

Forecast

- The ratio against PPP-based GDP sees an almost flat line, implying a possibility of strong correlation.

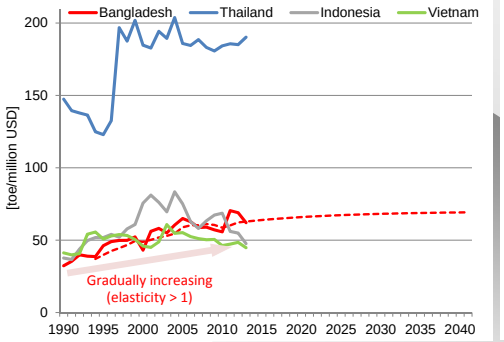


Agricultural Sector Energy Demand

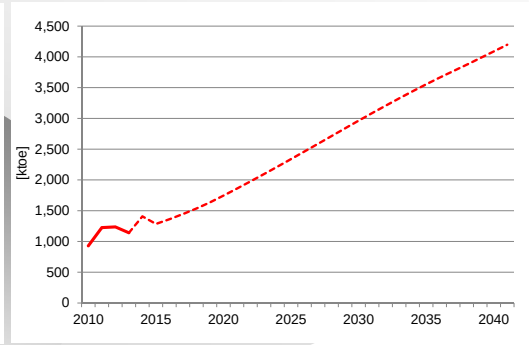
Projection of Agricultural Sector Energy Consumption

- Agricultural sector's energy intensity, i.e. a ratio of energy consumption to sectorial valued added (= GDP) is formulated to analyze how much energy (toe) is consumed for the sector to yield of 1 million USD.
- In Bangladesh, energy intensity has taken an gradually increasing trend (GDP elasticity > 1), which is considered due to the modernization of production process. In the meanwhile, in Indonesia and Vietnam, where the energy intensity is almost as high as in Bangladesh, a constant or declining trend is observed.
- This study assumes that the sector's energy intensity will be almost constant and projects that the sector's energy consumption will reach around 4,200 ktoe in 2041, about four times increase from 2013.

Energy Consumption per Sectorial Value Added (projection)



Sectorial Energy Consumption (projection)

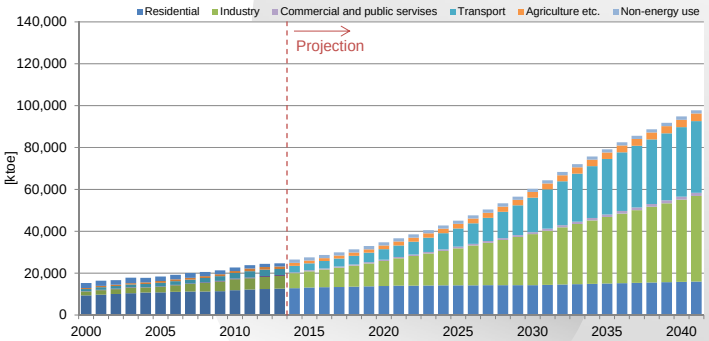


Energy Supply & Demand Balances

Total Final Energy Consumption (BAU Case)

- The total final energy consumption of Bangladesh in the BAU case, i.e. without additional energy efficiency measures, is expected to reach about 136,000 ktoe in 2041, about 5.5 times growth (6.3% p.a.) from 2013.
- While the residential sector sees a relatively moderate growth (2.2% p.a.), the industrial sector will grow faster (7.1% p.a.) and become the largest sector of energy consumption from mid-2020s.
- The energy consumption of the transport sector will grow still faster (11.0% p.a.) and will become the second-largest sector of energy consumption.
- Scenarios of energy consumption considering energy efficiency target will be discussed in the later section.

Projection of Total Final Energy Consumption (BAU Case)



Sectors	TFC in 2041 (ktoe)	Growth ('14-'41)
Residential	22,797 (17%)	2.2%
Industrial	54,526 (40%)	7.1%
Commercial & Public Service	1,776 (1%)	5.1%
Transport	51,187 (38%)	11.0%
Agriculture	4,197 (3%)	4.1%
Others	47 (0%)	0.4%
Non-energy use	1,534 (1%)	-
Total	**136,604 (100%)**	**6.3%**

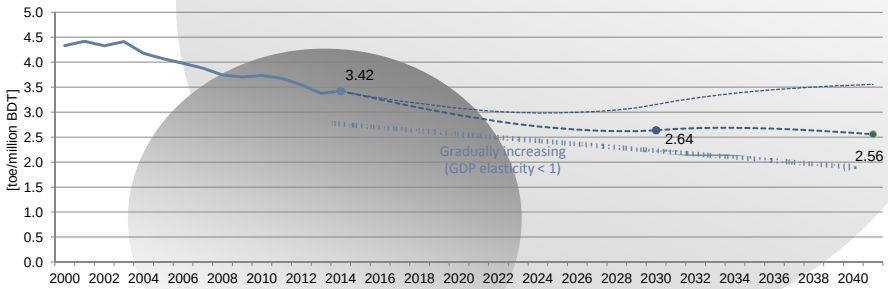
Energy Efficiency Target Setting

- The JICA study suggests that energy efficiency measures are to be implemented in Bangladesh so that the energy intensity will be lowered to
  - 2.64 toe/million BDT in 2030 (down -23% from 2014) and
  - 2.56 toe/million BDT in 2041 (down -25% from 2014)

* The definition of energy intensity is different from that in JICA's Energy Conservation Master Plan (ECMP: March 2015), in that:
- ECMP's energy intensity does not include transport sector energy consumption and biofuel consumption in the residential sector;
- Instead ECMP takes into account the combustion loss during power generation;

Using the definition of Energy Conservation Master Plan, the energy intensity as of 2030 is 2.44 toe/million BDT, down -20% from 3.04 toe/million BDT in 2014, and the energy intensity will be around 2.33 toe/million BDT in 2041.

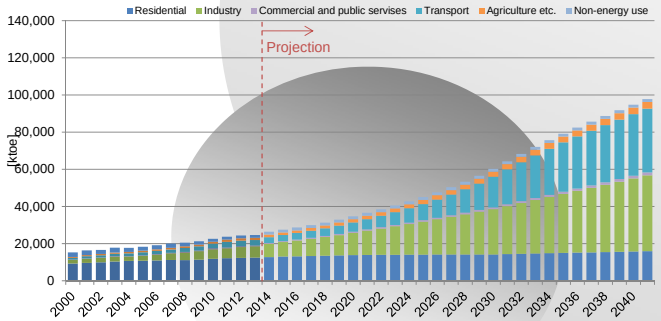
Historical Trend and Projection of Energy Intensity (considering energy efficiency measures)



Energy Efficiency Target Setting

- After considering the energy efficiency, the total final energy consumption in 2041 will be 97,805 ktoe, about 4.0 times increase from 2013 (5.0% p.a.).
- In order to achieve this, the energy efficiency target for each sector needs to be achieved as follows:
  - Residential sector: 30% reduction from BAU case;
  - Industrial sector: 25% reduction from BAU case;
  - Commercial & public sector: 15% reduction from BAU case;
  - Transport sector: 33% reduction from BAU case;
  - Agriculture: 15% reduction from BAU case;

Projection of Total Final Energy Consumption (Energy Efficiency Scenario)

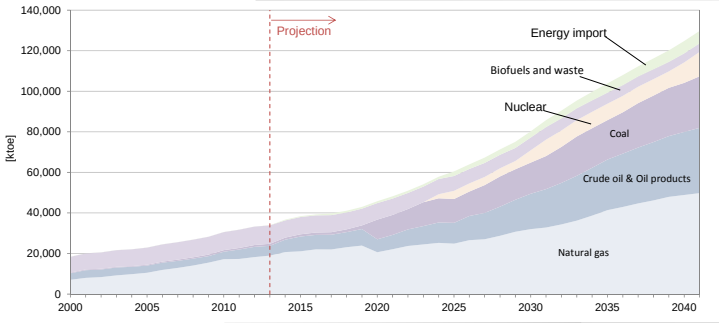


Sectors	TFC in 2041 (ktoe)	Growth ('13-'41)
Residential	15,958 (16%)	0.9%
Industrial	40,894 (42%)	7.0%
Commercial & Public Service	1,510 (2%)	4.5%
Transport	34,295 (35%)	9.2%
Agriculture	3,568 (4%)	4.2%
Others	47 (0%)	0.4%
Non-energy use	1,534 (2%)	-
Total	**97,805 (100%)**	**5.0%**

Primary Energy Supply (Scenario 3)

- Based on the projection of total final energy consumption as seen in the previous slide, the total primary energy supply is forecasted as shown in the following figure.
- In this projection, which is based on Scenario 3 of power development plan (i.e. gas and coal account for 35% each in power generation capacity (MW) in 2041), the share of natural gas and oil products in transport sector won't change (i.e. about 1:2). The share of fossil fuel sources may vary depending on the choice of scenarios.

Projection of Total Primary Energy Supply (Scenario 3)



Primary Energy	2041 ktoe	2041 (share)	Growth ('14-'41)
Natural gas	49,783	(38%)	3.3%
Oil	32,162	(25%)	6.4%
Coal	25,401	(20%)	12.6%
Nuclear	12,029	(9%)	-
Hydro, Solar, Wind etc.	199	(0%)	6.6%
Biofuels & Waste	4,086	(3%)	-2.7%
Electricity (import)	6,027	(5%)	10.8%
Total	**129,687**	**(100%)**	**4.8%**

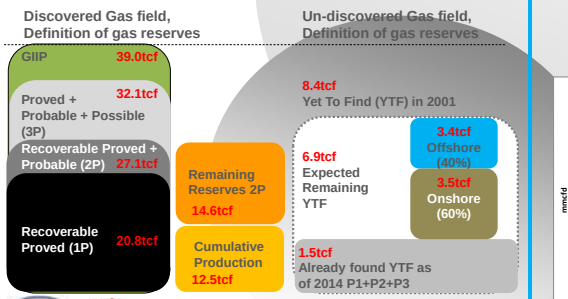
B-2 Domestic Gas Supply

PSMP2016 Technical

Domestic Gas Supply

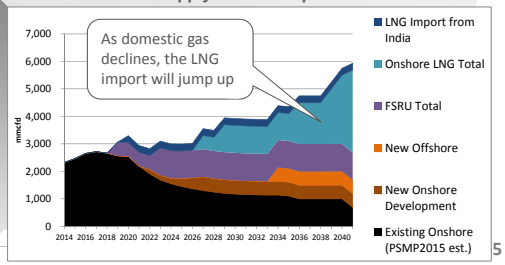
- Gas Supply from current domestic gas field will peak out in 2017-2018, and decline thereafter.
- Recoverable proven reserve of natural gas is 20.8TCF. 12.5 TCF has been produced and consumed by 2014. Remaining gas reserve will be 8.3 TCF (Reserve to Production ratio is 9.5 years).
- Current gas development performance is not satisfactory.
- New gas fields need to be explored and developed in an efficient manner.

GIIP and YTF 2015 Update



- Domestic gas 2,000 mmcfd should be produced in 2041.
  - Current PSC should be reviewed to attract IOCs. Technologically advanced and financially sound IOCs should be invited to onshore/offshore field development under revised PSC.
  - Strategic partnership between IOCs and domestic production companies should be considered.
  - Role of BAPEX should be revised and include acquisition of energy resources in overseas.
  - The efficiency of gas use to save indigenous gas resources should be improved. Legal framework needs to be introduced to discourage inefficient use.

Gas Supply Scenario up to 2041

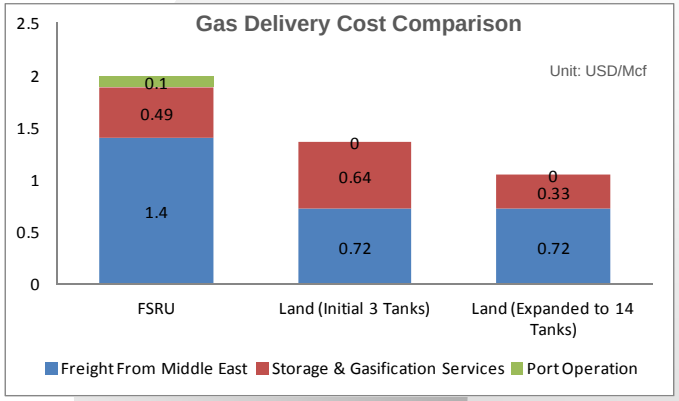


B-3 LNG Supply

PSMP2016 Technical

Economic Comparison b/w FSRU and Land-based LNG terminal

- The longer term, the more land-based LNG terminal has economic competitiveness over FSRU

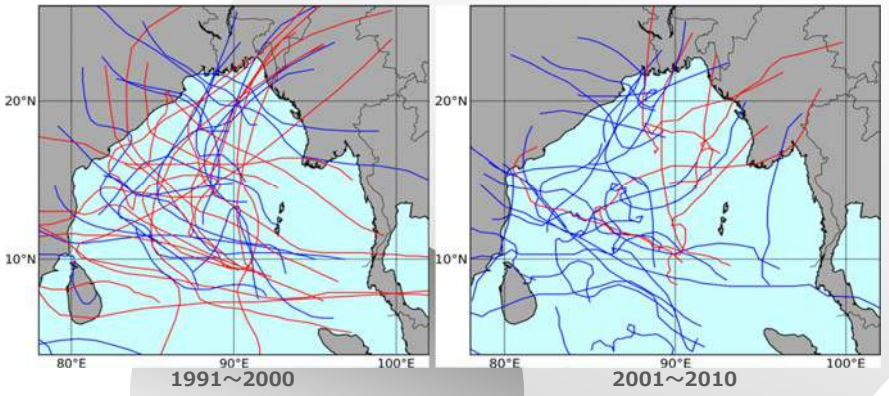


PSMP2016 Technical

FSRU – Cyclones may impact to its operation

- Supply Risk and Downtime, and Storage Capacity need to be considered.

Cyclone Outbreak Record in the Bay of Bengal

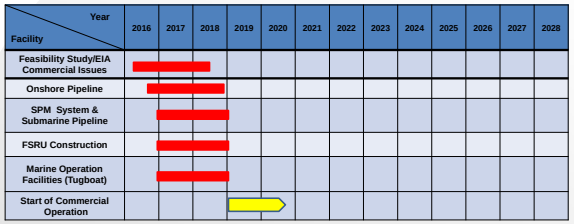


Legend:
Red : Larger than 32 m/sec
Blue: Smaller than 32 m/sec

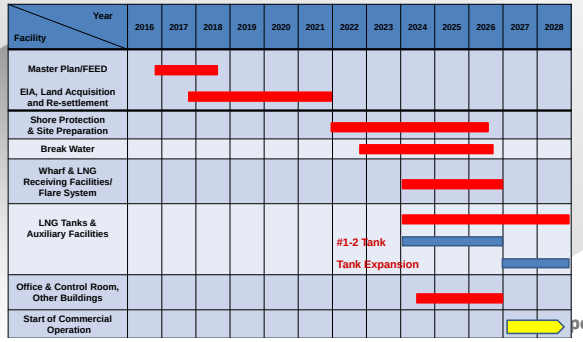
However FSRU has advantage on the short-term terminal delivery

- Normally FURU takes about only three yeas from planning to the terminal delivery, while land-based terminal takes 7 to 10 yeas since it involves land acquisition and resettlement issues.

FSRU
Typical Project Timeline



Land-based LNG terminal
Typical Project Timeline



Next steps for LNG Import

LNG should be imported effectively and a comprehensive study to cover short term and long term issues to be carried out.

- Gas supply risk and storage capacity in view of cyclone influence should be reviewed.
- LNG Purchase Strategy
  - Use of Spot market in addition to long term contract.
    - Fluidization of LNG Market has started. Relying on long-term “Take or Pay” is considered risky.
- Joint infrastructure projects with neighboring countries should be pursued.
- Introduction of Advanced Gas Infrastructure Control System
  - Change from “Allocation Based Operation” to “Demand Based Operation”
    - Under the unrestricted gas supply condition, gas operator should supply gas to meet the demand profile of each customers.
  - Attain Safe Operation and Minimize “lost Profit Opportunities”
    - Gas in and out balance should be monitored and location of leak or system loss should be identified.

Next steps for LNG Import

- Electronic Mapping System
  - Electronic Mapping System is to support the advanced control system, preventive maintenance, operation safety and emergency transaction, and asset management.
    - Gas infrastructure asset, i.e., pipes, fittings, pressure gages, governors, and valves etc. should be registered and linked with GPS
    - Accurate transmission and distribution model in the computer with appropriate Supervisory Control and Data Acquisition (SCADA) System allows to monitor accurate gas flow and assist in directing emergency transaction.
- Impact to Gas Processing Facilities
    - With the introduction of LNG, pressure balance of the gas system may be changed and this may cause insufficient condensate separation at the gas field facilities. This needs to be investigated.

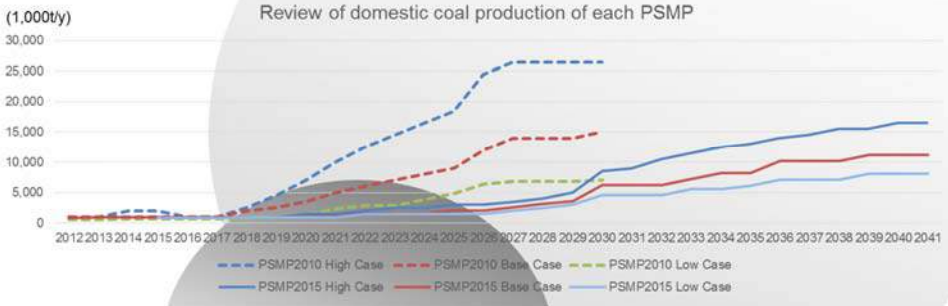
B-4 Coal Supply

Coal Review

National Coal Development Policy

PSMP2010 Review

[Fact Finding]



The reasons that lowered amount of production of PSMP2015 in comparison with PSMP2010 are following the fact that;

(1) Coal Policy was almost ready for publication and domestic coal development was strongly recommended by the Government in PSMP2010.

