People's Republic of Bangladesh
Ministry of Power, Energy and Mineral Resources (MOPEMR)
Bangladesh Power Development Board (BPDB)

People's Republic of Bangladesh Power & Energy Sector Master Plan (PSMP2016)

Final Report
Summary

September 2016

Japan International Cooperation Agency (JICA)

Tokyo Electric Power Services Co., Ltd.
Tokyo Electric Power Company Holdings, Inc.

BD
JR
16-003

Contents

List of Tables

Page

List of Figures

Page

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

Abbreviation	Full Tytle
CEB	Ceylon Electricity Board
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

Abbreviation	Full Tytle
FD	Finance Division
FDI	Foreign Direct Investment
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

Abbreviation	Full Tytle
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IOC	International Oil Company
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

Abbreviation	Full Tytle
MPR	Maintenance Period Rate
MRT	Mass Rapid Transit
MW	Megawatt
MWh	Megawatt Hour
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

Abbreviation	Full Tytle
Q & A	Questions & Answers
R&D	Research and Development
Re	Relaiability
REB	Rural Electrification Board
RES	Renewable Energy power Source
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

Abbreviation	Full Tytle
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
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

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

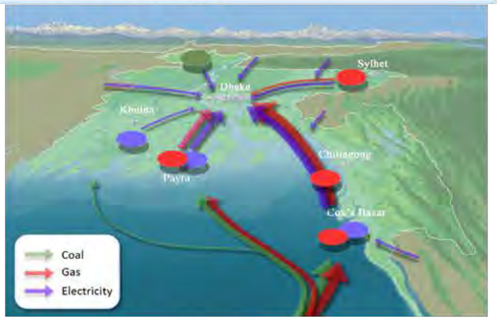
Value-up Plan 3 High-Quality and Robust Power System Development

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

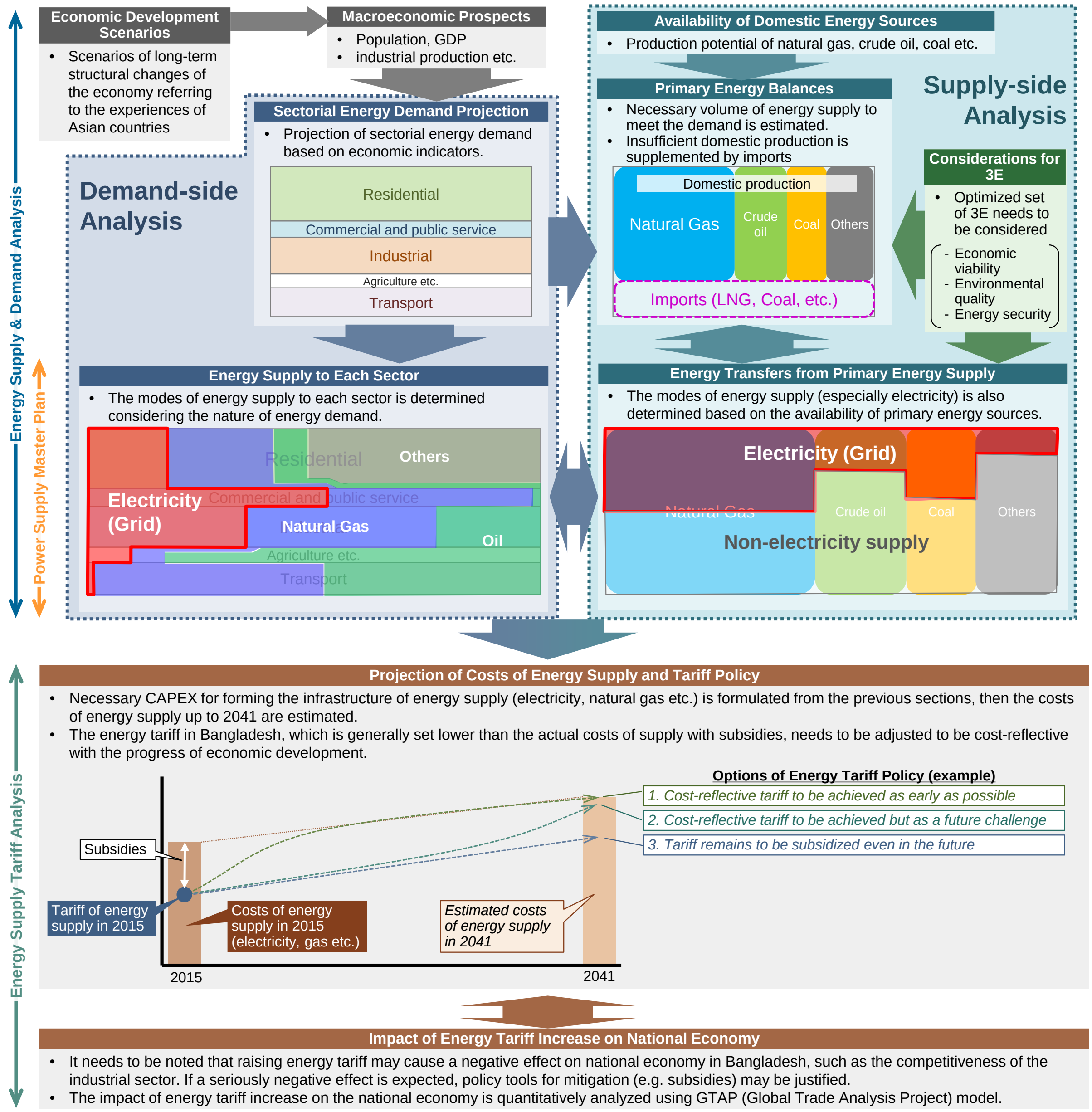
The table below shows the relationship between “the five key policy viewpoints” mentioned above and the components of the master plan. The master plan is composed of a policy for the economic growth, a plan on the primary energy balance, a plan on the power balance mainly based on the power development 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.

Practical Vision	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
	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 • 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** ✧ 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

	Contents of the Study
	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. ✧ 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). ✧ 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

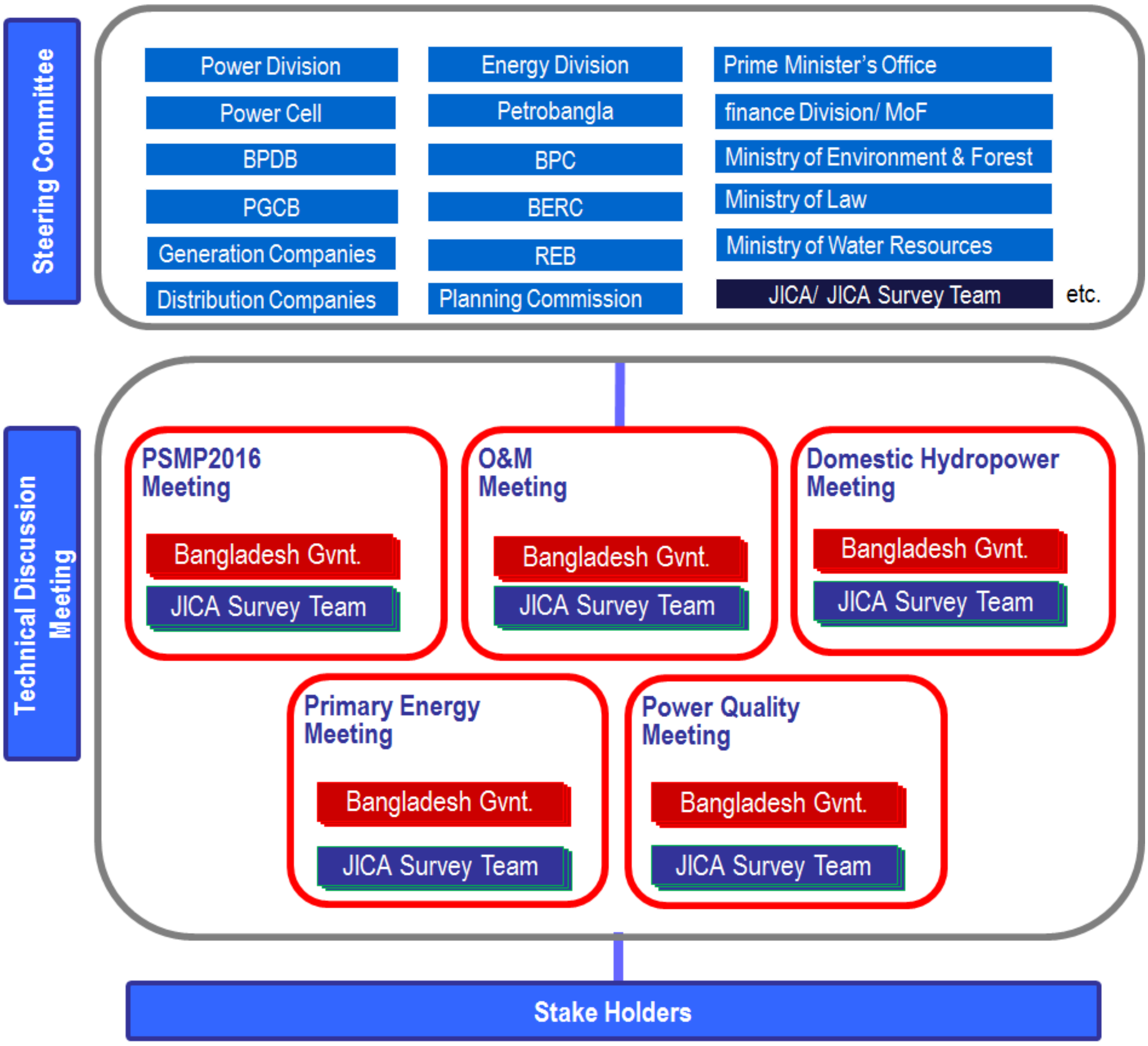
The Hydropower Development Working Group members include PD of MPEMR, MWR, and BPDB. Technical discussion meeting will discuss the impacts and countermeasures downstream due to the planned dam construction, and issues related to the executing agencies.

(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



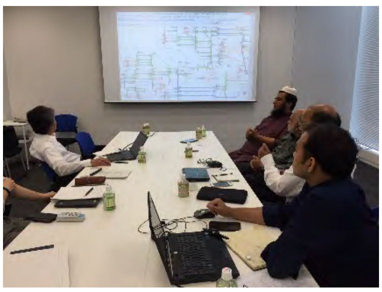
(6) 4th Seminar (4th Steering Committee)

- ■ 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

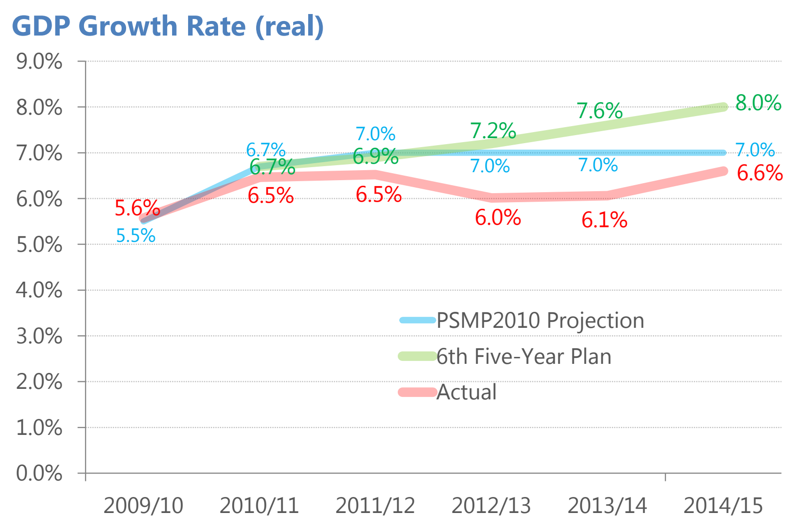
Table 1-3 and Figure 1-3 compares the actual performance of GDP growth rate with the projected growth rate in PSMP 2010 and the target of GDP growth rate in the Sixth Five-Year Plan that was set forth by the GOB in 2011. During the period of the Sixth Five-Year Plan, Bangladesh achieved annual average of 6.3% growth rate. This was higher than the actual growth rate in each of the past five-year plans (1^{st}-5^{th}) 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 [%]	6^{th} 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

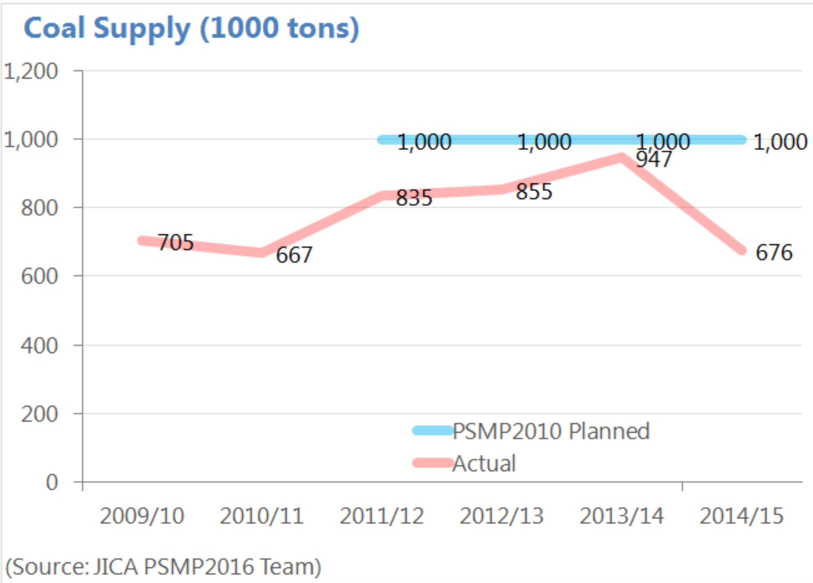
Table 1-4 shows the performance and the forecast of coal production in PSMP2010 and Figure 1-4 shows them by chart. Annual production of 1 million tones will be possible using existing facilities.

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 [1000tons]	Actual [1000tons]	Gap [%]
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)

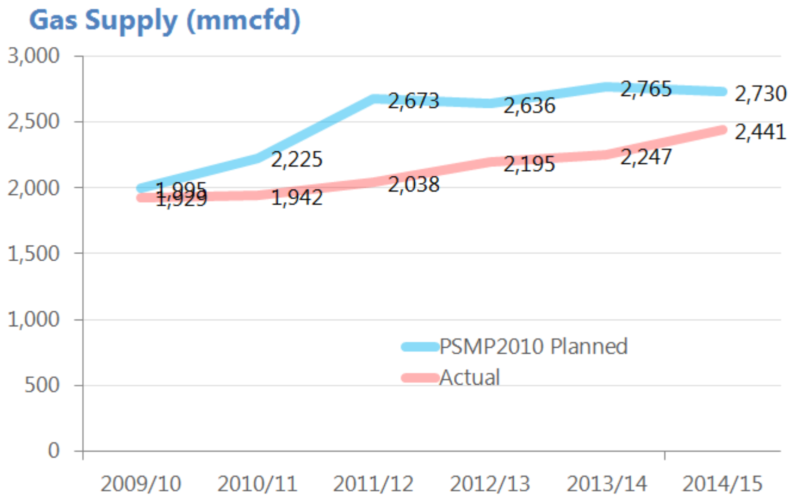
(3) Gas Supply

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 [mmsfd]	Actual [mmsfd]	Gap [%]
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

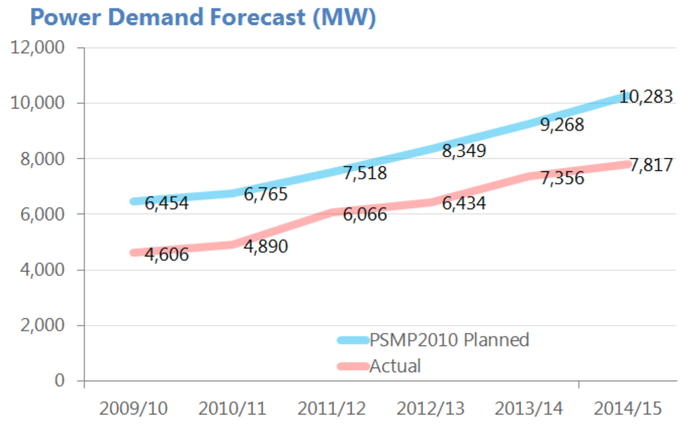
Figure 1-5 PSMP2010 Review (Gas Supply)