(2) Domestic coal development is in a difficult social situation in PSMP2015, urging for coal import.

Coal

National Coal Development Policy

The present situation of the coal policy

[Fact Finding]

No particular new movement is observed regarding the coal policy.

[Discussion and Proposal]

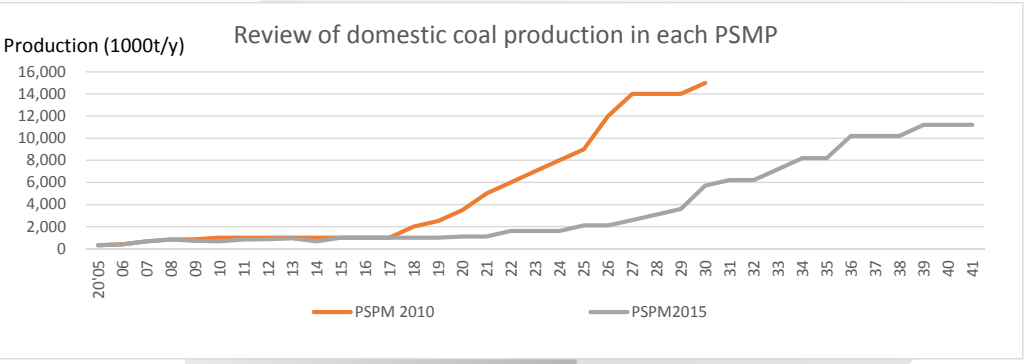
- The coal is the cheapest primary energy resource at present and in the future.
- On the other hand, a coal-fired power station in the Southern Asia including Bangladesh is increasing rapidly, and coal demand is increasing simultaneously.
- As a result, supply, quality and price of import coal become very unstable.
- Therefore, domestic coal development policy becomes important in future, since abundant coal of high grade quality is available in Bangladesh.

Coal

National Coal Development Policy

PSMP2010 Review

[Fact Finding]



Coal

Current Situation and Issues of Supply and Demand of Domestic Coal

Coal reserve of each coal field and estimated minable coal reserve

[Fact Finding]

As new coal development fields, Dighipara and Khalaspir will be selected. But they are still waiting for a mining approval from government, though they completed Feasibility Study.

Table 8-3 Minable Coal Reserve depending on Mining Method

	Coal field name	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured reserves (million tons)	Mining method	Minable coal reserve (million t)
1	Barapukuria (Dinajpur)	118 -506	6	51	303	U/G (15%)	45.5
2	Phulbari, (Dinajipur)	150 -240	2	15-70	572	O/C (60%)	343.2
3	Khalaspir, (Rangpur)	257 -483	8	42.3	143	U/G (15%)	21.5
4	Dighipara, (Dinajipur)	328 -407	5	62	150	U/G (15%)	22.5
5	Jamalgonj, (Bogra)	640-1,158	7	64	1,053		
6	Kuchma, (Bogra)	2,380 -2,876	5	51.8			
Total					3,300		438
Source: Edited by PSMP Study Team							

Coal

Current Situation and Issues of Supply and Demand of Domestic Coal

Current situation and issue of Barapukuria coal mine (BCMCL)

[Fact Finding]

- Petrobangla and XMC-CMC in China concluded an agreement of MPM & M in 2011. Though designed capacity is one million ton /year, the production has never reached the target after 10 years operation due to some difficult mining conditions.
- F/S of the expansion plan is being carried out now, necessitating an approval by the government
- 250MW coal-fired power station is in operation, and a study is on the table to build another 125MW power station.
- A small-scale open-cut mining is feasible. Indian company's TATA suggested open cut mining, but the government does not give a concurrence at present.

[Discussion and Proposal]

As U/G mining technology is established now at BCMCL, the most important issue is to train Bangladeshi engineers who are capable to manage by themselves coal mining and safety.

Coal

Current Situation and Issues of Supply and Demand of Domestic Coal

An aspect of un-developing coal field

[Fact Finding]: No new particular movement is observed.

Forecast of domestic coal production

[Fact Finding]

Year	Total coal production (HC) (1,000t/y)	Total coal production (BC) (1,000t/y)	Total coal production (LC) (1,000t/y)	Production of Domestic Coal Mine (1,000t/y)														
				Existing Coal Mine & New O/C					New Coal Mine (U/G & O/C)									
				Barapukuria U/G & new O/C					Kalaspir(U/G)			Dighipara(U/G)			Phulbari(O/C)		
				U/G			O/C		U/G			U/G			O/C		U/G
				(HC)	(BC)	(LC)	(HC)	(BC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)
2014-15		676			676												
2020-21	1,500	1,100	1,000	1,500	1,100	1,000											
2030-31	8,000	5,700	3,600	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	1,000	1,000	1,000	500	500	500
2040-41	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000
2041-42	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000

[Discussion and Proposal]

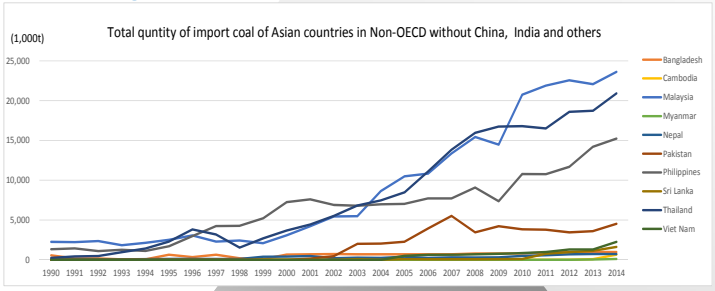
The development of a new coal mine will be considered after importing coal from abroad in the near future. On the other hand, the preparation of a new coalmine requires at least 5 years. Therefore, basic study for a new coalmine should be carried out from now on.

Coal

The Present Aspect and Issues of the Import coal

General view

[Fact Finding]



The Quantity of Import Coal by Southeast Asian Countries excluding China, India and some other countries

[Discussion and Proposal]

The Bangladeshi coal import environment will become severer and severer.

Coal

The Present Aspect and Issues of the Import coal

Import coal price

[Fact Finding]

The Coal Price of 1,000kcal/kg Movement at Newcastle Port in Australia



Total Coal Cost including FOB, Freight, Insurance and Handling Cost of High Grade Coal from Australia

Year	FOB Price of 6,300kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	50.5	15.0	16.0	81.5	0	65.5
2020	67.7	17.8	17.8	103.3	0	85.5
2025	85.0	20.5	19.7	125.1	0	105.5
2030	102.2	23.2	21.5	147.0	0	125.5
2035	119.5	26.0	23.4	168.9	0	145.5
2040	136.8	28.7	25.2	190.7	0	165.5

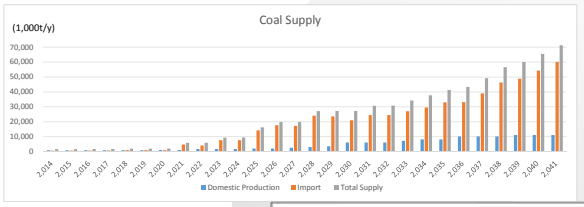
Total Coal Cost including FOB, Freight, Insurance and Handling Cost of Low Grade Coal from Indonesia

Year	FOB Price of 4,700kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost (US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	34.61	9.1	16.0	59.7	0	43.7
2020	46.43	10.7	17.8	75.0	0	57.2
2025	58.26	12.4	19.7	90.3	0	70.7
2030	70.09	14.1	21.5	105.7	0	84.1
2035	81.92	15.7	23.4	121.0	0	97.6
2040	93.76	17.4	25.2	136.4	0	111.1

Coal

Prediction of Coal Demand

[Fact Finding]



			2014	2015	2020	2025	2030	2035	2040	2041
Demand	Power Sttion	New Coal fired Power Station				14,129	24,917	38,837	62,904	68,704
		Barapukuria PS(125MW x 2)	433	433	433	433	433	433	433	433
		Barapukuria PS(125MW x 1)			217	217	217	217	217	217
	Industry	Forcast following IEA import figures	1,000	1,023	1,136	1,249	1,362	1,475	1,588	1,610
		Present Local user at BCMCL	300	300	300	300	300	300	300	300
		Total Demand	1,733	1,755	2,085	16,327	27,228	41,261	65,441	71,263
Supply	Domestic	BCMCL & Other new mine	1,000	1,000	1,100	2,100	6,200	8,200	11,200	11,200
	Import	Balance Between Total Demand And Domestic Production	733	755	985	14,227	21,028	33,061	54,241	60,063
		Total Supply	1,733	1,755	2,085	16,327	27,228	41,261	65,441	71,263

[Discussion and Proposal]

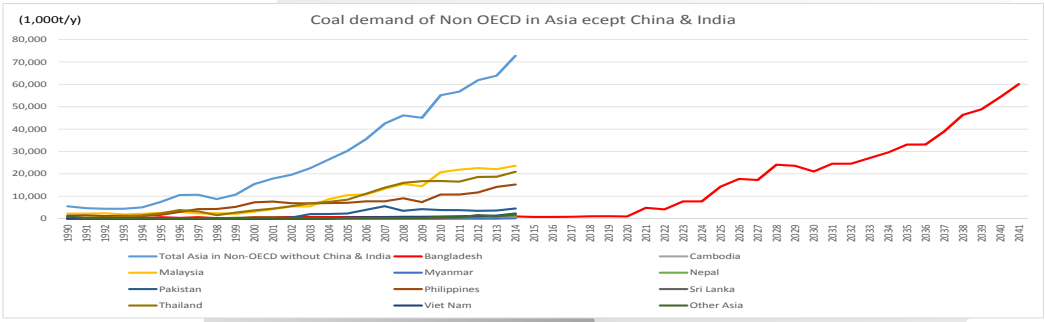
It is an important issue to make a strategy how Bangladesh secures quantity of future coal demand.

Coal

Prediction of Coal Demand

[Fact Finding]

The amount of import coal of Bangladesh in 2041 is almost same as total amount of import coal of all Non OECD countries except China and India in 2014.



[Discussion and Proposal]

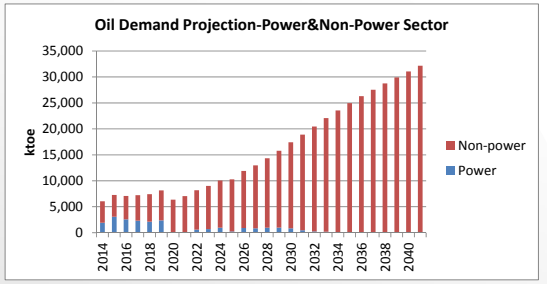
➢Stable supply of coal in future is a critical issue in Bangladesh.

➢The domestic coal development is the choice that is not avoided.

B-5 Oil Supply

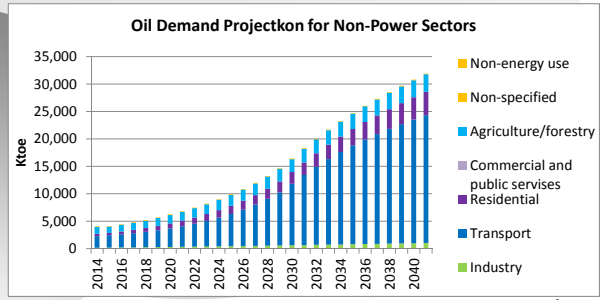
Oil demand projection reveals drastic growth in non-power

- [Fact Finding] Total oil demand (Power + Non-Power) in 2041 will become 6-fold from 2015 (5.2% p.a.).
- Oil demand for Power sector will continue to increase until early 2020s, when Matarbari Coal USC becomes online, but later decline.



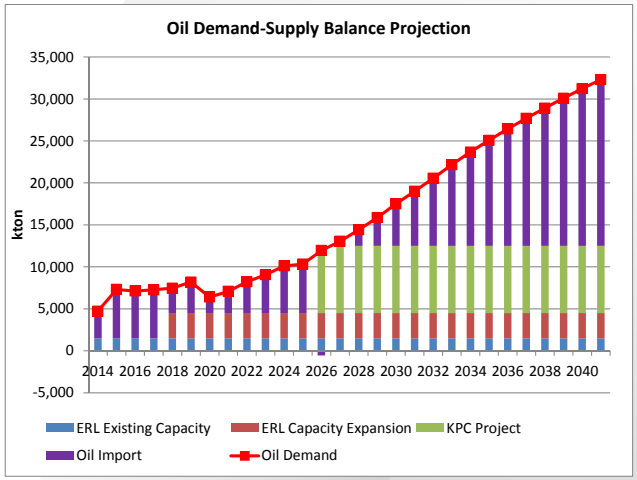
Sources:
JICA PSMP2015 Survey Team

- [Fact Finding] Oil demand in Non-power sector growth is mainly led by Transport sector demand growth (11-fold).



Several oil supply enhancement projects, but is it the best way?

- [Fact Finding] There are several initiatives to enhance oil supply; however, drastically growing oil demand associated with economic development (motorization + industrialization) will surpass its supply capacity.



Source: JICA Southern Chittagong Survey Team and PSMP2015 Survey Team

Several oil supply enhancement projects, but is it the best way?

- [Fact Finding] There are both advantages and disadvantages on owing refinery/petro-chemical complex .

Advantages of Constructing a Refinery against Product Import

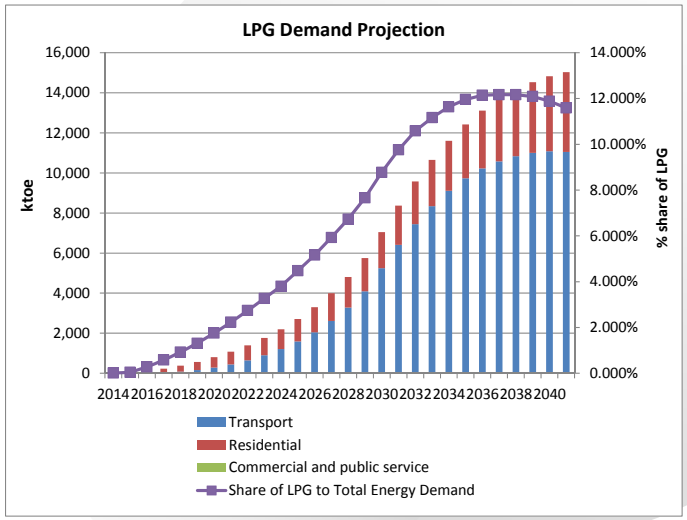
Advantages	Disadvantages
● More oil product procurement option (diversification of oil product procurement) ● Lower freight cost ● Lower price volatility ● Oil product control	● Large upfront capital expenditures & long-term loan repayment ● Risk of low utilization depending on domestic and export demand ● Risk of low refining margin for a long period of time

Source: JICA Southern Chittagong Survey Team

- [Proposal] Comprehensive analysis (including economic, market opportunity and operation) is required to finalize the investment. As oil is matured market, procuring oil products in some cases (e.g. Thailand) could have more economic advantage over facility investment.
- [Proposal] For the medium term, storage capacity expansion would be the best option to meet the growing demand, and avoid the large upfront capital expenditures and long-term loan repayment.

LPG demand growth may be the most radical change

- [Fact Finding] LPG demand is currently a few % share of oil and 0.02% of all energy demand; however the future demand will be considerable to 12% of all energy demand.



Source: JICA Southern Chittagong Survey Team and PSMP2015 Survey Team

LPG is really a solution for household energy access?

- [Fact Finding] GoB has stipulated a new policy to limit pipelined gas use for household and commercial sector and promote LPG instead.
- [Fact Finding] LPG is cleaner and less CO2 fuel than other fossil fuels, but it is expensive solution for most of Bangladesh people
  - LPG "actually marketed" price is much higher than "official rate" – For one 12kg Cylinder, Tk.1050 (Mkt in Bogra) vs. Tk.700 (Official)
  - The difference of the unit price of LPG (marketed price) and the current pipelined natural gas is big – approx. 8:1.

	Fixe Price for one burner	Unit Sales Price	Heat Value per Unit	Unit Price per MJ
Natural Gas	Tk 600 Tk/month	Tk 8.33 /m3	39.59 MJ/m3	Tk 0.21 /MJ
LPG	Tk 1,050 Tk/12 kg (1 cylinder)	Tk 87.50 /kg	50.80 MJ/kg	Tk 1.72 /MJ

Source: JICA Survey Team

- [Proposal] Countermeasures (e.g. regulation) should be taken
  - ✓ To correct the current actual-official price gap
  - ✓ to correct the unaffordability of LPG, .e.g. cross subsidy among petroleum products, or alternative such as off-grid biogas for rural poor.
- [Proposal] LPG subsidy, if introduced, should come with a sound exit strategy, as LPG subsidy will grow astronomically coupled with its demand growth.

C Power Balance

C-1 Power Demand Forecast

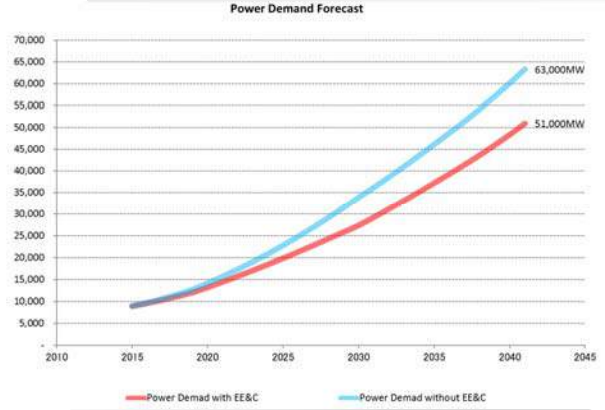
Power Demand Forecast

Assumptions:

- GDP growth rate: around 6% for 2014/41.
- Reserve Margin (RM) kept down to 10% by 2030

Projections:

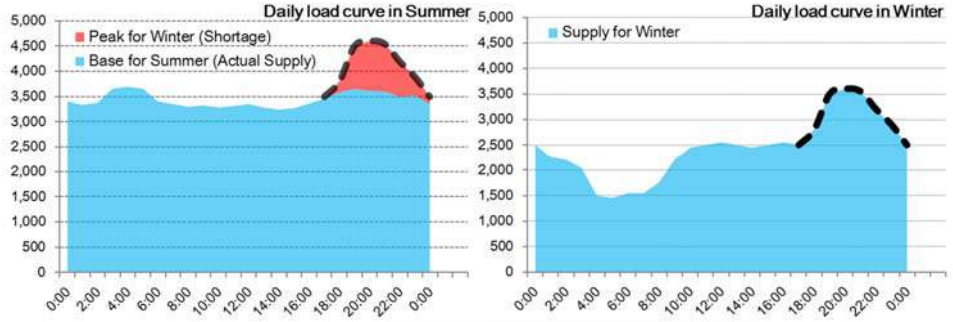
- Required supply will be at 57,000MW including Reserve Margin
- Energy Efficiency and Conservations (EE&C) is challenging and important issue for Nation



Estimation of the maximum power including potential demands

- The power supply has constantly remained strained in peak. Potential demands have not been met, and rotational outage has frequently occurred. The actual recorded maximum power has not included these potential demands.
- To estimate the maximum power that includes potential demands, PSMP adopts a method for calculating the generated power energy with which a compound daily load curve is produced by adding the evening peak demand for lighting, calculated from a daily load curve with no rotational outage on weekends and holidays in winter, to a daily load curve suppressed by rotational outage on weekdays in summer.

Typical daily load curves in Bangladesh in summer and winter



Estimation of the maximum power including potential demands

- The actual recorded maximum load in fiscal 2015 was 7,356 MW.
- The maximum load estimated by giving consideration to latent intermediate load, peak load and actual efficiency in the assumed base load of 6,170MW is approximately 8,921MW. Accordingly, in prediction of the long-term demands up to fiscal 2041, 8,921MW reached in this study will be adopted as an initial value for fiscal 2015.

Estimated maximum power including potential demands(2005-2015)

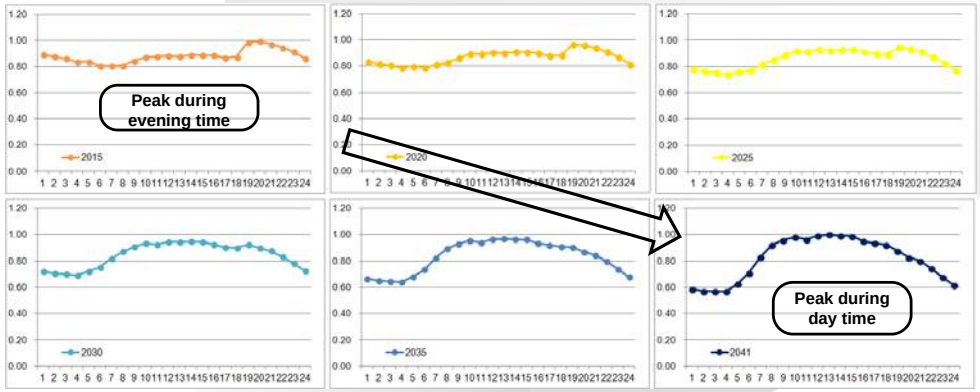
Fiscal Year	Estimated Base Load (MW)	Estimated Intermediate Load (MW)	Estimated Base Over Peak Load (MW)	Estimated Peak Load (MW)	Actual Net/Gross	Estimated Net Peak Load(MW)	Growth (%)	Actual Net Peak Load (MW)	Growth (%)
2005	3,097	-	1,379	4,476	0.95	4,230		3,900	
2006	3,600	-	1,413	5,013	0.95	4,737	12.00%	4,200	7.70%
2007	4,050	-	1,063	5,113	0.95	4,832	2.00%	4,500	7.10%
2008	4,190	-	1,484	5,674	0.95	5,362	11.00%	4,600	2.20%
2009	4,150	-	1,500	5,650	0.95	5,339	-0.40%	5,050	9.80%
2010	4,300	817	1,462	6,579	0.95	6,258	16.40%	5,550	9.90%
2011	4,400	836	1,496	6,732	0.95	6,411	2.30%	5,550	0.00%
2012	5,000	950	1,700	7,650	0.96	7,326	13.60%	6,600	18.90%
2013	5,300	1,007	1,802	8,109	0.96	7,764	6.00%	6,600	0.00%
2014	5,487	1,043	1,811	8,341	0.96	8,039	2.90%	7,356	11.50%
2015	6,170	1,111	1,974	9,255	0.96	8,921	11.00%	7,500	2.00%

Assumption of daily load curve

General of daily load curve

- Daily load curve in 2015 is estimated based on actual power consumption in Bangladesh.
- Daily load curve is gradually sifted to type of developed country's daily load curve until 2041

Shift of Daily Load Curve (2015-2041)



Power Demand Forecast

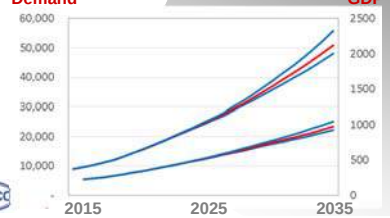
Power Demand Forecast

- Power demand is estimated by multiplying estimated maximum power and estimated daily load curve from 2015 to 2041.
- Estimated power demand forecast from 2015 to 2041 shows a change of daily load curve shifting from evening peak to daytime peak and increasing peak demand from 8,921 MW to 50,400 MW.

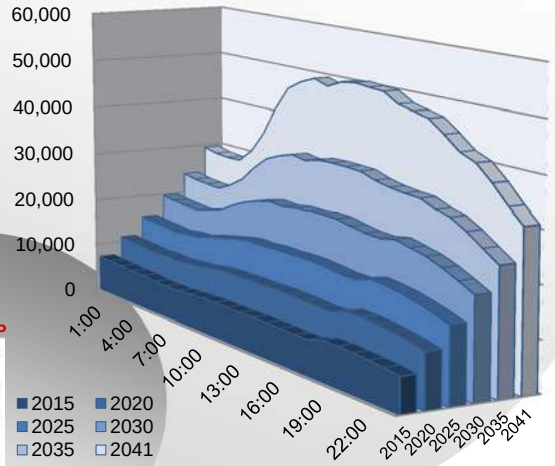
Peak Demand Forecast and GDP (2015-2041)

	Demand	Demand with Energy Conservation
High case	60,267	55,802
Base case	55,057	50,979
Low case	51,830	47,991

Demand **GDP**



Estimated Power Demand Forecast (2015-2041)

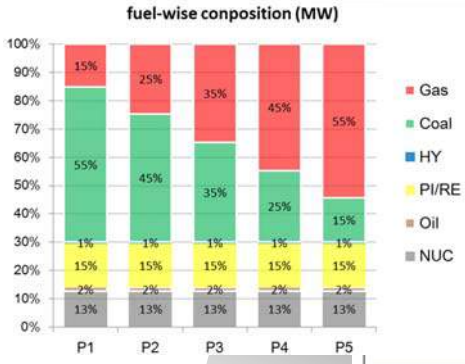


C-2 Power Development Plan

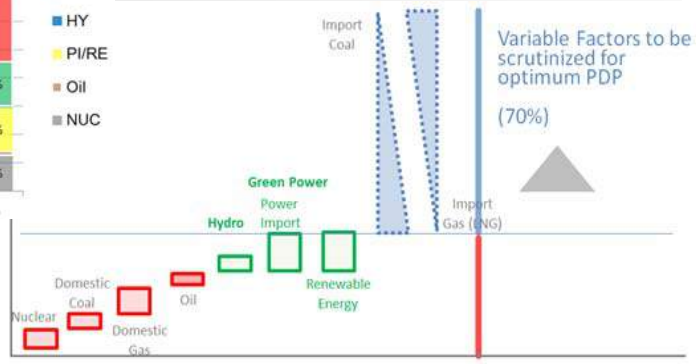
Fixed and Variable Factors for PDP

Assumptions;

- Fixed Factor; Nuclear, oil, Power Import, Dom coal, Dom Gas, Renewable Energy
- Variable Factor; Imp Coal, Imp Gas



- The energy mix should be examined based on the fixed factor and the variable factor as shown in the figure below.
- Five scenarios with the share of coal and gas in the energy mix as of 2041 changed from P1 to P5 are studied.



PDP Scenarios

1:Coal 55%, Gas 15% @2041



2:Coal 45%, Gas 25% @2041



3:Coal 35%, Gas 35% @2041



4:Coal 25%, Gas 45% @2041



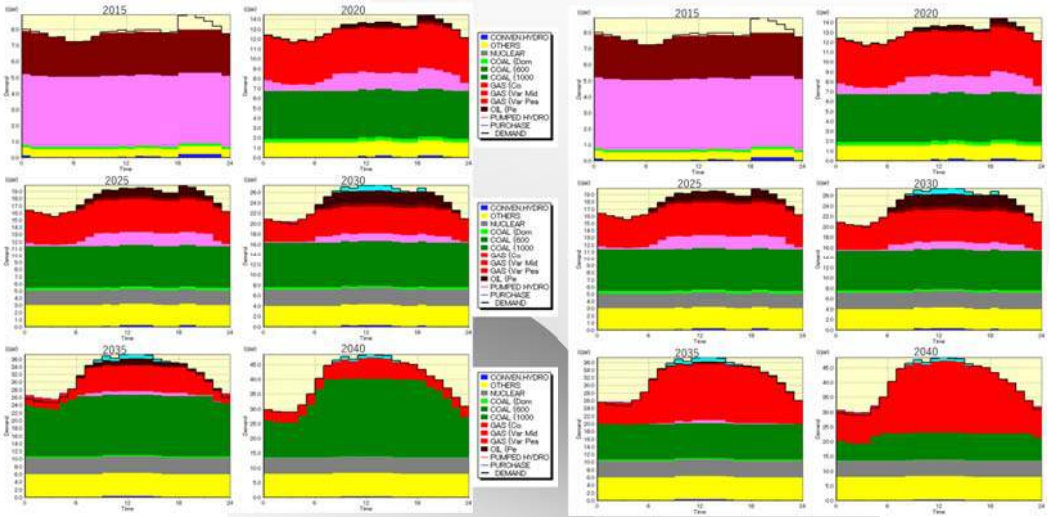
5:Coal 15%, Gas 55% @2041



PDP Scenarios

P1Scenario

P5Scenario



2015 2020 2025

3E Evaluation of Energy Mix Scenarios

- 3E (Economy, Energy Security, and Environment) of 5 scenarios are evaluated using following indices.
- Smaller value of these index shows better composition.

Economic Index	Environmental Index	Energy Security Index	3E Index
Generation cost per electricity supply [US cent / kWh]	Carbon cost per electricity supply [US cent / kWh]	GDP loss when energy is not delivered [US cent / kWh]	Total of these indices [US cent / kWh]

Economic Index

- Generation cost (fixed price + fuel price) per electricity supply
- Assuming fuel price of F5 Scenario (Revised IEA's Low Oil Price Scenario) cf. "Fuel Price Scenario" slide

Environmental Index

- Carbon cost per electricity supply
- Assuming carbon price in IEA's 450 scenario

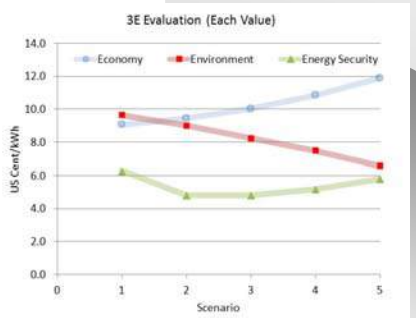
Table 1.4 ▷ CO_2 price assumptions in selected countries and regions by scenario ($2014 per tonne)

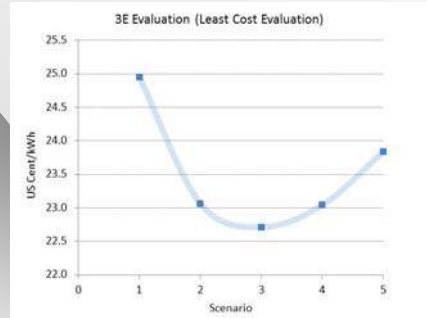
	Region	Sectors	2020	2030	2040
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry	10	75	125

3E Evaluation in 2041

- Three indices (Economy, Environment, Energy security) in 2041 are calculated and integrated as follows:

	Composition (MW base)	Economy [US cent/kWh]	Environment [US cent/kWh]	Energy Security [US cent/kWh]	Total [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	9.06	9.64	6.29	25.0
Scenario 2	Gas 25%, Coal 45%	9.45	9.00	4.82	23.1
Scenario 3	Gas 35%, Coal 35%	10.03	8.23	4.81	22.7
Scenario 4	Gas 45%, Coal 25%	10.84	7.48	5.18	23.0
Scenario 5	Gas 55%, Coal 15%	11.89	6.57	5.81	23.8



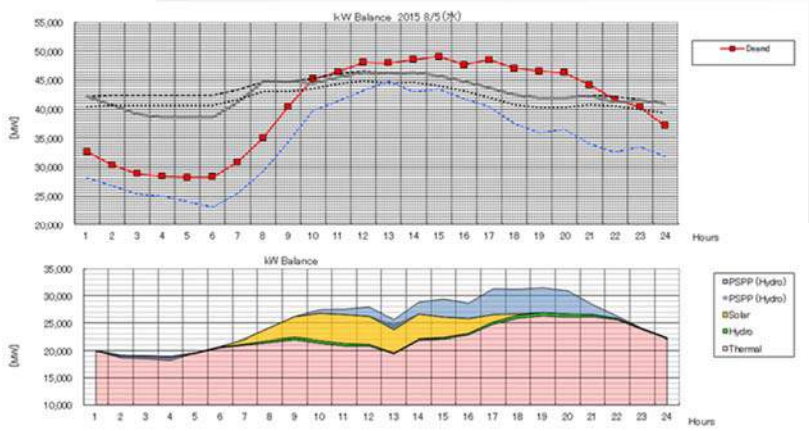


PSMP2016 Technical

3E Evaluation in 2041

- Difficulty in Estimating Supply Potential of Renewable Energy

The introduction of a 5,000 MW photovoltaic power plant has created a time in a day when 5,000 MW of the installed capacity of a thermal power plant remains unused, or a total of 30,000 MW of installed capacity, 5,000 MW and 25,000 MW for the photovoltaic and thermal power plants, respectively, is required for meeting the daytime peak demand of 25,000 MW.



C-3 Renewable Energy

PSMP2016 Technical

Renewable Energy – Bangladesh's potential

- [Fact Finding] Bangladesh has vast RE potential specially solar PV. However, utility-scale solar requires vast area of land. If the non-agricultural land use policy is properly complied, Bangladesh will have at maximum 1,400MW solar park power generation.
- [Fact Finding] For some RE technologies, potential is still yet confirmed:
  - Wind potential is yet confirmed and waiting for the USAID-supported Wind Resource Assessment to be completed in 2017.
  - Waste to energy requires established waste delivery procedures to a power station to identify potentials. 13 kton /day waste (in a whole country) totally under utilized and the opportunity is not pursued.
  - Mini/micro grid "potential" is in fact the accumulation of 20 projects (100~500kWp)

Technology	Resource	Capacity (MW) WITH land use policy	Capacity (MW) WITHOUT land use policy
Solar Park	Solar	1400	18,978
Wind Park	Wind	637	1,033
Solar Rooftop	Solar	635	635
Solar Home Systems, (SHS)	Solar	100	100
Solar Irrigation	Solar	545	545
Biomass Generation	Rice husk	275	275
Biogas Generation	Animal waste	10	10
Waste to Energy	Municipal waste	1	1
Small hydro power plants	Hydropower	60	60
Mini-grid, Micro-grid	Hybrid	3	3
Total		3,666 or more	21,640

Source: SREDA-World Bank "Scaling Up Renewable Energy in Low Income Countries (SREP), Investment Plan for Bangladesh, October 2015"

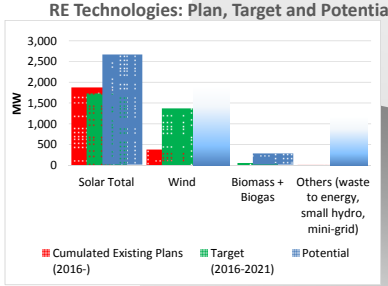
- [Proposal] To pursue waste to energy opportunity, a good coordination among concerned ministries and municipal government (e.g. SREDA, Housing Ministry, and RAJUK) should be built to collect waste and deliver to power stations.