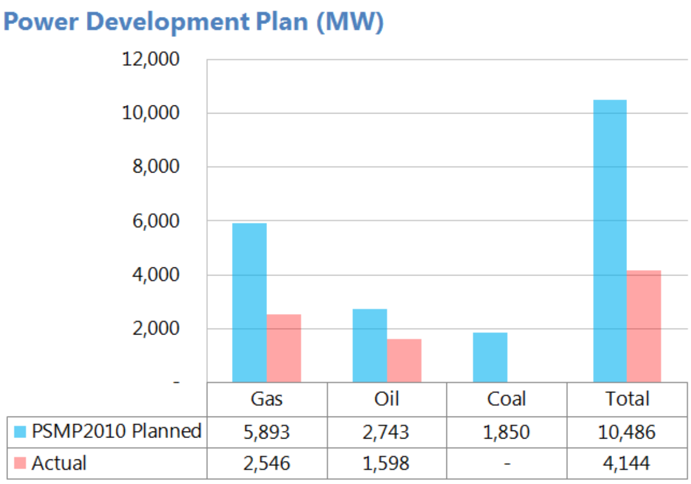
(4) Power Demand and Power Development Plan

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.





Source: JICA Survey Team

Figure 1-6 PSMP2010 Review (Power Development Plan)

1.6.2 Economic Development Policy

(1) Current Status and Issues

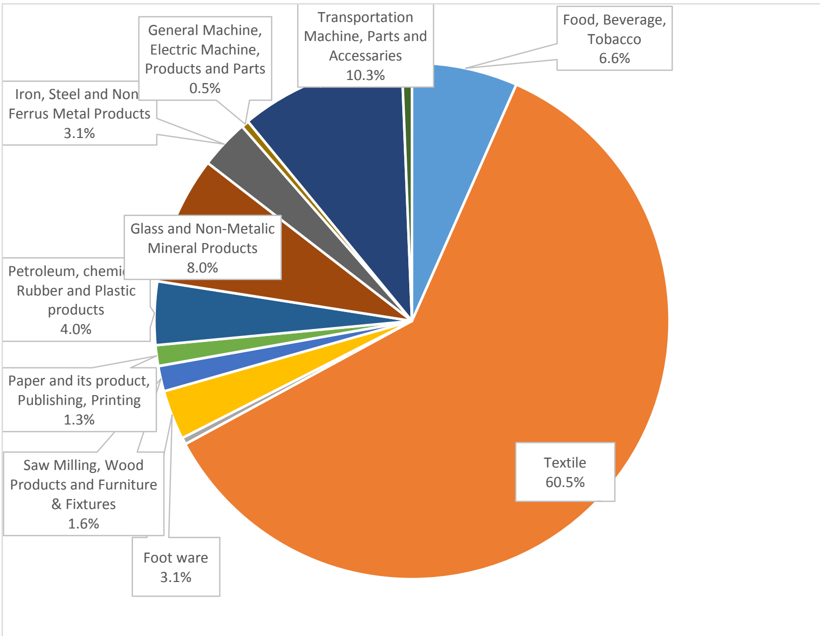
Bangladesh's economy has seen steady growth since independence was declared in 1971. GDP per capita has been steadily expanding since the 1990s, when the ready-made garments (RMG) sector emerged as a major export industry for the country. GDP annual growth rate during the Sixth Five-Year Plan from 2011 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

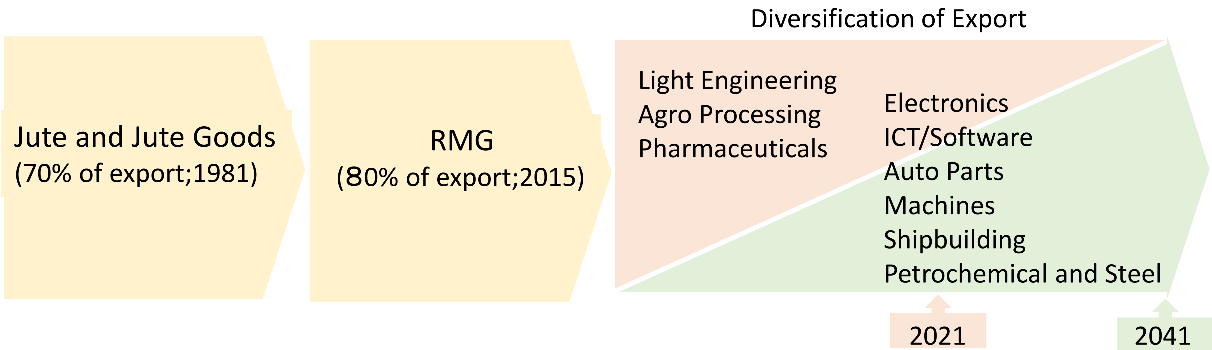
Until now, Bangladesh's economic growth has been maintained by labor-intensive industries such as the garment industry. However, heavy dependence on these industries is not sufficient to sustain further economic growth on a long-term basis. It is necessary to achieve industrial structural changes in 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

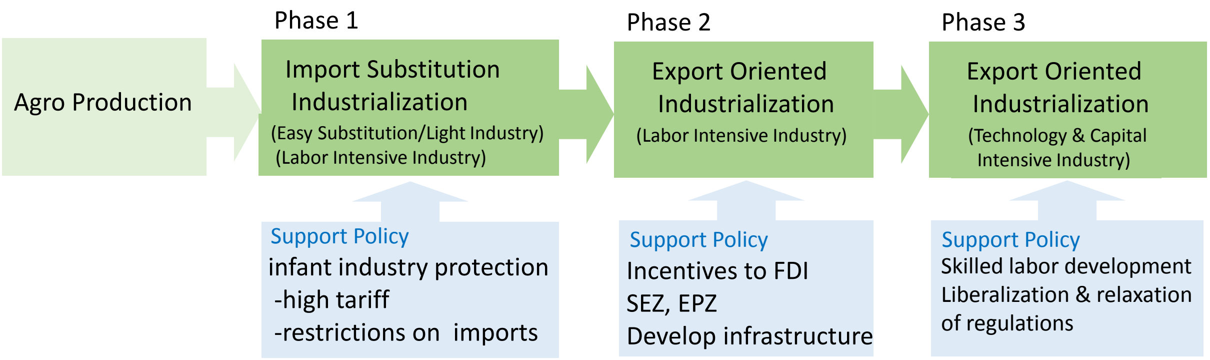
high-income economies (at a GNI per capita of 12,736 US$ or more) by 2041.

- 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.



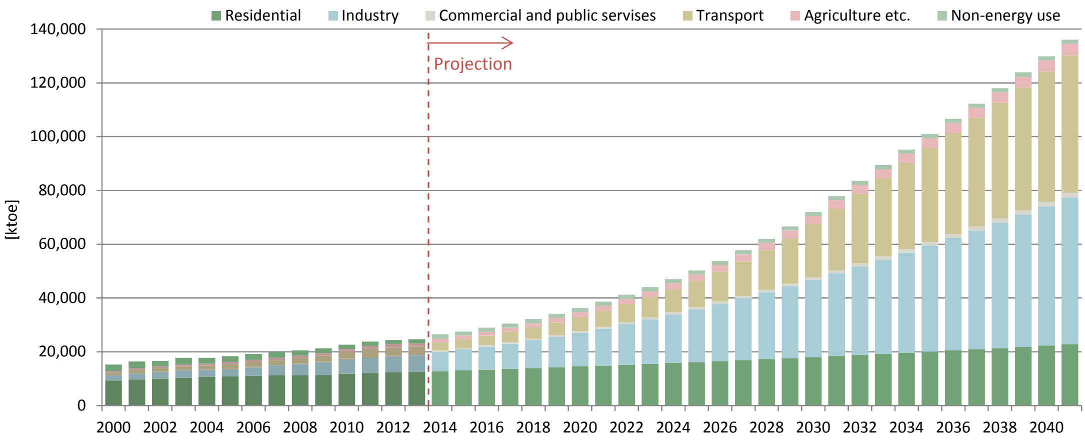
Source: JICA Survey Team

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.

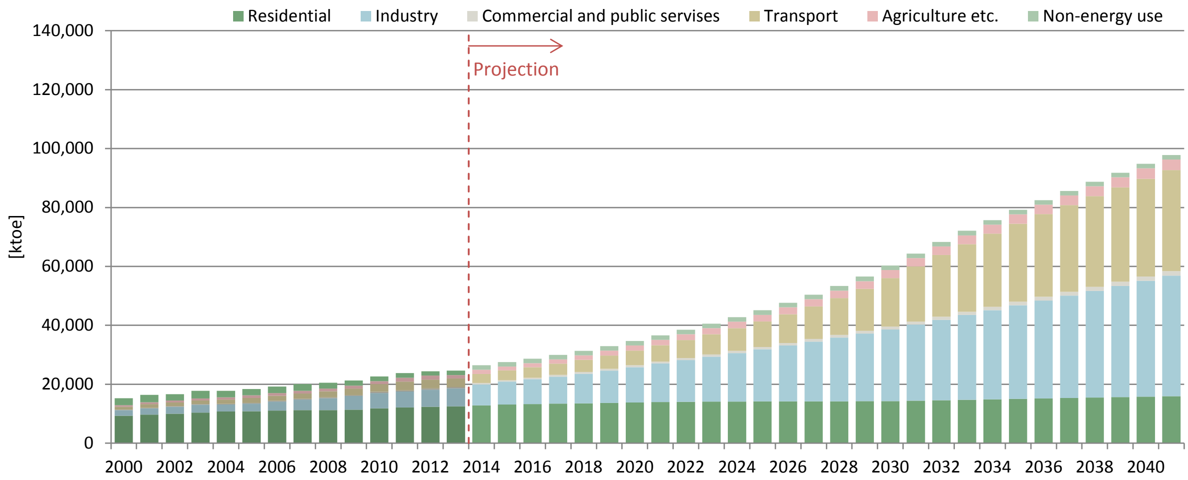


Source: JICA Survey Team

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.

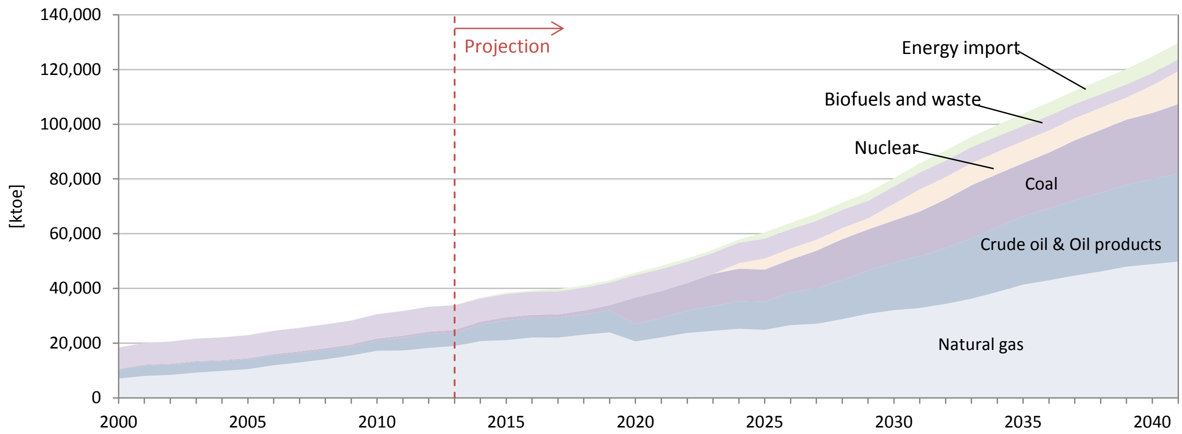
- 2.65 toe/million BDT as of 2030 (decrease of 23% compared to 2014)
- 2.56 toe/million BDT as of 2041 (decrease of 25% compared to 2014)



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

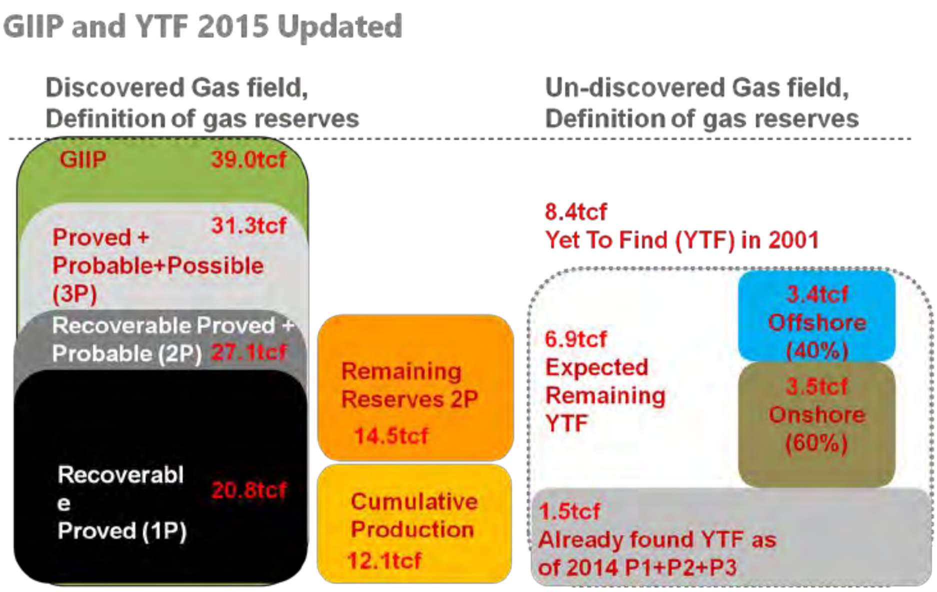
In the transport sector, not only the improvement of fuel consumption efficiency for passenger vehicles but also the improvement of traffic conditions in urban areas (within Dhaka city), which are affected by chronic heavy traffic congestion, needs to be considered.

- 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

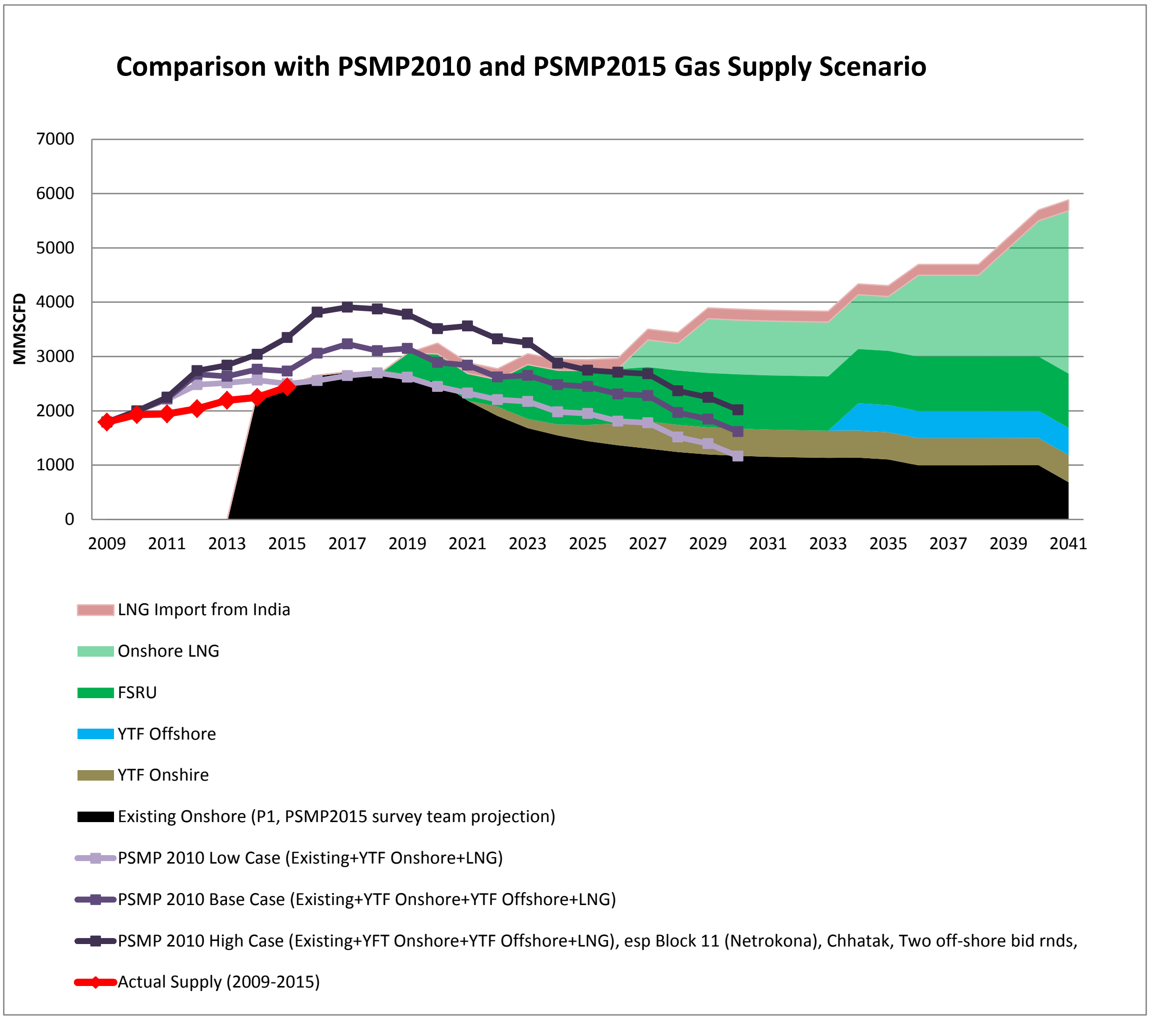
- Legal framework to enhance gas efficiency to be in place by 2019
    - Efficiency to be enhanced to the international level and discourage the use of substandard facilities.