PSMP2016 Technical

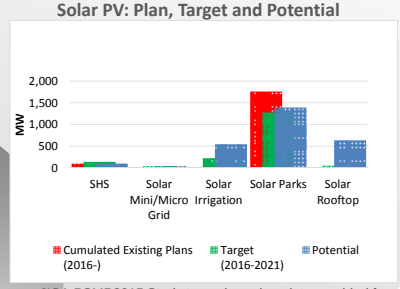
Awesome in SHS, but yet other RE technologies

- [Fact Finding] Bangladesh has been awesome in SHS deployment and reaching to its potential quite soon; however, other RE technologies yet far distance to utilize its potential.
- [Fact Finding]
  - Several utility-scale solar PV projects are in progress. Jamalpur IPP 3MW was contracted in December 2015 and tariff was set @ 18.7 Tk/kWh. This defines the highest tariff for solar park.
  - Solar park plans exceed the potential and will be screened with an established procedures in SREDA, based on the investor's financial soundness, technical soundness, land use and tariff proposed from the project side.

RE Technologies: Plan, Target and Potential



Solar PV: Plan, Target and Potential

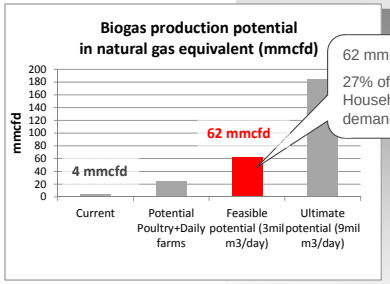


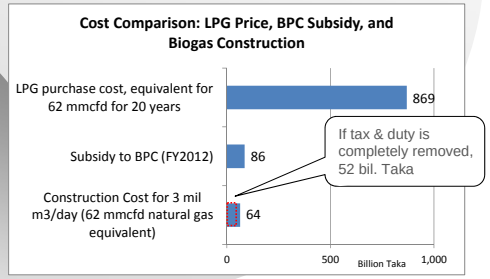
Source: JICA PSMP2015 Study team, based on data provided from SREDA

- [Proposal] Although the grid-connected RE potential might be a small % out of the total on-grid electric generation (GWh), Bangladesh needs technical standard and regulation for grid-connected RE.

Biogas potential for Universal Access of modern energy

- [Fact Finding] Household gas connection is unevenly concentrated in Dhaka area. Rural households are exposed to respiration disease risks due to inefficient burning of solid fuels on an open fire or traditional stove indoors.
- [Fact Finding] Bangladesh has a robust biogas potential, ultimately 9 million m^3/day. If the potential is feasibly developed, 3 million m^3/day" or 62 mmcfd natural gas worth" biogas could be produced. This could meet 27% of Household gas demand in 2041.
- [Fact Finding] Potential biogas supplier, poultry and daily farms 110 k for 25 mmcfd natural gas equivalent production capacity, if decent incentive & subsidy is provided.
- [Proposal] Biogas is in fact cost effective as far as digester lasts, and carbon neutral solution to promote universal access of energy. GoB should pursue further promotion of biogas digester roll out, and remove impediments if any.



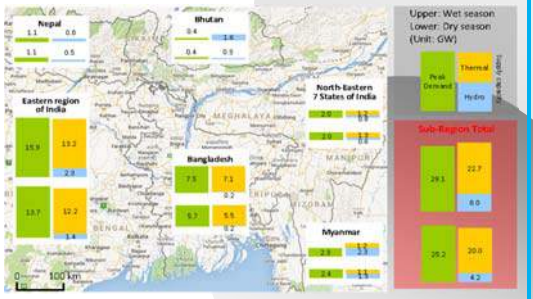


C-4 Power Import

Power Import

Current Status and Issues

- The neighboring countries of Bangladesh have rich hydropower potential. However, the total amount of hydropower already developed at present is small, and a great amount of hydropower potential is expected to be exploited in the future.



Power supply and demand situation in 2030

Future Goals

- Three new cases of inter-connection have begun to be planned.
- JICA Survey Team proposes a set of evaluation criteria for the selection of candidate areas for hydropower development.
- JICA Survey Team considers six areas as possible candidate areas for hydropower development to be connected with Bangladesh.



C-5 Transmission Analysis

Power Plant 2035

Bogla		
Bagabari	GAS	102
Barapukuria	DC	434
Barapukuria HVDC	PI	3,500
Sirajgonj	GAS	618
Sirajgonj	OIL	431
		5,085

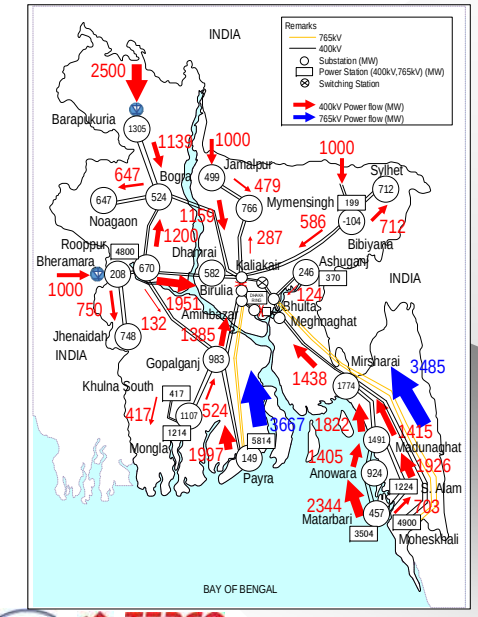
Chittagong		
Anowara	OIL	300
Cchittagong S. Alam	IC	1,224
Kaptai	HYD	330
Maheshikhali	IC	1,200
Matabari	IC	3,504
Shikalbaha	GAS	218
Tentative allocation to Maheshkhali*	GAS	3,400
Tentative allocation to Anowara*	GAS	750
		10,926

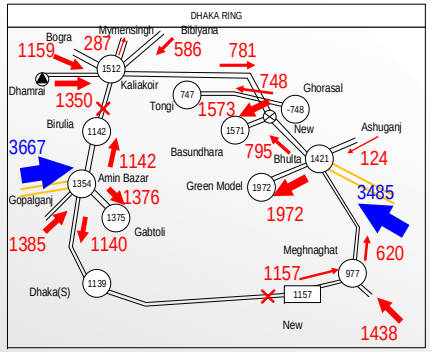
Sylhet/Comilla		
Bibiyana	GAS	1,101
Bibiyana PSPP	PI	1,000
Chandpur	GAS	158
Comilla	PI	500
Shahajibazar	GAS	98
Shajibazar	GAS	322
Sylhet	GAS	221
		3,400

Dhaka		
Ashuganj	GAS	949
Dhaka	IC	635
Ghorasal	GAS	1,128
Haripur	GAS	400
Jamarpur HVDC	PI	1,000
Kushiara	GAS	163
Maowa	IC	522
Meghnaghat	OIL	305
Siddirganj	GAS	328
		5,430

Khulna		
Bheramara	GAS	402
Bheramara HVDC	PI	1,000
Bhola	GAS	189
Bhola	OIL	220
Khulna	IC	630
Khulna	OIL	417
Payra	IC	2,414
Rampal#1,2	IC	1,214
Roopoor	NC	4,632
Tentative allocation to Payra	GAS	4,200
		15,317

Power Flow 2035



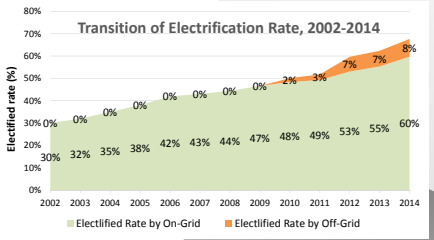


- **The locations of gas-fired power stations should be identified** by considering location of LNG receiving points as well as GAS infrastructure and transmission line.
- In case of Matabari and Payra where LNG import facility is planned, **765kV transmission lines are required from power center to load center.**

C-6 Rural Electrification (Distribution)

Rural Electrification (Distribution)

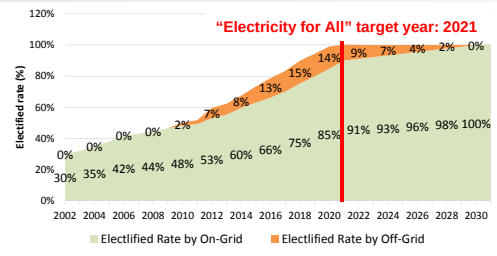
- In total 68% Bangladesh population were electrified as of 2014 (60% by on-grid, 8% by off-grid).
- The explosive increase of SHS contributes to the electrification.



- Another 140,000 km line is required for on-grid electrification. BREB has already plans to add 120,000km.
- About 14,000 km to cover non-electrified areas have technical difficulties for grid extension (e.g. far from PGCB line, population scarce, river-crossing). If electrification is met only by the grid-extension, it would take until 2030s.
- After the on-grid electrification is completed, millions of SHS wastes would occur.

- A good communication and coordination between BREB and IDCOL is required to complement electrification projects, and achieve "Electricity for All" by 2021.
- Only one definition of electrification rate should be selected and adopted to keep its integrity (currently there are three in Bangladesh).
- SHS waste will increase after early 2020s. The current recycling process should prove effective and scalable.

Electrification after 2020s - Projection



C-7 Power Quality

Current Status and Good Practice

Each utility has a strong initiative and accurate understanding to improve power:

1. Significant deficiency of power source including spinning reserve.
2. No application of automatic control such as LFC, free-governor operation. Instruction by telephone communication only.
3. Inadequate coordination of daily generation scheduling between NLDC and GenCos.
4. NLDC has less regulatory authority to make a balance between demand and supply.

Challenges in NLDC proves Bangladesh has enormous power system quality improvement potential.



Frequency chart of Free Governor mode operation test with Khulna gas turbine generator (158MW)

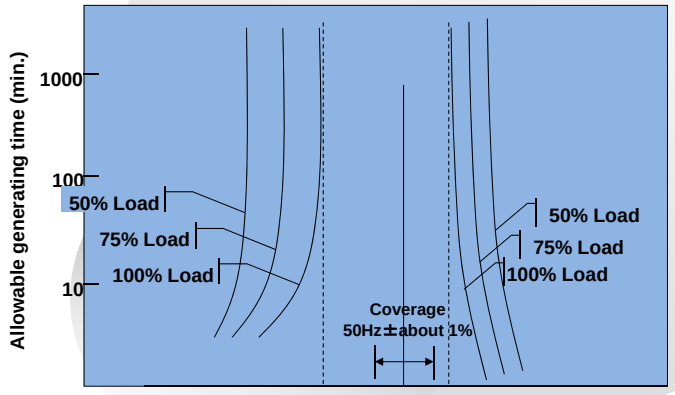
Higher Value-Added Economy

- There are high potential needs of frequency quality, in particular, from business sectors, in order to realize a higher value-added economy and more sophisticated industrial structure
- Frequency fluctuations could cause negative impacts as follows:

Industries	Effects by frequency fluctuations
Chemical fiber manufacturing	The change of winding speed could lead thread breakage and bad quality of thickness of the thread.
Paper	The change of winding speed could lead paper breakage and bad quality of thickness of the paper.
Oil	Bad pressure control for decomposition and desulfurization could lead to failure of impurity removal.
Iron and Steel Aluminum	Bad rolling process could cause uneven of thickness of products.
Motor vehicle	The change of weld time for automotive body panels could lead to bad effect for weld strength and quality of products appearance.

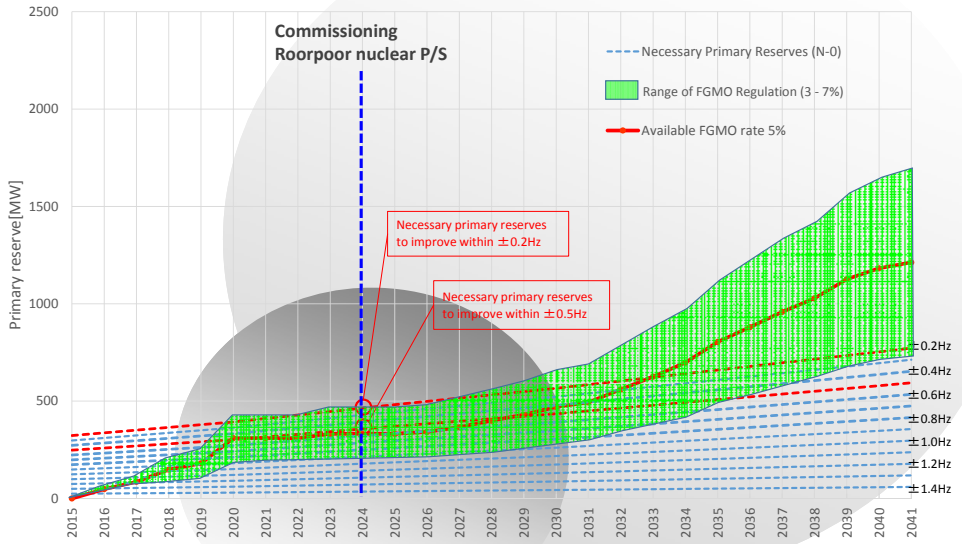
Stable Operation of Power Plants

- For stable operation of synchronous machines, such as large capacity generating units, there is a quantitative requirement that **a frequency quality shall be raised within ±1.0% of standard value (50±0.5Hz).**
- In particular, the equivalent frequency quality is required, in order to connect and operate stably **the nuclear power plant** planned to be commissioned in **2024**. Therefore, **±1.0% can be set as a short-term target value.**



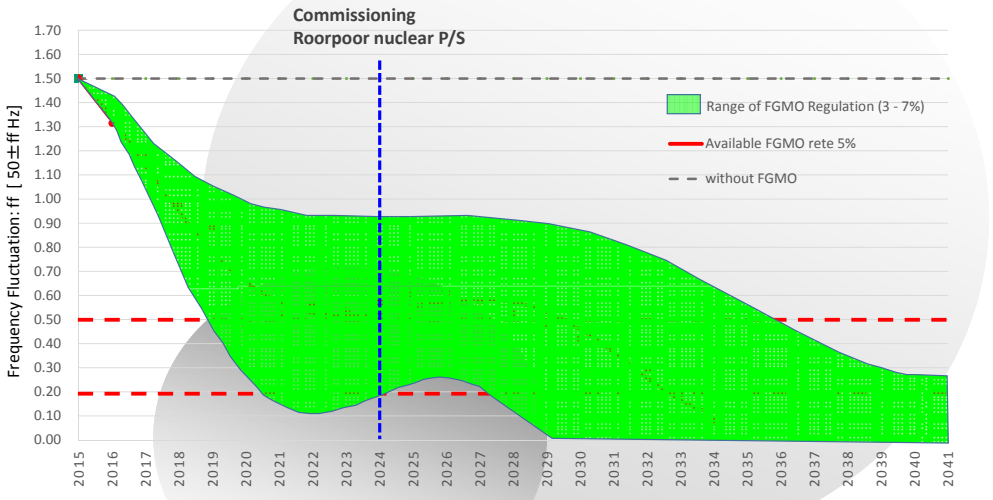
Future Prospect of Reserves

Supply-Demand Balance of Reserves for FGMO



Future Prospect of Frequency Improvement

Trend of Quality Improvement of Frequency Fluctuation by FGMO



Conclusion

◆ **Adequate reserves for FGMO** should be prepared in a planned way enough to improve frequency fluctuation within ± 0.5 [Hz] (1/3 of fluctuation at present) which is recommended in IAEA guidelines until the operation start of Roopoor nuclear power plants in 2024 and 2025.

- **All Gas thermal, Hydro** and **a half of Coal-fired,** which will be newly constructed after June 2015, should provide reserves for FGMO.
- Obligatory rate for reserves: **3-7% of rated output, each**

Provisions for securing reserves of FGMO in Grid Code should be enhanced

◆ **Adequate reserves for load shedding by UFR** should be set in order to prevent a blackout as a tentative measure.