- 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.

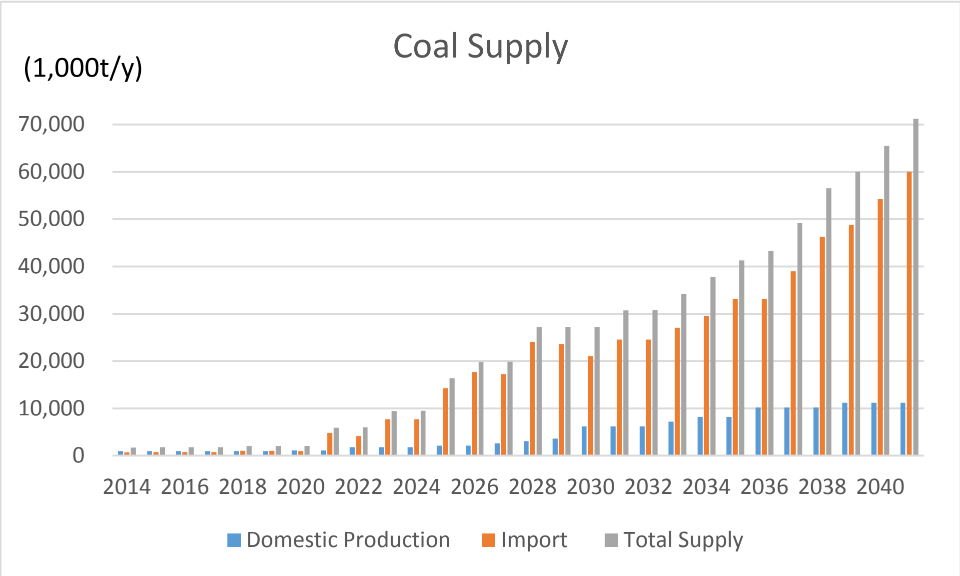
1.6.6 Coal

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.

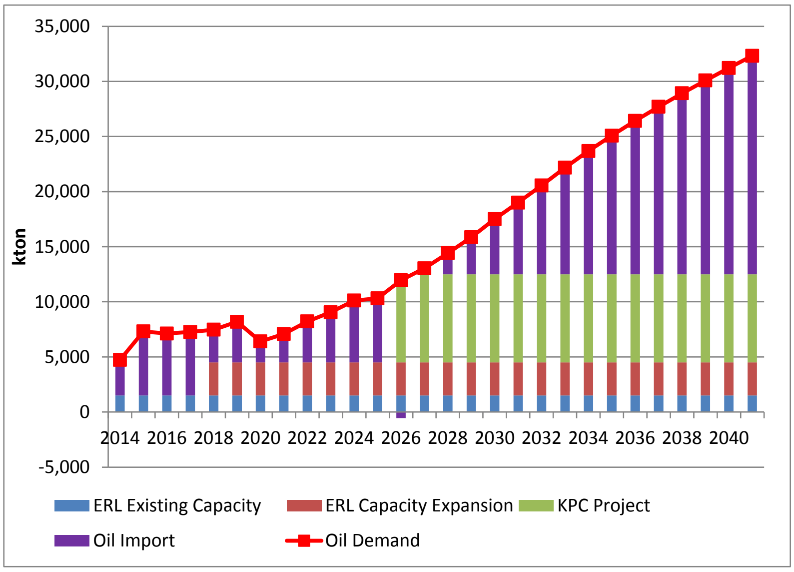
4) The acquisition of coal mine technology by Bangladesh
It should be the case that by 2020 systems have been established through which Bangladesh can learn in technologies such as mining, ventilation and mine safety technology for stable production in the Barapukuria coal mine, and that Bangladesh can 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

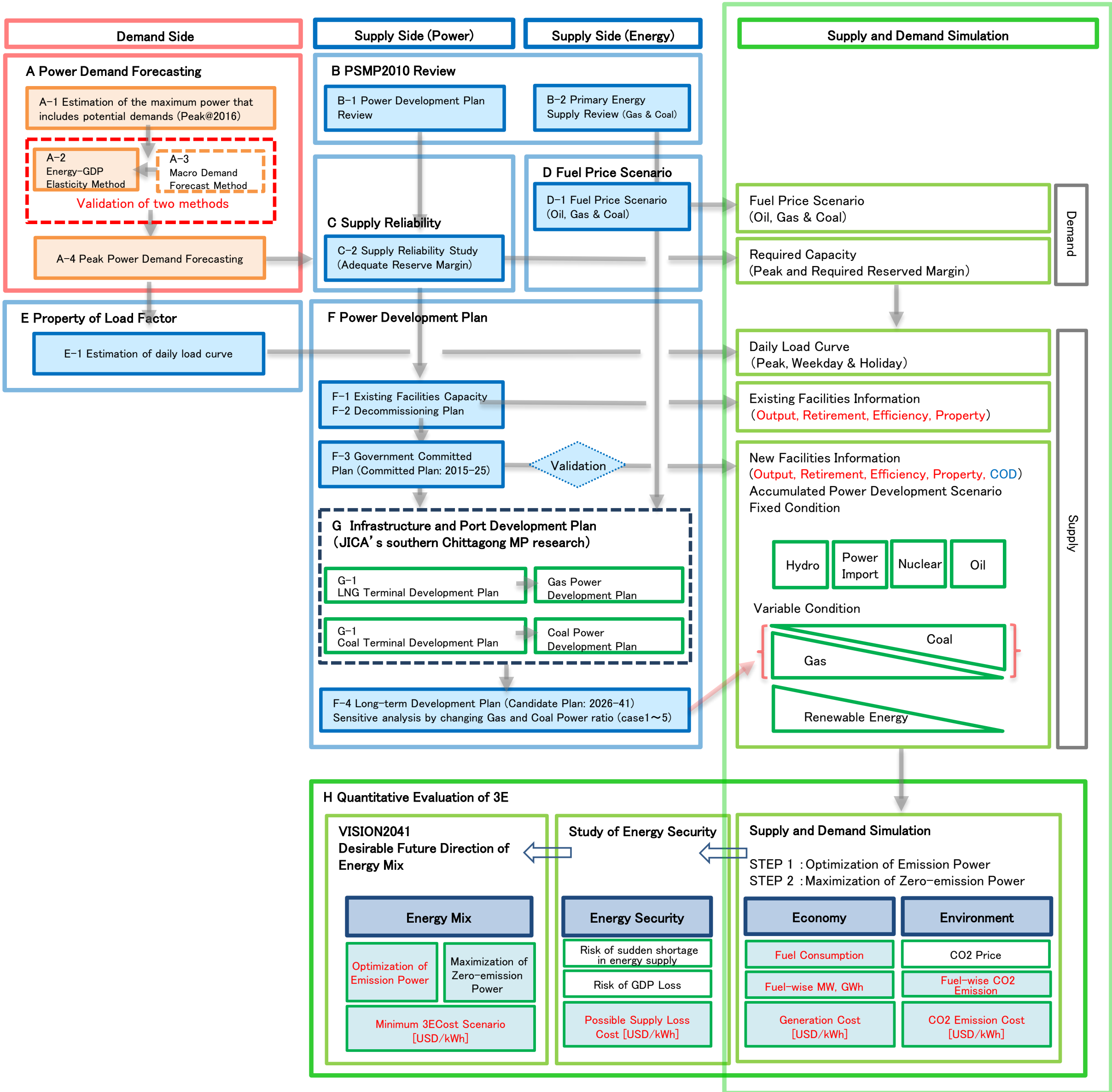
As mentioned in Chapter PSMP2010 review, five-year power demand by PSMP2010 and its actual performance had remained in about 8,000MW which is about 80% level of the plan, because it was delayed power plant construction which had been planned and necessary infrastructure such as port which is essential 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

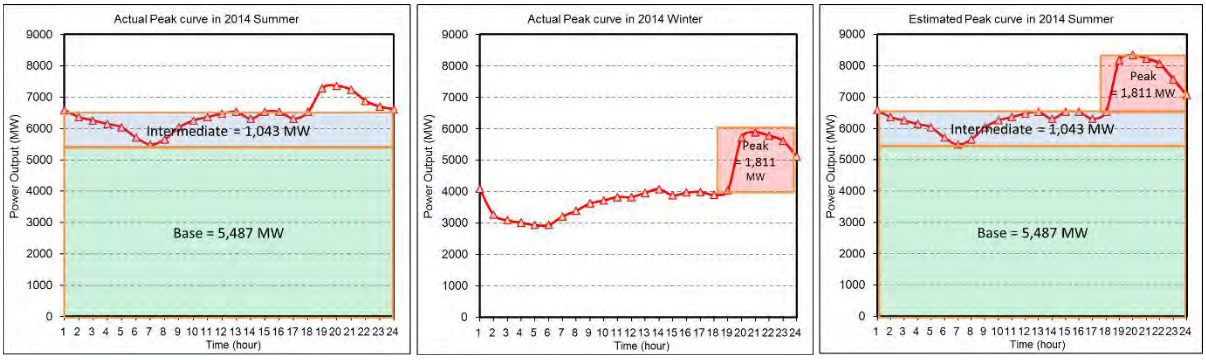
As for the methodology of peak demand projection for PSMP2016, this study adopted the "GDP elasticity method", which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan. However, it has to be noted that this 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.

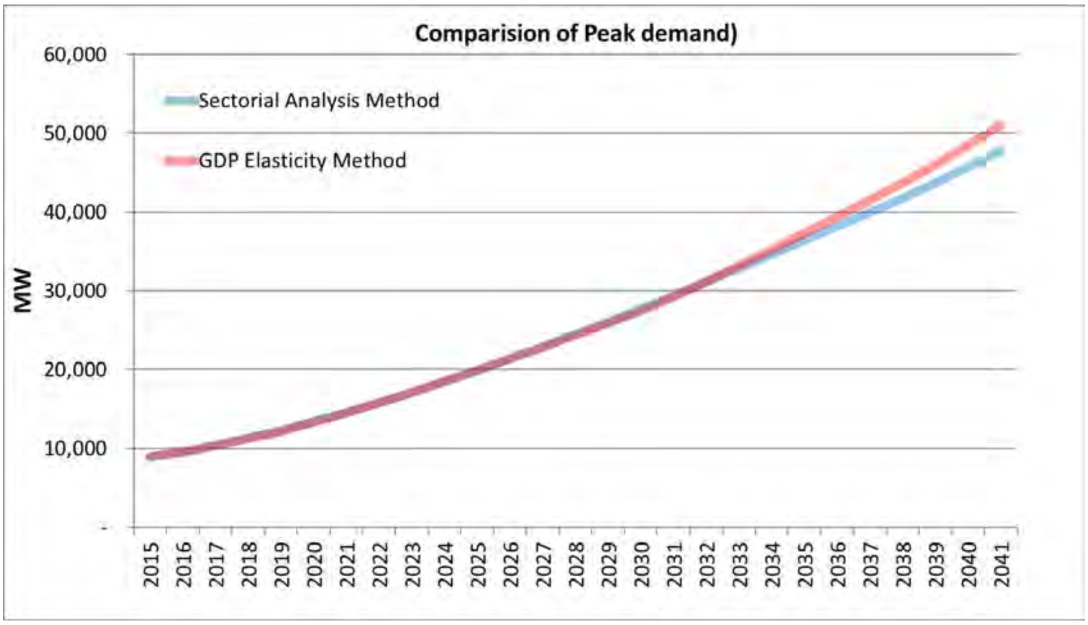


Source : JICA Survey Team

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

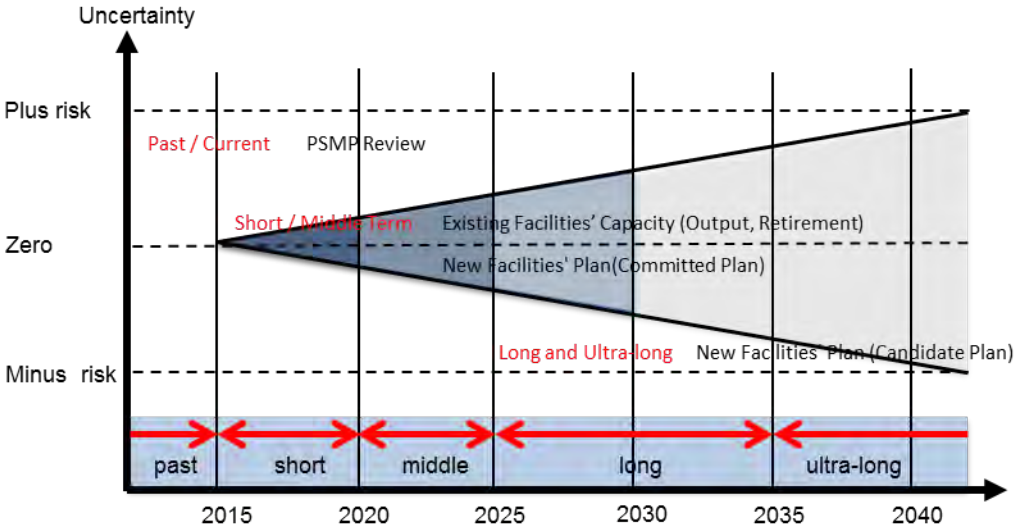
(d) Integration of Peak Power Demand Projection and Energy Supply-Demand Projection

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

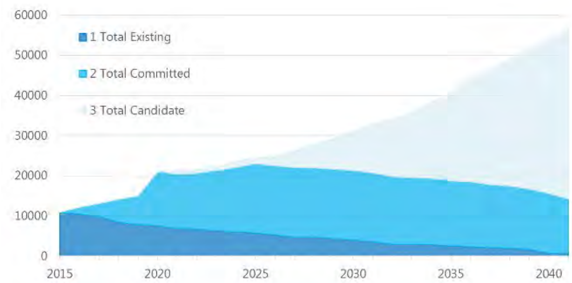
Guarantee of the long-term stability of the fuel supply is a very important factor in the formulation of a power development plan. The existence of a port infrastructure required for the importing of fuels including gas and coal during operation has to be a precondition for the decision on the CODs of 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)

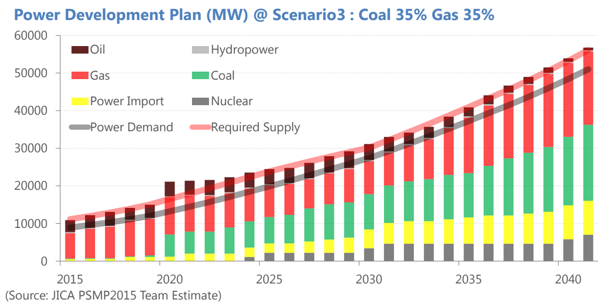
A study on increasing the power sources by changing the ratios of the gas and coal power generation in accordance with the progress in the infrastructure and port development planned in JICA's Southern Chittagong MP Survey is to be conducted for the formulation of the candidate plan. In this section, 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

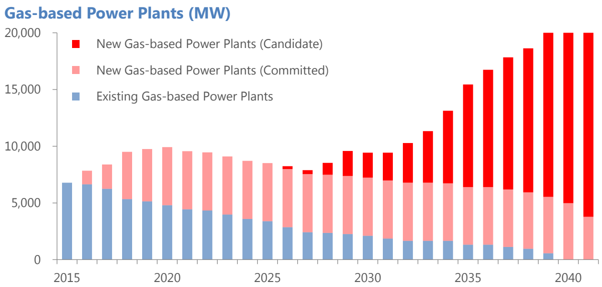
The figure below shows the power supply plan formulated by adding the capacity of the existing plants estimated with the retirement plan in the plan for the existing facilities taken into consideration (existing capacity), the capacity of the plants mentioned in the Committed Plan to be constructed by 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.