C-8 Operations and Maintenance

Ascertaining actual conditions

Survey result

Item	Contents
Maintenance plan	Based on manual and experience
Implementation of maintenance plan	Cannot proceed as scheduled
Reasons for not periodical maintenance	Waiting for budget approval, bidding and shutdown permission
Manufacturer support for daily maintenance	None
Daily maintenance	Maintenance staff
Major inspection	Maintenance staff and manufacturer
Safety for staff	Only have BPDB guideline

Item	Contents
Fuel analysis	No analysis
Efficiency management	Nobody cares
Environmental regulation	No regulation
Report for Head office	Handwritten monthly report
Equipment issues	Does not reach rated output
Staff issues	Shortage of human resources
Training system	OJT Only theoretical lectures

Issues and countermeasure

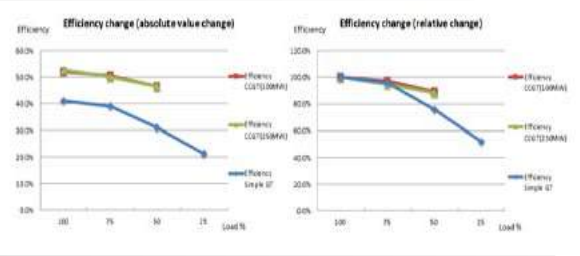
Focused on four categories and countermeasure to optimize O&M

Equipment and maintenance plan	*Budget approval and shutdown permission are delayed because there is no mid-long term maintenance information *Cannot repair because of shortage of power generation *Do not care about power plant efficiency *Does not reach rated output	→	**Equipment and maintenance plan**	Rehabilitation	Steam turbine rehabilitation
					Combined cycle power generation remodeling
Staff	*No effective training curriculum *Lack of technical skill		**Staff / Budget / Information**	Utilize the information effectively	Information management strategy
Budget	*No mid-long term maintenance plan				
Information	*Lack of information strategy			Human resource development	Training center

Rehabilitation

Merit of small size combined cycle power generation remodeling

Plant capacity	Hot start	Cold start	efficiency
400MW Class CCGT	1hour	6hours	50%
250MW Class CCGT	< 1hour	4hours	50%
100MW Class CCGT	0.5hour	2hours	50%
Simple GT	0.5hour		40%(new) 30%(old)



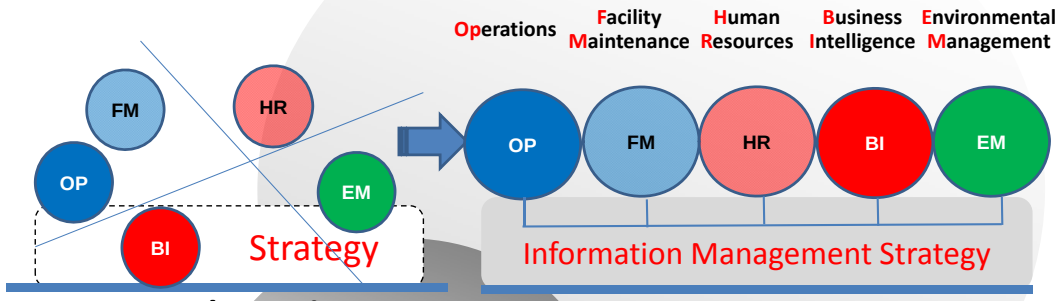
merit1 : short start time characteristics

merit2 : High efficiency under low load operation

	Site name	Target unit	COD	Capacity condition: installed (A)	de-rated (B)	remarks (C)	New (D)	output increase (D-C)	Estimated Cost (Mill dollar)	Unit price (mill dollar / MW)	Efficiency: after	Efficiency: now	Manufacture support	Remaining plant life after rehabilitation (assumed plant life time 30years) (years)	year cost (mill dollar / MW)
Build and scrap (for CCGT)	Siddhirganj	Unit1	2004	210	150	110 (gas limitation)	150	40MW	200	5.0	50	33.8 (*1)	MHPS/Kawasaki	30	0.17
	Haripur	Unit1,2,3	1987	96	60	40(Unit 3 stopped)	100	60MW	150	2.5	50	21.2			0.08
	Tongi	Unit1	2005	105	105	105	150	45MW	200	4.4	50	25.9 (*2)			0.15

Information Management (1)

Strategic Approach to Integrated Information Management



[Bad Practice]
- Data proliferation
- Ambiguity, Uncertainty

Implementation of Information Management

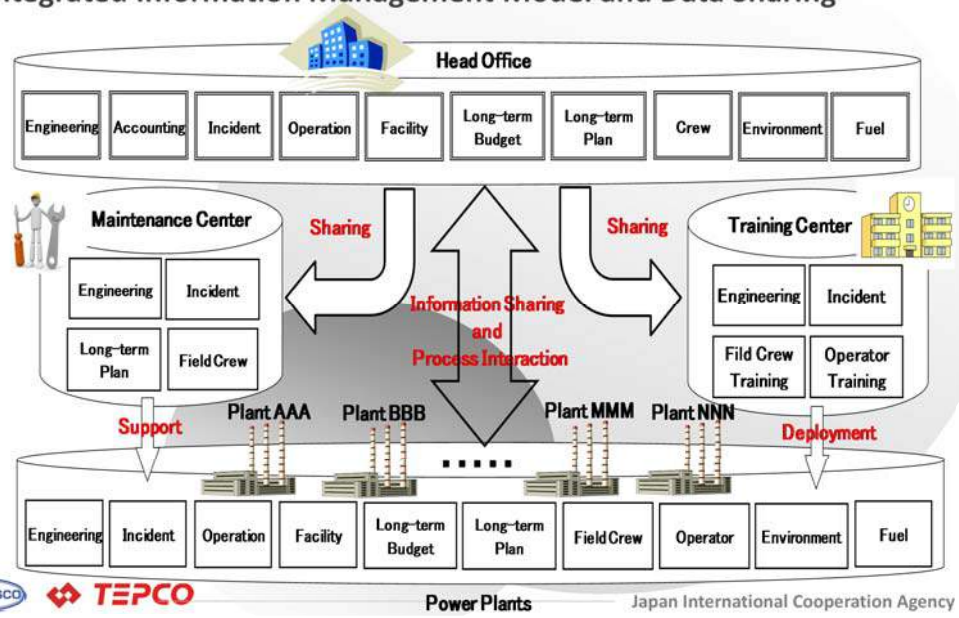
Transparency
- Shared
- Measurable
- Multi-viewpoint

Benefit

Management
- Efficiency
- Corporate governance
- Stable Power Supply

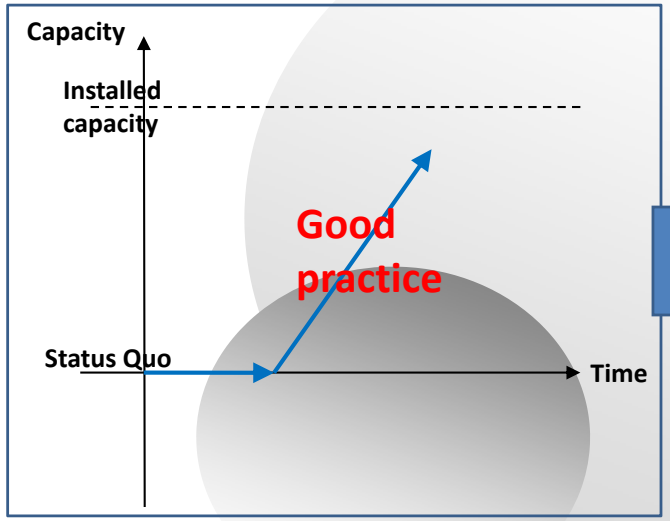
Information Management (2)

Integrated Information Management Model and Data Sharing



Information Management (3)

Operating at Constant Generation Level with High Quality



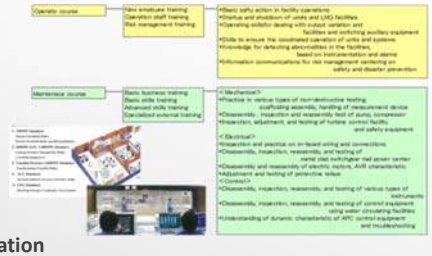
By applying proper maintenance, it is possible to bolster capacity.

By practicing planned maintenance, it is possible to mitigate shut-down impact on the grid.

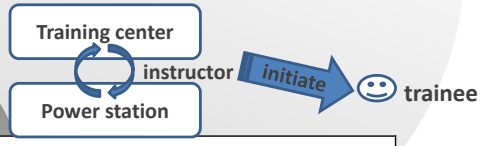
Training

Key item of human resource development

a. training curriculum
⇒ From a new face to a veteran, the maintenance of various curricula is necessary



b. Development of the instructor
⇒ rotation between the training center and power station
→ instructor getting site knowledge and feeding
→ back into the training content



c. Training facility

For operator	Operation simulator
For maintenance staff	Motor , pump , fan , instruments , Non Destructive Inspection/Test facilities, vibration analysis device …etc.,

O&M Legal Framework

Legal framework (1)

O&M Problems and Solutions

① Problems
- MW Down (Output)
- η Down (Efficiency)
- Re Down (Reliability)

② Main Reasons
- Insufficient Maintenance
- Insufficient Inspection
- Insufficient η management

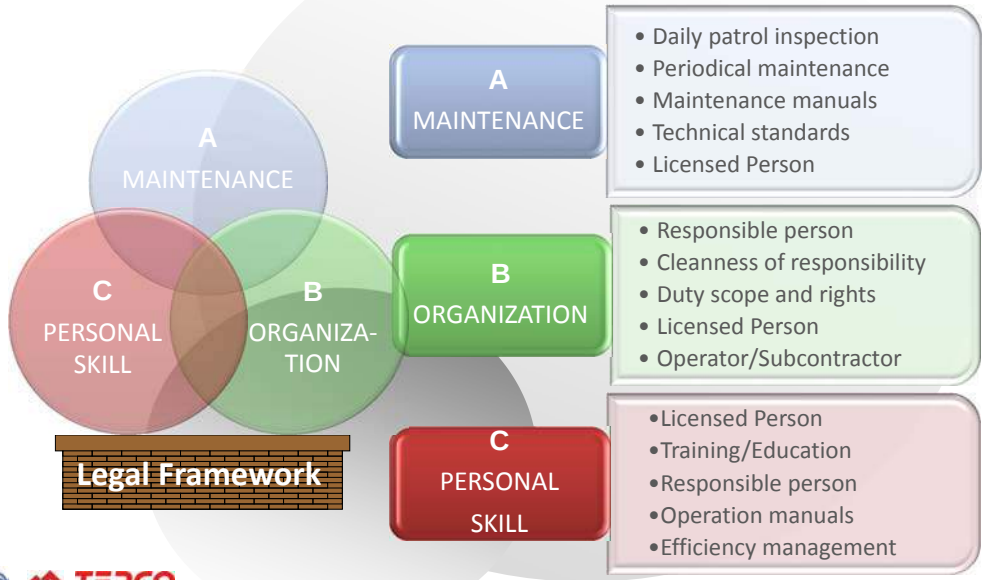
③ Why ?
- Lack of budget
- Lack of technical skill
- Lack of time
  - It is not easy to stop for maintenance due to power shortage.

④ O/M Solutions
- Operating efficiently
  - Efficiency management
  - Reduction of maintenance period
- Personal skill-up
  - Training, Education
- Efficient maintenance
  - CBM, Daily maintenance, Patrol inspection

⑤ Legal Framework Solutions
To build the mechanism for O/M legal solutions
- Formation of organization
- Clarification of responsibility
- Sustainability, PDCA
- Incentives and penalty

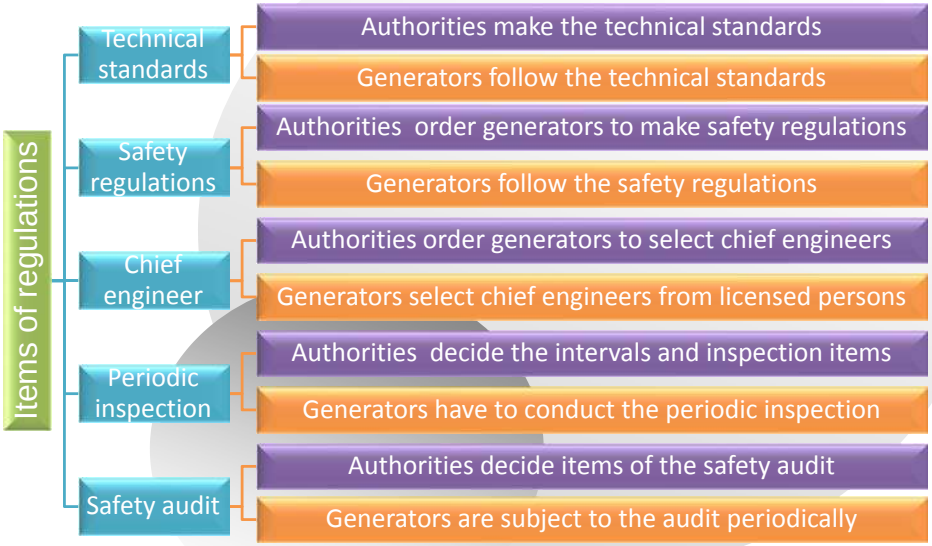
Legal framework (2)

Legal framework should support key factors of O&M



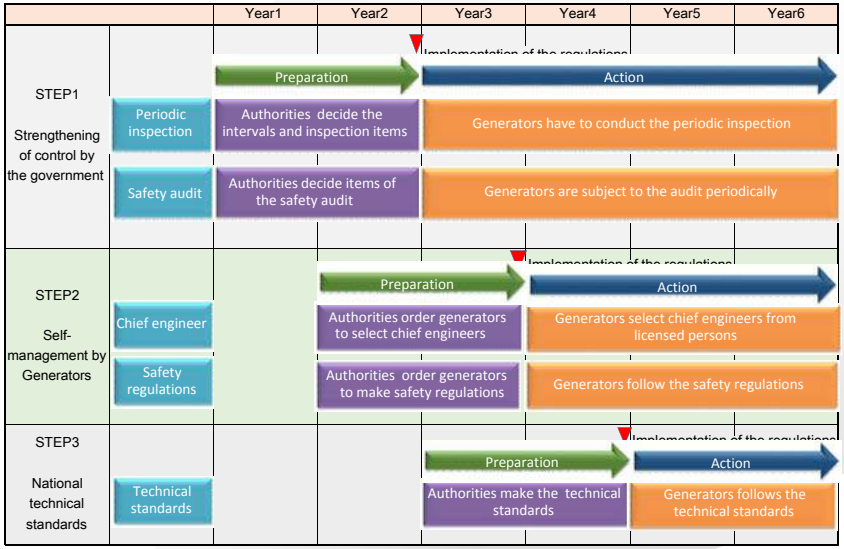
Legal framework (3)

Recommended items of regulations for Bangladesh



Legal framework (4)

Recommended schedule of regulations for Bangladesh



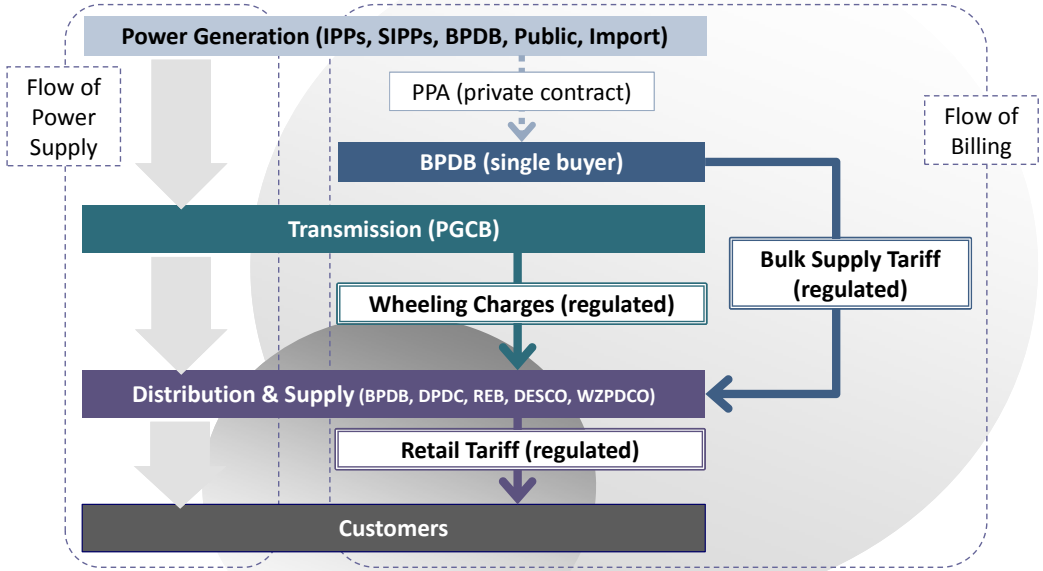
D Cost and Tariff Balance

D-1 Tariff Policy

Financial Performance of the Power Sector

Overview

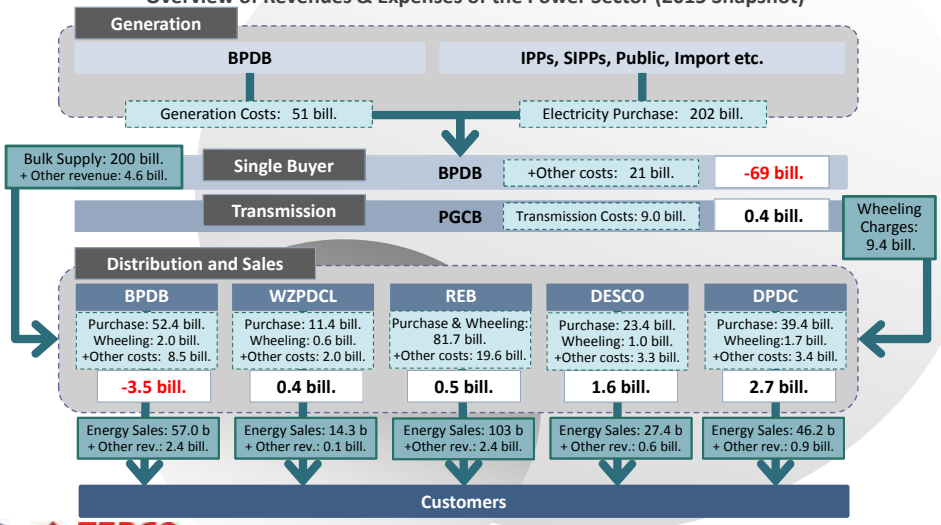
Flow of Power Supply & Flow of Billing



Overview of Expenses & Revenues of the Power Sector

- In FY2014-2015, BPDB purchased 202 billion BDT worth of power from IPP's, SIPP's, Public, rental, and import. BPDB, as single buyer, sold the electricity for a total of 200 billion BDT to distribution entities. As a result, a total loss of 72.8 billion BDT was incurred in BPDB.

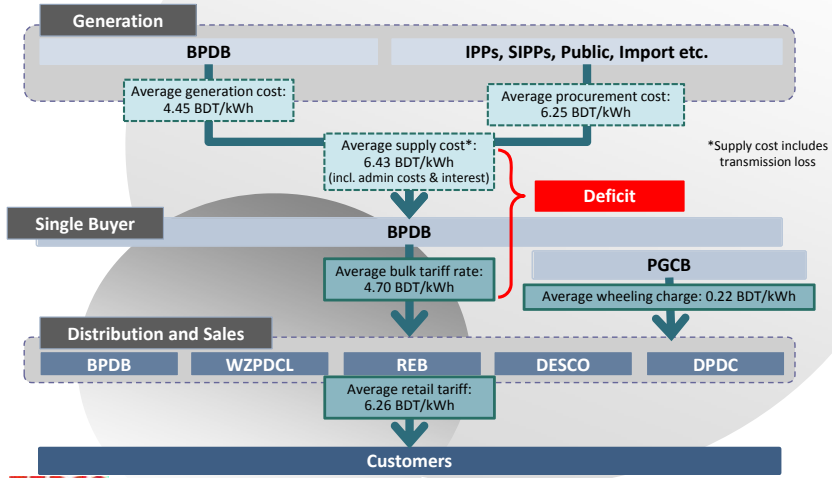
Overview of Revenues & Expenses of the Power Sector (2015 Snapshot)



Current Financial Situation of the Power Sector

- In FY2014-2015, BPDB sold to distribution entities at average bulk rate of 4.69 BDT/kWh. In the meanwhile, the average costs for power wholesale, which covers both BPDB's own generation and power purchase from generators, was 5.94 BDT/kWh. The high costs of power procurement, especially from small rental powers, is the main cause of BPDB's deficit.
- The distribution entities sold power to consumers at tariff set by BERC, which was at an average 6.26 BDT/kWh.

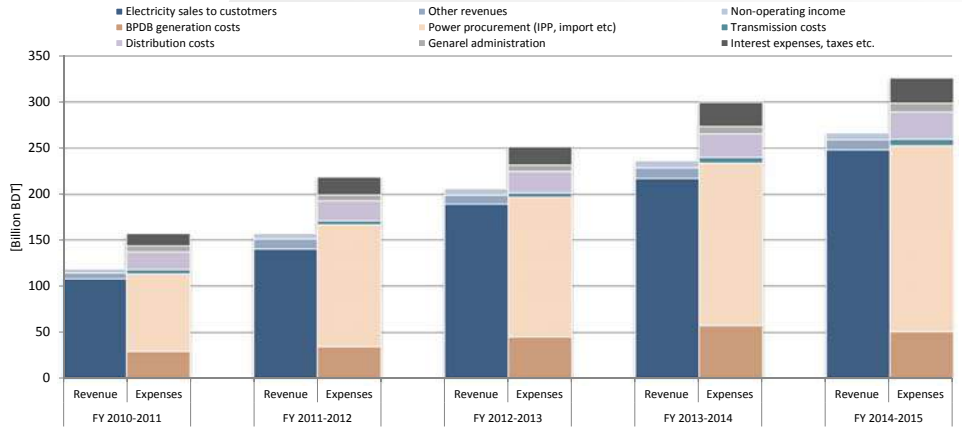
Average Supply Cost, Bulk Rate, and Average Retail Sales of Electricity (FY2014-2015)



Consolidated Revenues and Expenses of the Entire Power Sector

- In order to analyze the financial balance of the whole power sector, this study prepared a consolidated revenue and expenses of the power utilities (BPDB, PGCB, and distribution utilities) which is summarized in the figure below.
- The figure shows that the revenue from electricity sales to customers does not even cover the costs of generation including the costs of power procurement.

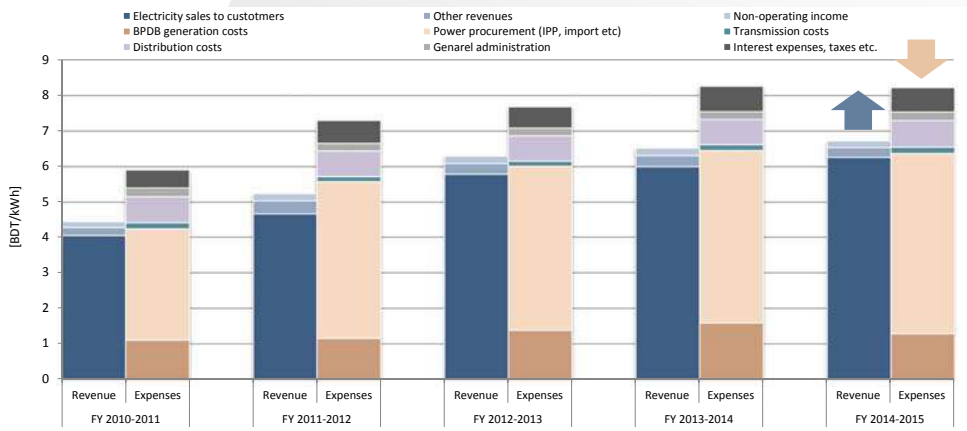
Consolidated Revenue and Expenses of the Bangladesh Power Sector (billion BDT)



Consolidated Revenues and Expenses (continued)

- This figure shows the consolidated revenue and expenses of the power sector (BPDB, PGCB, and distribution utilities) per electricity sales to customers (BDT/kWh).
- While further increase of electricity tariff is required to cover the full costs of supply and to sustain the financial soundness of the power sector, reduction of costs of supply, especially power procurement, needs to be dealt with to mitigate the tariff increase.

Consolidated Revenue and Expenses of the Bangladesh Power Sector per Energy Sales (BDT/kWh)

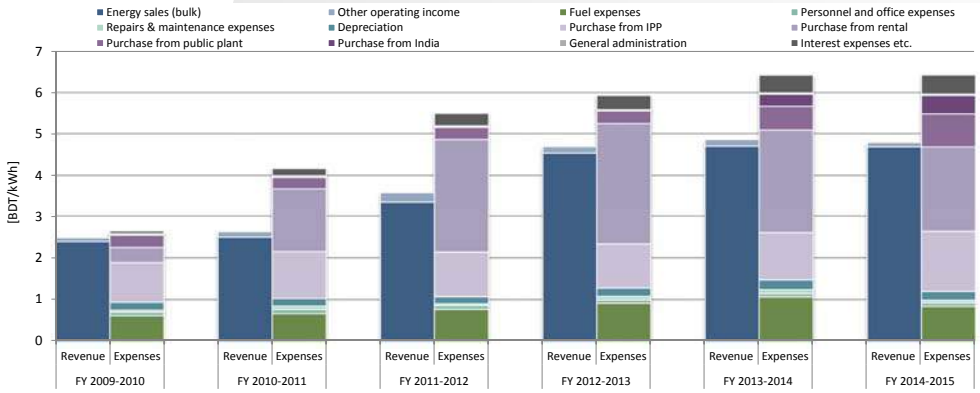


BPDB's Financial Conditions and Generation Costs

Revenues and Expenses of BPDB Power Generation Division

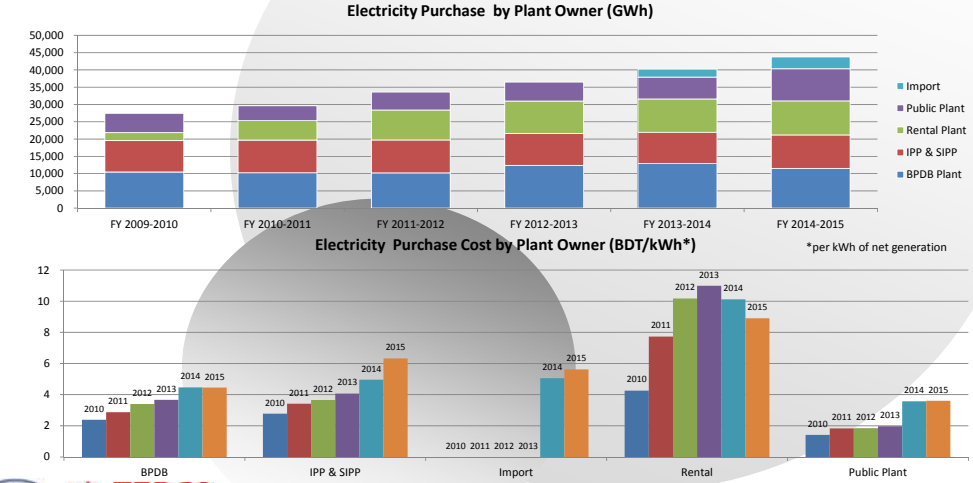
- BPDB's generation sector has continuously been in a financial deficit.
- With the increase of electricity demand, BPDB has expanded its portion of electricity purchase, instead of increasing its own generation plant. Despite the increase of bulk supply tariff, BPDB's revenue has not been able even to cover the swelling cost of electricity purchase.
- The power purchase cost from rental power increased sharply from 2009 to 2012 though it has been slightly decreasing for the past two years.

Revenue and Expenses of BPDB Power Generation Division per Energy Sales (BDT/kWh)



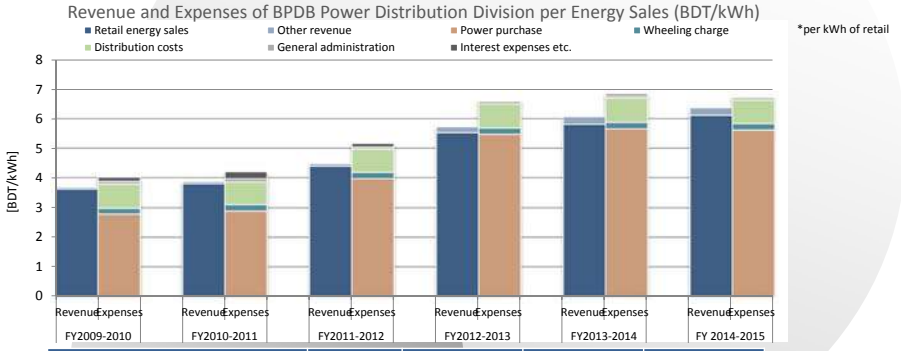
Electricity Purchase Cost by Plant Owner

- Amount of electricity purchase, especially from rental plants, has been increasing. The average electricity purchase cost of rental plants was 8.90 BDT/kWh in FY2014-2015, whereas the average for IPP/SIPP and public plants in the same year was 6.33 BDT/kWh and 3.61 BDT/kWh, respectively.
- Thus, one of the main contributing factors of increasing electricity cost can be accredited to the increasing electricity purchase from rental plants that are much costlier than other types of power generation.



Revenues and Expenses of BPDB Power Distribution Division

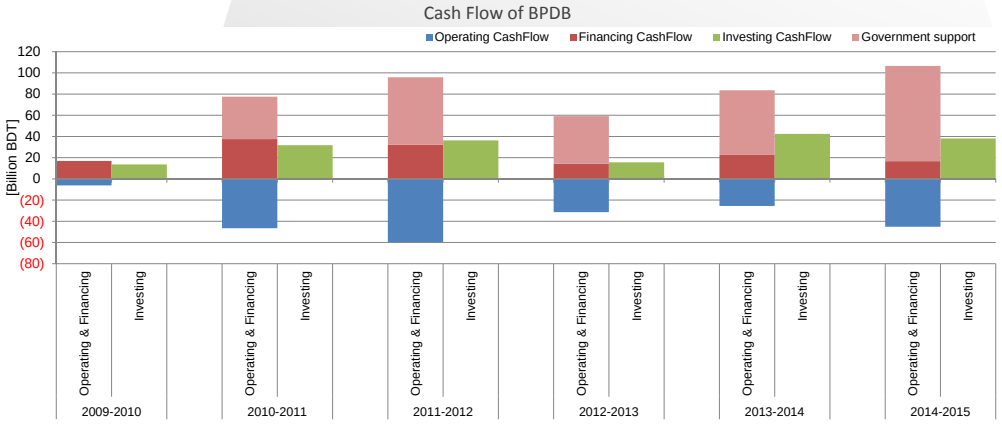
- BPDB's revenue is not sufficient to cover the full costs of supply, including its own distribution expenses and wheeling charge; therefore, BPDB's distribution division has continuously been in a financial deficit.
- Considering that other distribution entities have mostly been balancing their revenue and expenses, BPDB may be setting a higher standard of bulk supply tariff for itself (the distribution division), in order to mitigate the financial deficit of the generation sector.



Particulars	Unit	FY2013-14	FY2013-14	FY2014-15
Purchase from BPDB wholesale	mil. BDT	42,161	47,896	52,365
	GWh	8,737	9,597	10,486
Average bulk tariff rate	BDT/kWh	4.83	4.99	4.99
Sales to consumers	mil. BDT	42,562	49,163	57,024
	GWh	7,693	8,456	9,315
Average retail tariff rate	BDT/kWh	5.53	5.81	6.12

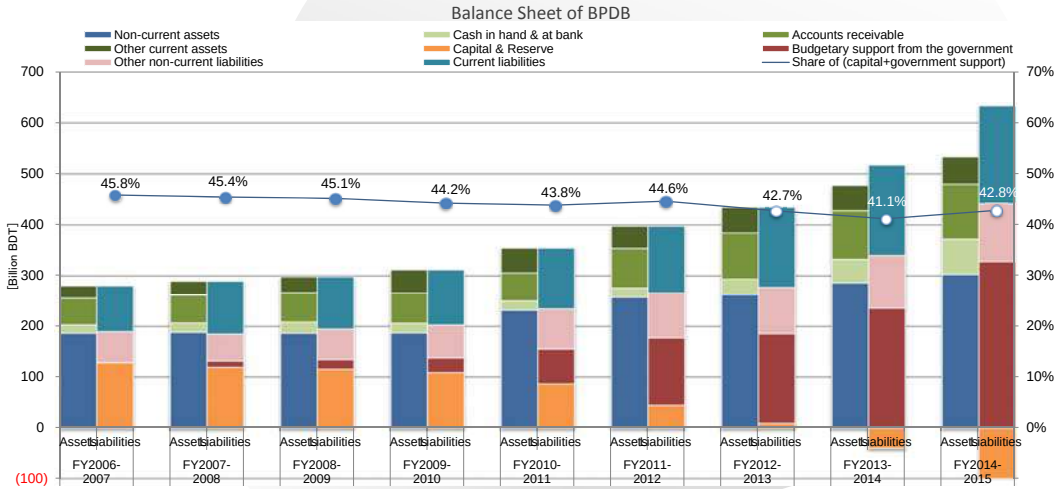
Cash Flow of BPDB

- In general, operating cash flow of power utilities is positive because of depreciation which the return from past CAPEX. This positive cash flow is used for reinvestment, i.e. the renewal of their facilities.
- However, the financial deficit of BPDB's generation division is far too large hence its operating cash flow is negative. Such situation is very strange considering the nature of power utilities' business model.
- Budgetary support has been supplied from the government in order to offset such deficit. The amount of this budgetary support has been growing for the past three years.



Balance Sheet of BPDB (Subsidization Issue)

- Due to the accumulated losses BPDB's capital reserve has been depleted and became capital deficit from FY2013.
- Budgetary support from the government to BPDB has been increasing rapidly to make up for the depleting capital reserve. In fact, the sum of capital reserve and government support has been rather stable around 40% of the total asset.
- If such situation continues, it is highly likely for BPDB to ask the government to turn this liability into capital equity.



Summary of the Observations

- In order to achieve the revenue-cost balance so that the power sector does not need to rely on government subsidies, not only tariff increase to meet the costs of supply but also cost reduction, especially reduction of power procurement cost, needs to be taken.

Tariff Increase

- Considering that BPDB's financial condition is in a critically serious situation, raising bulk supply tariff for BPDB to cover the costs of power generation is indispensable.
- This will also lead to the increase of retail tariff, otherwise the distribution companies will also be faced with financial difficulties.

Cost Reduction

- In the meanwhile, reducing the costs of power supply, especially power procurement, should also be addressed.
- Above all, power procurement from small rental power, which is much costlier than other types of power generation and recently has been increasing both in volume and price, needs to be dealt with.
- Because the efficiency of theses small power generators are not high, they should be driven away gradually. Developing large-scale power plants timely to meet the increasing power demand is important also from this point of view.

Necessity of Mid- and Long-term Plan for Improving Financial Situation

- However, both of the aforementioned can be made only gradually and it is supposed to take certain time to achieve the revenue-cost balance and totally remove the subsidies.
- If government support is still needed for some period, the government should provide mid- and long-term plan to show how and when the revenue-cost balance will be achieved.

Impact on National Economy

Impacts of Gas Price and Electricity Tariff Increase on National Economy

- JICA Survey Team analyzed impact of gas price and electricity tariff Increase on national economy by Global Trade Analysis Project (GTAP) model.
- For GTAP analysis, we set the following model.

Model for GTAP analysis

Categories	Average Electricity Price Increase
Categories of Area	Bangladesh, Asian countries, other countries in the other region.
Categories of Sector	Agriculture, coal, oil, gas, electricity, industry, service *coal, oil, gas are used only for analysis of gas price increase

(1) Single-year Analysis of Electricity Tariff Increase : Methods

- For electricity tariff, we set the following scenarios for single-year analysis

Scenarios for Analyzing Impact of Electricity Tariff Increase

Scenarios	Average Electricity Tariff Increase in USD
(a)	10%
(b)	20%
(c)	30%

Impacts of Gas Price and Electricity Tariff Increase on National Economy

(2) Single-year Analysis of Electricity Tariff Increase : Results

- Increase of electricity tariff gives negative impact on GDP. In comparison of GDP current growth, this amount might be large.
- Impact on real export and real import seem to be slightly smaller than impact on real GDP.