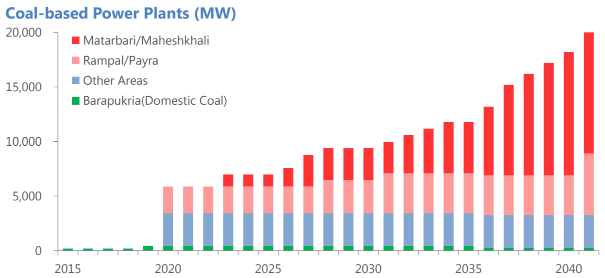
PowerDevelopment Plan (Base case)



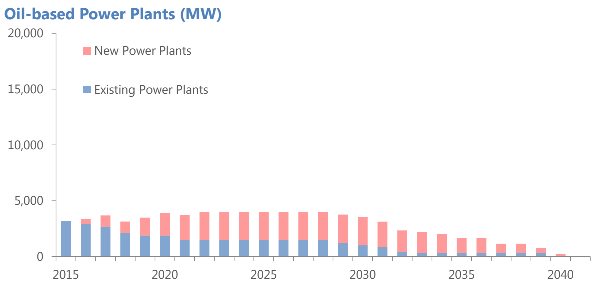
Power Development Plan (Base case)



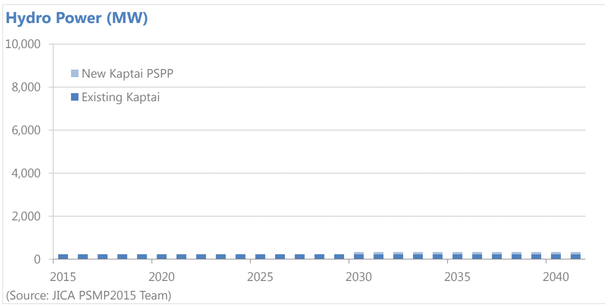
Gas



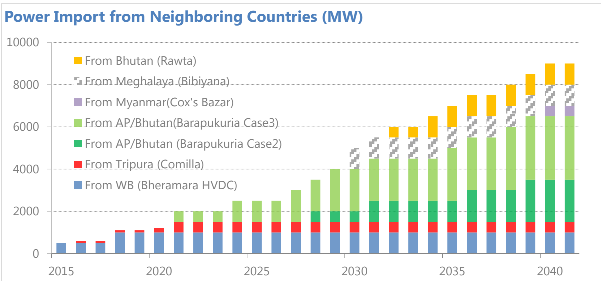
Coal



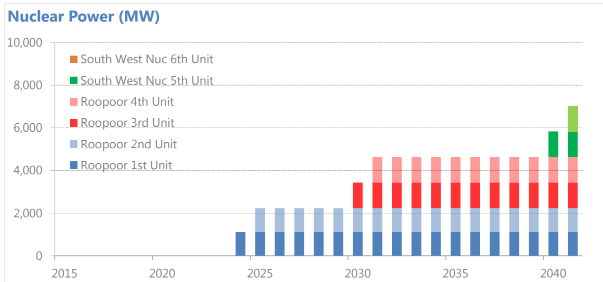
Oil



Hydro



Power Import



Nuclear

Source：JICA Survey Team

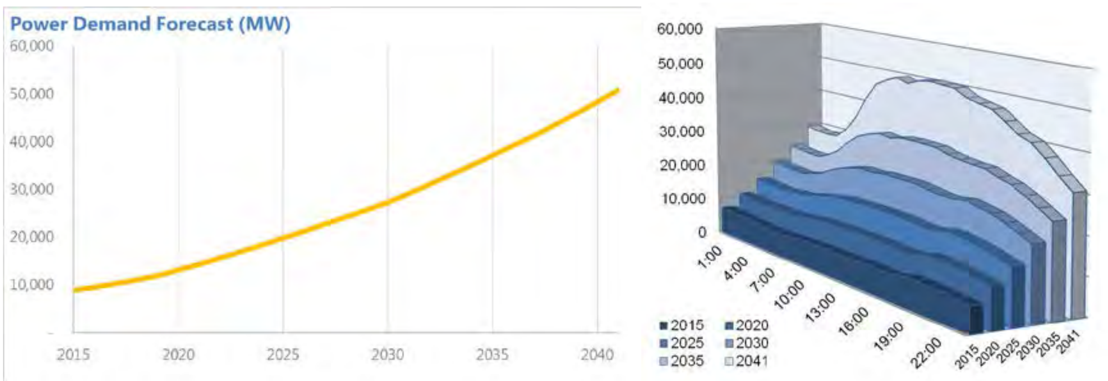
Figure 1-21 Annual Trend of Each Power Plants（MW）

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.

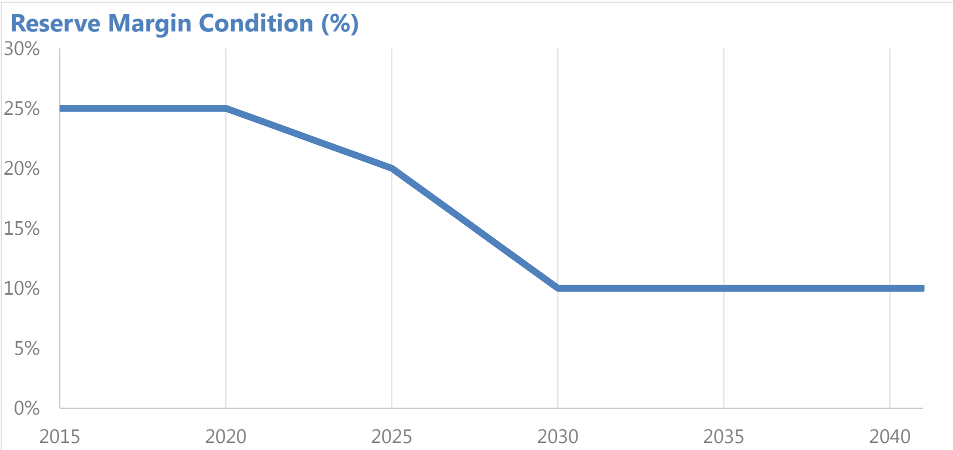


Source: JICA Survey Team

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

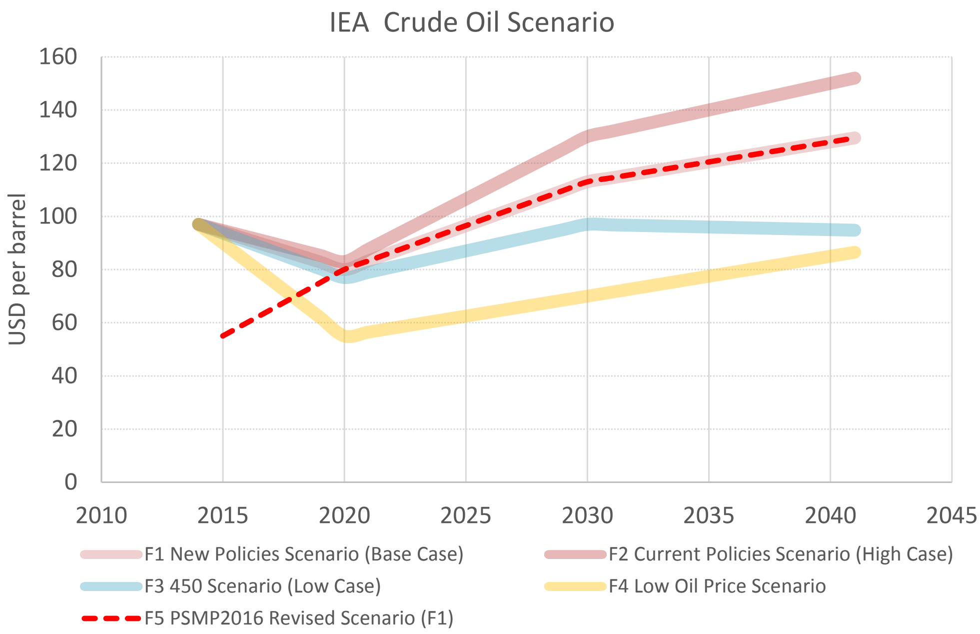
Figure 1-23 Reserve Margin

(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.