Impacts of Electricity Tariff Increase on National Economy

	(a) 10% Increase		(b) 20% Increase		(c) 30% Increase	
	Change ratio (%)	Change amount (millon USD)	Change ratio (%)	Change amount (millon USD)	Change ratio (%)	Change amount (millon USD)
Impact on real GDP	-0.72	-811	-1.45	-1619	-2.17	-2424
Impact on real export	-0.28	-79	-0.56	-158	-0.83	-235
Impact on real import	-0.27	-95	-0.55	-190	-0.82	-284

Impacts of Gas Price and Electricity Tariff Increase on National Economy

(3) Time Series Analysis of Electricity Tariff Increase : Methods

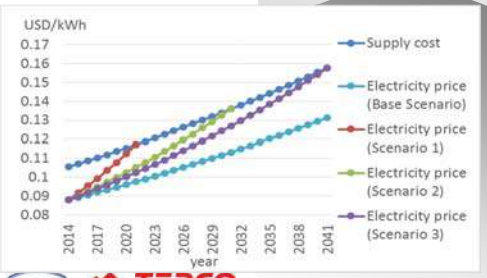
Scenarios of Electricity Tariff Increase
(Pattern 1 : Supply Cost Increase 1.5%/year)

Scenario	Annual Increase in USD
Increase of Cost	1.5%/year
Base Scenario	1.5%/year
1	4.2%/year until 2021 1.5%/year from 2022
2	2.6%/year until 2031 1.5%/year from 2032
3	2.2%/year until 2041

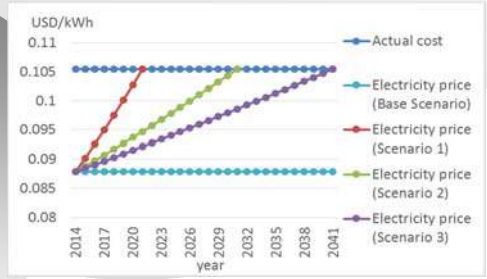
Scenarios of Electricity Tariff Increase
(Pattern 2 : No Supply Cost Increase)

Scenario	Annual Increase in USD
Increase of Cost	0%/year
Base Scenario	0%/year + minor fluctuation in the model calculation
1	2.6%/year until 2021 0%/year + minor fluctuation from 2022
2	1.1%/year until 2031 0%/year + minor fluctuation from 2032
3	0.7%/year until 2041

Scenarios of Electricity Tariff Increase (Pattern 1)



Scenarios of Electricity Tariff Increase (Pattern 2)



Impacts of Gas Price and Electricity Tariff Increase on National Economy

(4) Time series Analysis of Electricity Tariff Increase : Results

- In comparison of GDP current growth, negative impact of Scenario 2 and Scenario 3 might be moderate.

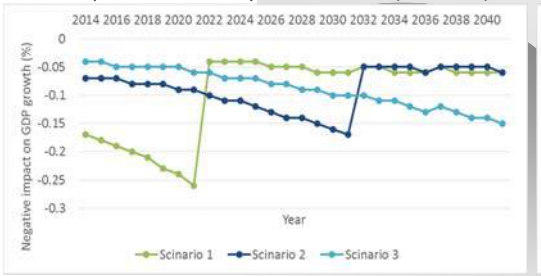
Impacts of Electricity Tariff Increase on National Economy
(Pattern 1: Supply Cost Increase 1.5%/year)

	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.06	-0.06
Scenario 2	-0.07	-0.09	-0.17	-0.06
Scenario 3	-0.04	-0.06	-0.1	-0.15

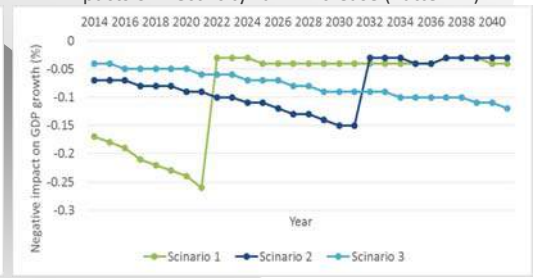
Impacts of Electricity Tariff Increase on National Economy
(Pattern 2: No Supply Cost Increase)

	2014	2021	2031	2041
Scenario 1	-0.17	-0.26	-0.04	-0.04
Scenario 2	-0.07	-0.09	-0.15	-0.03
Scenario 3	-0.04	-0.06	-0.09	-0.12

Impacts of Electricity Tariff Increase (Pattern 1)



Impacts of Electricity Tariff Increase (Pattern 2)



Impacts of Gas Price and Electricity Tariff Increase on National Economy

(5) Single-year Analysis of Gas Price Increase : Methods

- For single-year analysis of gas price increase, we set the following scenarios.

Scenarios for Analyzing Impact of Gas Price Increase

Scenarios	Average Gas Price Increase in USD
(a)	50%
(b)	100%

Impacts of Gas Price and Electricity Tariff Increase on National Economy

(6) Single-year Analysis of Gas Price Increase : Results

- Increase of gas price gives negative impact on GDP. In comparison of GDP current growth, this amount might be large.
- Impact on real export and real import seem to be slightly smaller than impact on real GDP.

Impacts of Electricity Price Increase on National Economy

	(a) 50% Increase		(b) 100% Increase	
	Change ratio (%)	Change amount (millon USD)	Change ratio (%)	Change amount (millon USD)
Impact on real GDP	-1.26	-1408	-2.47	-2759
Impact on real export	-0.72	-205	-1.35	-383
Impact on real import	-1.36	-473	-2.70	-938

Impacts of Gas Price and Electricity Tariff Increase on National Economy

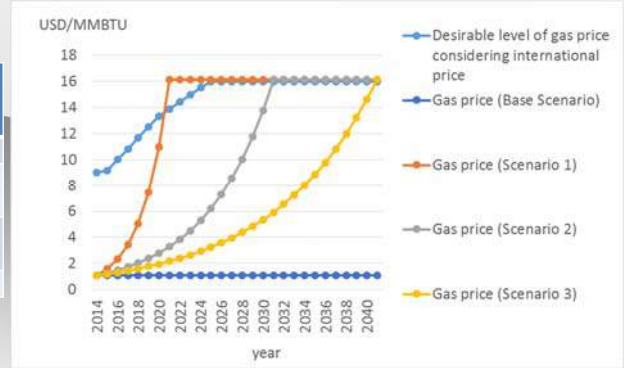
(7) Time Series Analysis of Gas Price Increase : Methods

- For analyzing the impact of gas price increase considering the timeframe, three scenarios are prepared in varying the period when the domestic gas price will come up with the international price level.

Scenarios for Analyzing Impact of Gas Price Increase

Scenario	Annual Increase of Gas Price in USD
Base Scenario	0%
1	47.2%/year until 2021 0%/year from 2022
2	17.3%/year until 2031 0%/year from 2032
3	10.6%/year until 2041

Scenarios of Gas Price Increase



Impacts of Gas Price and Electricity Tariff Increase on National Economy

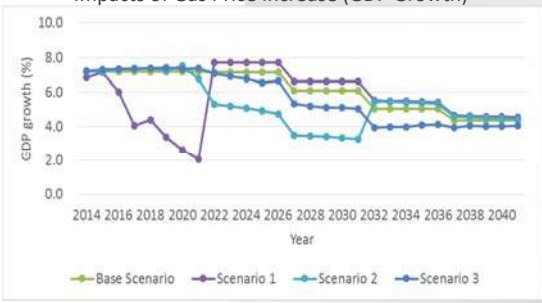
(8) Time Series Analysis of Gas Price Increase : Results

- Increase of gas price gives negative impact on GDP. Scenario 1 and 2 gives huge negative impact but impact of Scenario 3 might be moderate.

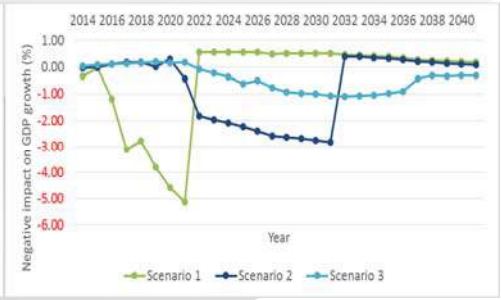
Impacts of Gas Price Increase on National Economy (Difference between Scenario 1 to 3 and Base Scenario)

	2014	2021	2031	2041
Scenario 1	-0.33	-5.13	0.52	0.18
Scenario 2	-0.02	-0.43	-2.82	0.09
Scenario 3	0.04	0.19	-1.08	-0.32

Impacts of Gas Price Increase (GDP Growth)



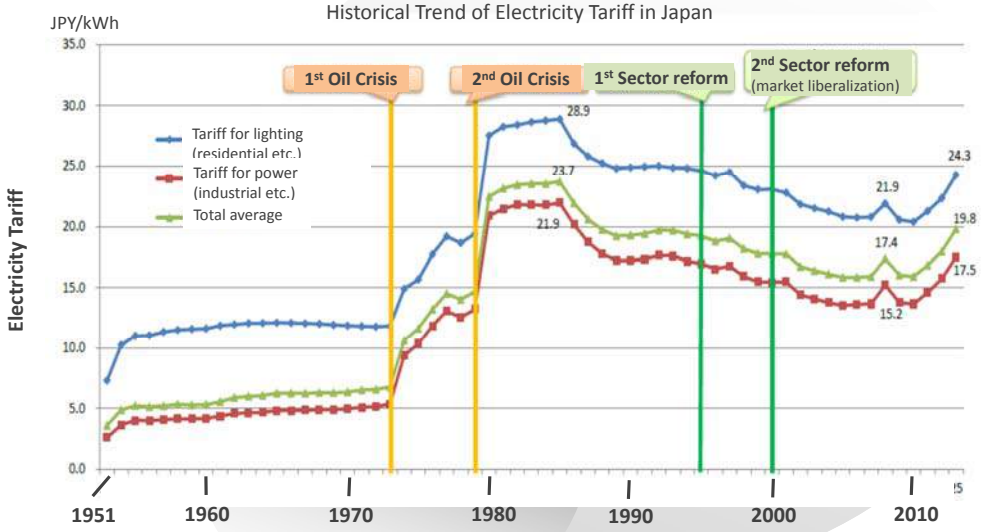
Impacts of Gas Price Increase (Difference)



Recommendation: Electricity Tariff Policy for Bangladesh

- In developing stage, Japanese electricity price were kept stable.

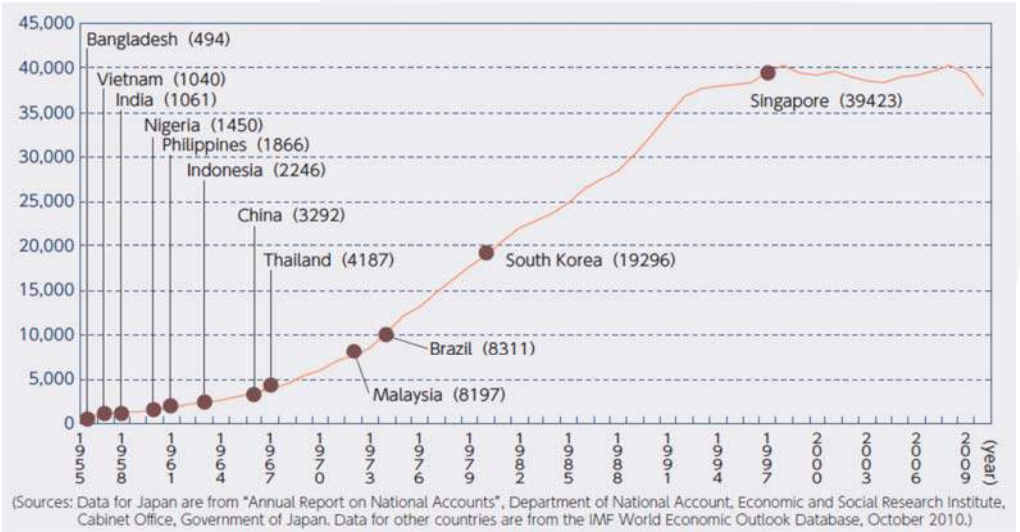
Historical Trend of Electricity Tariff in Japan



Recommendation: Electricity Tariff Policy for Bangladesh

- Bangladesh GDP per capita is same as those in 1950's and 60's in Japan

History of Economic Development in Japan

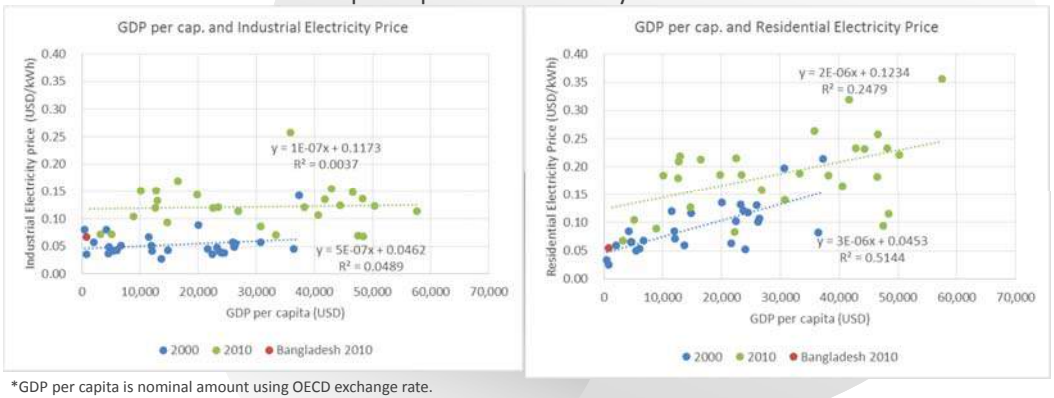


(Sources: Data for Japan are from "Annual Report on National Accounts", Department of National Account, Economic and Social Research Institute, Cabinet Office, Government of Japan. Data for other countries are from the IMF World Economic Outlook Database, October 2010.)

Recommendation: Electricity Tariff Policy for Bangladesh

- The following figure plots the relation between GDP per capita and electricity tariff (industrial and residential) of various countries in 2000 and 2010 as well as that in Bangladesh.
- Both industrial electricity tariff and residential electricity tariff are not too much low in comparison with the other developing countries.
- Residential electricity tariff is expected to be increased according to economic growth.

GDP per capita and Electricity Price



*GDP per capita is nominal amount using OECD exchange rate.
Source: IEA Energy prices and taxes 2008 and 2012, and BERC

Recommendation: Electricity Tariff Policy for Bangladesh

- It is desirable to have a policy to revise residential electricity tariff as well as tariff for other categories in accordance with economic growth of Bangladesh.

Example of Electricity Tariff Increase

Consumer Category	Range (kWh)	Scenario of Price Increase
Domestic-A	1-75	Keep minimum increase (e.g. 1.5%/year increase)
	76–600	Increase according to the scenario. (e.g. 2.6%/year increase until 2031, 1.5%/year increase from 2032)
	Above 600	+the amount cover the price cost gap of lower categories
Agricultural pumping-B	Flat	Keep minimum increase (e.g. 1.5%/year increase)
Small industry –C	Flat/Peak/ Off peak	Increase according to the scenario. (e.g. 2.6%/year increase until 2031, 1.5%/year increase from 2032)
Non-residential –D		
Commercial –E	Flat/Peak/ Off peak	
Medium Voltage –F	Flat/Peak/ Off peak	
Extra High Voltage –G	Flat/Peak/ Off peak	
High Voltage –H	Flat/Peak/ Off peak	
Street Lights & Pump –J		

Recommendation: Gas Price Policy for Bangladesh

- According to the demand increase of gas, Bangladesh will be obliged to import more natural gas.
- If Bangladesh covers the gap between domestic gas price and international gas price by subsidy, financial deficit of Bangladesh government will be expanded.
- It is therefore desirable to increase domestic natural gas price gradually.
- In consideration of huge negative impact, continuous annual increase of 10 to 20% (in terms of real USD) would be suitable for Bangladesh.

- *Besides electricity and gas, the issue of oil subsidies also needs a exit strategy in order to avoid huge pressure to the national coffer.*
  → To serve for this, transparency of costing is required for further analysis.

তোমাকে ধন্যবাদ

23.7 Official comments meeting for Final Report (FR)

- Date: 1, 2, 4 August 2016
- Venue: TEPCO Headquarter (Tokyo)
- Discussion Point:
  - ✓ Economic Development
  - ✓ Primary Energy Balance
  - ✓ Power Balance
  - ✓ Cost and Tariff Balance





- Participants

Participants are shown below table.

No.	NAME	Designation	Organization
1	Mohamed Abul Kashem Mahmud	Director of System Planning Director	BPDB
2	MD. Monower Zahid Khan	Assistant Engineer of System Planning Director	BPDB
3	Mr.Arun Kumar Saha	Planning & Design Department	PGCB
4	Mr. Rahman Sahbun Nur	Planning & Design Department	PGCB

(Alphabetical order)

23.8 Official comments meeting for Final Report (FR)

- Date: 7 September 2016
- Venue: TEPCO Headquarter (Tokyo)
- Discussion Point:
  - ✓ Continuous Technical Support for Post-PSMP2016





- Participants

Participants are shown below table.

No.	NAME	Designation	Organization
1	Mr. Md Mahbub Ul Alam	Additional Secretary	Power Division, Ministry of Power, Energy and Mineral Resources

(Alphabetical order)

23.9 Document List

List of collected documents are shown below table.

Category No.	Title	Source	File type	File name
ADB - 1	ADB Bangla Economic Indicator	ADB	EXCEL	ADB-1
ADB - 2	ADB Bangladesh facts 2013	ADB	EXCEL	ADB-2
ADB - 3	Corporatization of Bangladesh Power Development Board (1)	ADB	PDF	ADB-3
ADB - 4	Corporatization of Bangladesh Power Development Board (2)	ADB	PDF	ADB-4
ADB - 5	Energy outlook for Asia and Pacific	ADB	PDF	ADB-5
ADB - 6	Sector Assistance Program Evaluation for Bangladesh Energy Sector	ADB	PDF	ADB-6
ADB - 7	PREPARING THE POWER SECTOR DEVELOPMENT PROGRAM II	ADB	PDF	ADB-7
ADB - 8	Power System Master plan Update	ADB	PDF	ADB-8
Coal - 1	Draft Bangladesh Coal Policy	Ministry of Power, Energy and Mineral Resources	Word	Coal-1
Coal - 2	2014/2015 Annual Report of Barapukuria Coal Mining Compny Ltd.	BCMCL	Book	Coal-2
Coal - 3	Presentation on Coal Fields of Bangladesh	BCMCL	PPT	Coal-3
Coal - 4	Proposal for ADB financing for Furubari Coal mining	Environment& Social Society center	PDF	Coal-4
Economic - 1	Bangladesh Vision 2021	NAGORIK COMMITTEE 2006	PDF	ECON-1
Economic - 2	Perspective Plan of Bangladesh 2010-2021	Planning Commission HP	PDF	ECON-2
Economic - 3	Sixth Five Year Plan FY2011-FY2015 Part 1 Strategic Directions &Policy Framework	Planning Commission HP	PDF	ECON-3
Economic - 4	Sixth Five Year Plan FY2011-FY2015 Part 2 Accelerating Growth and Reducing Poverty	Planning Commission HP	PDF	ECON-4
Economic - 5	Sixth Five Year Plan FY2011-FY2015 Part 3 Statistical Annex	Planning Commission HP	PDF	ECON-5
Economic - 6	Seventh Five Year Plan FY2016-FY2020	Bangladesh Planning Commission	PDF	ECON-6
Economic - 8	World Economic Outlook https://www.imf.org/external/pubs/ft/weo/2016/01/weodata/index.aspx	IMF	URL	ECON-7
Economic - 9	Global Economic Prospects http://www.worldbank.org/en/publication/global-economic-prospects	WB	URL	ECON-8
Economic - 9	Asian Development Outlook 2015 https://www.adb.org/publications/asian-development-outlook-2015-financing-asias-future-growth	ADB	URL	ECON-9

Category No.	Title	Source	File type	File name
Economic - 10	World Population Prospects 2015	UN	PDF	ECON-10
Economic - 11	Perspective Plan of Bangladesh 2010-2021	Bangladesh Planning Commission	PDF	ECON-11
Economic - 12	Economic Zone wise Electricity Demand up to 2025 (projections)	Bangladesh Economic Zones Authority (BEZA)	WORD	ECON-12
Economic - 13	Economic Zone wise Gas Demand up to 2025 (projections)	Bangladesh Economic Zones Authority (BEZA)	WORD	ECON-13
Economic - 14	Welcome to Economic Zones of Bangladesh	Bangladesh Economic Zones Authority (BEZA)	PPT	ECON-14
Economic - 15	Sectoral Need-based Projections in Bangladesh	Bangladesh Bureau of Statistics	PDF	ECON-15
Economic - 16	Demographic and Health Survey 2011	National Institute of Population Research and Training	PDF	ECON-16
Economic - 17	Economic Census 2013 (in Abridged Form)	Bangladesh Bureau of Statistics	PDF	ECON-17
Economic - 18	Sixth Five Year Plan FY2011-2015	Planning Commission	PDF	ECON-18
Energy - 1	Bangladesh IEA data	International Energy Agency	EXCEL	ENGY-1
Energy - 2	Power and Energy Sector Road map	Ministry of Finance	PDF	ENGY-2
Energy - 3	Q5 _Primary Energy Analysis _Energy Balance 2__Questionnaire_Aoki_	Petrobangla	Word	ENGY-3
Energy - 4	Petrobangla reply21041117	Petrobangla	Word	ENGY-4
Energy - 5	Questionnaire_gas development _Primary energy analysis 2B__No2	Petrobangla	Word	ENGY-5
Energy - 6	October 29, 2014 The Baily Star	Petrobangla	Word	ENGY-6
Energy - 7	Petrobangla Annual report 2012	Petrobangla	PDF	ENGY-7
Energy - 8	Petrobangla Annual report 2013	Petrobangla	PDF	ENGY-8
Energy - 9	Population & Housing Census-2011	Bangladesh Bureau of Statistics	PDF	ENGY-9
Energy - 10	Report of the Household Income & Expenditure Survey (HIES) 2010	Bangladesh Bureau of Statistics	PDF	ENGY-10
Energy - 11	Study Report on the Potential Needs of BOP Business in Bangladesh: Energy Sector	JETRO (Japan)	PDF	ENGY-11

Category No.	Title	Source	File type	File name
Energy - 12	Restoring Balance; Bangladesh's Rural Energy Realities, World Bank Working Paper No.181	World Bank	PDF	ENGY-12
Energy - 13	Report on Labor Force Survey 2010	Bangladesh Bureau of Statistics	PDF	ENGY-13
Energy - 14	IEA Energy Balances http://www.iea.org/statistics/topics/energybalances/	IEA	URL	ENGY-14
Energy - 16	Index of US Energy Security Risk 2014	American Chamber of Commerce (ACC)	PDF	ENGY-15
Energy - 17	2010 Annual Report on Energy (Energy white paper 2010)	METI (Japan)	PDF	ENGY-16
Energy - 18	Measuring Short-term Energy Security 2011	IEA	PDF	ENGY-17
Energy - 19	ToT Course on Power & Energy Camp- 2015	Bangladesh Planning Commission	PDF	ENGY-18
Energy - 20	(Draft) Five Year Gas Supply Strategy (Year 2015- 2019)	Petrobangla	PDF	ENGY-19
Energy - 21	Petrobangla 2017	Petrobangla	PDF	ENGY-20
Energy - 22	(Draft) Investment Plan for Bangladesh Under Scaling Up Renewable Energy Program in Low Income Countries (SREP)	SREDA	PDF	ENGY-21
Energy - 23	Preparation and Development of Gas Sector Master Plan and Strategy for Bangladesh, Bangladesh Gas Sector Strategy Final Report	Petrobangla	PDF	ENGY-22
Energy - 24	Bangladesh Gas Sector Master Plan Final Report	Petrobangla	PDF	ENGY-23
Energy - 25	Sector-wise Use of Main Petroleum Product during 2003-04 through 2013-14	Bangladesh Petroleum Corporation (BPC)	WORD	ENGY-24
Energy - 26	BREB presentation	Bangladesh Rural Electrification Board (BREB)	PDF	ENGY-25
Energy - 27	MIS_Report_October 2015	Bangladesh Rural Electrification Board (BREB)	PDF	ENGY-26
Energy - 30	Energy Sector Development and Energy Security in Bangladesh	Bangladesh University of Engineering and Technology	PDF	ENGY-27
Energy - 31	Energy Security & Climage Change : Challenge for Bangladesh	Energy & Power	PDF	ENGY-28
Energy - 32	Energy Security : Trends and Challenges, Bangladesh Economic Update	Unnayan Onneshan	PDF	ENGY-29
Energy - 33	Energy Efficiency and Conservation Master Plan up to 2030	SREDA	PDF	ENGY-30
Energy - 34	Bangladesh Industrial Energy Efficiency Opportunities Assessment	USAID	PDF	ENGY-31

Category No.	Title	Source	File type	File name
Energy - 35	Survey of Manufacturing Industries 2012	Bangladesh Bureau of Statistics	PDF	ENGY-32
Energy Cost - 1	Category wise sale of Energy since FY 04-05	Bangladesh Power Development Board (BPDB)	PDF	COST-1
Energy Cost - 2	An Overview of Power Sector of Bangladesh	Bangladesh Power Development Board (BPDB)	PDF	Cost-2
Energy Cost - 3	BPDB Annual Report	Bangladesh Power Development Board (BPDB)	PDF	COST-3
Energy Cost - 4	DESCO Annual Report	Dhaka Electric Supply Company (DESCO)	PDF	COST-4
Energy Cost - 5	DPDC Annual Report	Dhaka Power Distribution Company (DPDC)	PDF	COST-5
Energy Cost - 6	PGCB Annual Report	Power Grid Company of Bangladesh (PGCB)	PDF	COST-6
Energy Cost - 7	REB Financial Data	Bangladesh Rural Electrification Board (BREB)	PDF	COST-7
Energy Cost - 8	WZPDCL Annual Report	West Zone Power Distribution Company (WZPDCL)	PDF	COST-8
Energy Cost - 9	Petrobangla Annual Report	Petrobangla	PDF	COST-9
Energy Cost - 10	BPC Annual Report	Bangladesh Petroleum Corporation (BPC)	PDF	COST-10
Energy Cost - 11	Energy Subsidies in Bangladesh: A profile of groups vulnerable to reform	International Institute for Sustainable Development (IISD)	PDF	COST-11
Energy Cost - 12	BERC http://www.berc.org.bd/index.php?id=101	Bangladesh Energy Regulatory Commission (BERC)	URL	COST-12
Energy Cost - 13	Planning Commission "ANNUAL DEVELOPMENT PROGRAMME FOR 2013-2014", http://www.plancomm.gov.bd/adp-2013-2014-english/	The Bangladesh Planning Commission	URL	COST-13

Category No.	Title	Source	File type	File name
Energy Cost - 14	Planning Commission "ANNUAL DEVELOPMENT PROGRAMME FOR 2014-2015" http://www.plancomm.gov.bd/adp/	The Bangladesh Planning Commission	URL	COST-14
Energy Cost - 15	Planning Commission "ANNUAL DEVELOPMENT PROGRAMME FOR 2015-2016" http://www.plancomm.gov.bd/adp-2014-2015-bangla/	The Bangladesh Planning Commission	URL	COST-15
Energy Cost - 16	Asian Development Fund: FAQs http://www.adb.org/site/adf/faqs	Asian Development Bank	URL	COST-16
Energy Cost - 17	IDA Terms (Effective as of July 27, 2016)	World Bank	PDF	COST-17
Energy Cost - 18	Lending and relending terms of local/Foregin currency loans	Ministry of Finance	PDF	COST-18
Energy saving - 1	Draft Energy Efficiency and Conservation Master Plan	JICA	PDF	ES-1
Energy saving - 2	Energy Efficiency and Conservation Rules, Draft October 2012	SREDA,	PDF	ES-2
Energy saving - 3	Interim Action Plan for Improvement of Energy Efficiency & Conservation	Power Division	PDF	ES-3
Energy saving - 4	Energy Efficiency Initiatives	Power Division	PDF	ES-4
Demand - 1	Bangladesh Map	Bangladesh Bureau of Statistics HP	PDF	EPD-1
Demand - 2	POPULATION AND HOUSING CENSUS 2011	Bangladesh Bureau of Statistics HP	PDF	EPD-2
Demand - 3	Population in Bangladesh	Bangladesh Bureau of Statistics HP	PDF	EPD-3
Demand - 4	Bangladesh Population 2014	United Nations HP	PDF	EPD-4
Environment - 2	IPCC AR5, WG3 report Chapter6	IPCC	PDF	ENV-1
Environmet - 3	Intended Nationally Determined Contributions (INDC)	Ministry of Environment and Forests (MOEF)	PDF	ENV-2
Environmet - 4	Mitigation of Short Lived Climate Pollutants (SLCPs) in Bangladesh and Integration in National Policies and Strategies	CCAC (Climate and Clean Air Coalition) Department of Environment	PDF	ENV-3
Environmet - 5	Second National Communication of Bangladesh to the UNFCCC	Ministry of Environment and Forests (MOEF)	PDF	ENV-4
Gas - 1	Field wise Gas Production	Petrobangla HP	PDF	Gas-1
Gas - 2	Five year Gas Production Strategy 12-03-2015	Petrobangla HP	PDF	Gas-2
Gas - 3	Five year Gas Production Strategy 12-03-2016	Petrobangla HP	Word	Gas-3

Category No.	Title	Source	File type	File name
Gas - 4	Field wise Gas Production Forecasts up to 2019	Petrobangla HP	PDF	Gas-4
Gas - 5	Gas consumption history	Petrobangla HP	PDF	Gas-5
Gas - 6	Natural gas Reserve in Bangladesh	Petrobangla HP	PDF	Gas-6
Gas - 7	Responses from Petrobangla on Gas production	Petrobangla	PDF	Gas-7
Gas - 8	Bangladesh Nastural Gas Survey 01	JICA	PDF	Gas-8
Gas - 9	Bangladesh Nastural Gas Survey 02	JICA	PDF	Gas-9
Gas - 10	Bangladesh Nastural Gas Survey 03	JICA	PDF	Gas-10
Gas - 11	Natural gas price list	Google	PDF	Gas-11
Gas - 12	Bangladesh Gas Sector Master Plan 2006	Wood Mackenzie	PDF	Gas-12
Gas - 13	Gas and Alternative balance	Petrobangla	Word	Gas-13
Gas - 14	Gas and Alternative balance	Petrobangla	Word	Gas-14
Gas - 15	Gas and Alternative balance	Petrobangla	Word	Gas-15
O&M - 1	Reply of questionnaire on legal framework	BERC	PDF	OM-1
O&M - 2	Reply of questionnaire on legal framework	NWCPL	WORD	OM-2
O&M - 3	Reply of questionnaire on legal framework	EGCB	WORD	OM-3
O&M - 4	Reply of questionnaire on legal framework	shahjibazar	WORD	OM-4
Oil - 1	BPC Production	Bangladesh Petroleum Corporation	PDF	Oil-1
PDP - 1	Sustainable-energy-for-development	Ministry of Power, Energy and Mineral Resources	PDF	PDP-1
PDP - 2	Energy and Nuclear Power Planning in Bangladesh	Bangladesh Atomic Energy Commission	PDF	PDP-2
PDP - 3	Power Pricing Framework	Power cell	PDF	PDP-3
PDP - 4	Power cell POWER PURCHASE FROM Captive power	Power cell	PDF	PDP-4
PDP - 5	PRIVATE SECTOR POWER GENERATION POLICY OF BANGLADESH	Power cell	PDF	PDP-5
PDP - 6	VISION STATEMENT	Power Division	PDF	PDP-6
PDP - 7	3-Year Road Map for Power Sector Reform	Power Division	PDF	PDP-7
PDP - 8	Power Generation Future Rolling Plan	Power Division	PDF	PDP-8
PDP - 9	Bangladesh Power System Planning Study	World Bank	PPT	PDP-9
PDP - 10	News Clipping September 2015	News paper	PDF	PDP-10
PDP - 11	BPDB Annual Report 2007-2008	BPDP	PDF	PDP-11
PDP - 12	BPDB Annual Report 2008-2009	BPDP	PDF	PDP-12
PDP - 13	BPDB Annual Report 2009-2010	BPDP	PDF	PDP-13
PDP - 14	BPDB Annual Report 2010-2011	BPDP	PDF	PDP-14
PDP - 15	BPDB Annual Report 2012-2013	BPDP	PDF	PDP-15
PDP - 16	BPDB Annual Report 2013-2014	BPDP	PDF	PDP-16
PDP - 17	BPDB Annual Report 2008-2014	BPDP	PDF	PDP-17
PDP - 18	BPDB Capacity & Demand	BPDP	PDF	PDP-18

Category No.		Title	Source	File type	File name
Power Quality	- 1	2015.05 Energy export	BPDB	EXCEL	PQ-1
Power Quality	- 2	Frequency Control	PGCB	PPT	PQ-2
Power Quality	- 3	Electric Grid Reliability for NPP- IAEA Pub1542	EAL	PDF	PQ-3
Power System	- 1	GRID CODE 2012	PGCB	PDF	PS-1
Power System	- 2	Dhaka City_Plan 2015-25_December'15	PGCB	PDF	PS-2
Power System	- 3	Grid Map_Plan 2015-21_May	PGCB	PDF	PS-3
Power System	- 4	On-going & Planned Projects of PGCB April 2016	PGCB	Excel	PS-4
Renewable	- 1	Preparatory Survey on Renewable Energy Development Project	JICA	PDF	RE-1
Renewable	- 2	Year-wise Installation of SHS & Plan 2015 - 2018	Grameen Shakti	PDF	RE-2
Renewable	- 3	IDCOL Solar Home System Program	IDCOL	Power Point	RE-3
Renewable	- 4	RE project data	IDCOL	EXCEL	RE-4
Renewable	- 5	Renewable Energy Projects under SREDA	SREDA	WORD	RE-5
Renewable	- 6	BREB RENEWABLE ENERGY PROGRAM	BREB	Power Point	RE-6
Renewable	- 7	Renewable Energy Projects by SREDA	SREDA	WORD	RE-7
Renewable	- 8	Installation of Solar Panels by Bangladesh Power Development Board	SREDA	WORD	RE-8
Renewable	- 9	Working Paper for progress review meeting of Power Division under renewable Energy (Solar, Wind, Hydro)	SREDA	WORD	RE-9
Renewable	- 10	"Scaling Up Renewable Energy in Low Income Countries (SREP) Investment Plan for Bangladesh October 2015"	World Bank/SREDA	PDF	RE-9
WB	- 1	WB Bangladesh Development Series	World Bank	PDF	WB-1
WB	- 2	Modeling and Forecasting Natural Gas Demand in Bangladesh	World Bank	PDF	WB-2
WB	- 3	WB Financial Restructuring and Recovery	World Bank	PDF	WB-3
WB	- 4	World bank Power Development assistance 2004	World Bank	PDF	WB-4
WB	- 5	World bank Power development policy credit 2008	World Bank	PDF	WB-5
WB	- 6	World bank Power sector reform 2001	World Bank	PDF	WB-6



Japan International Cooperation Agency