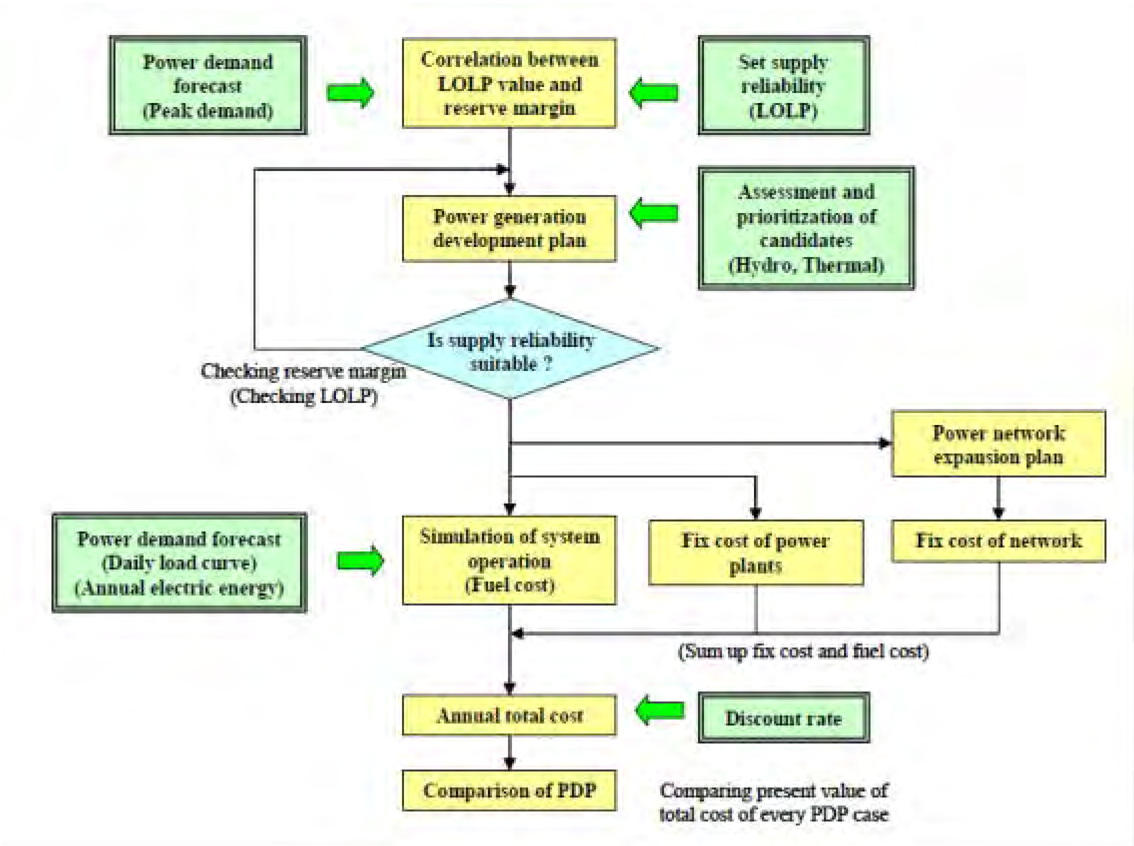
Source: JICA Survey Team

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.

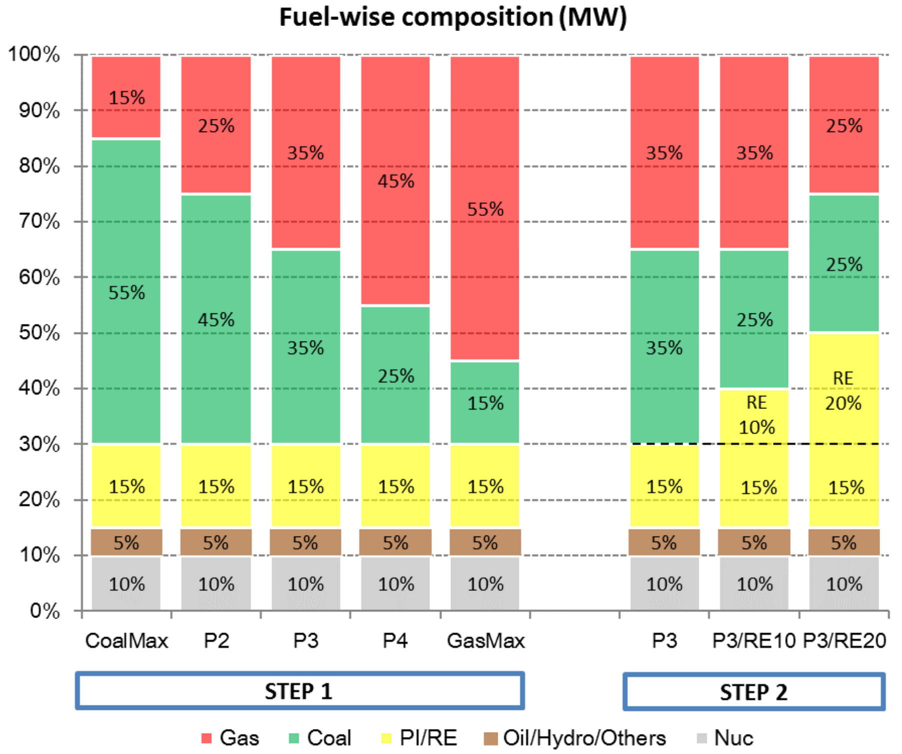


Source: JICA Survey Team

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.

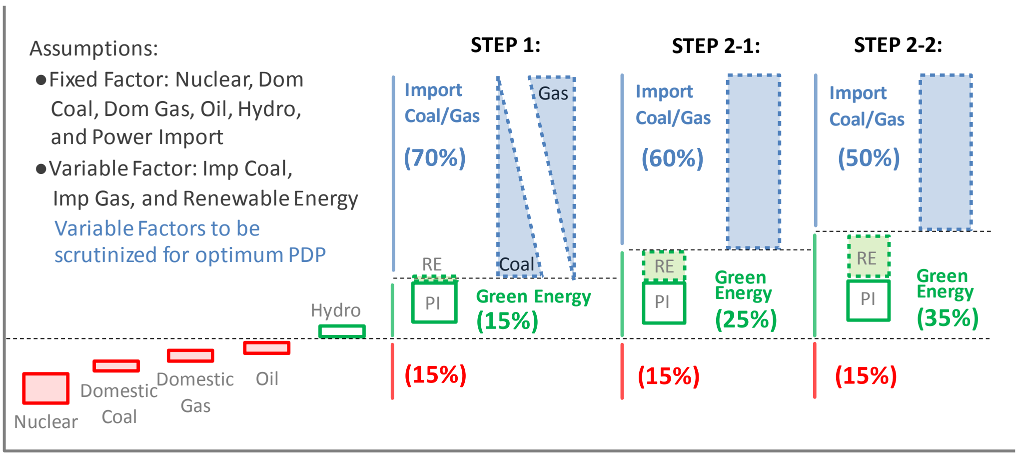
In this case, the share of oil and other fuels in the energy mix should not change in each scenario. The energy mix by fuel type from 2015 to 2041 in each scenario is as shown in the following figure.



Source: JICA Survey Team

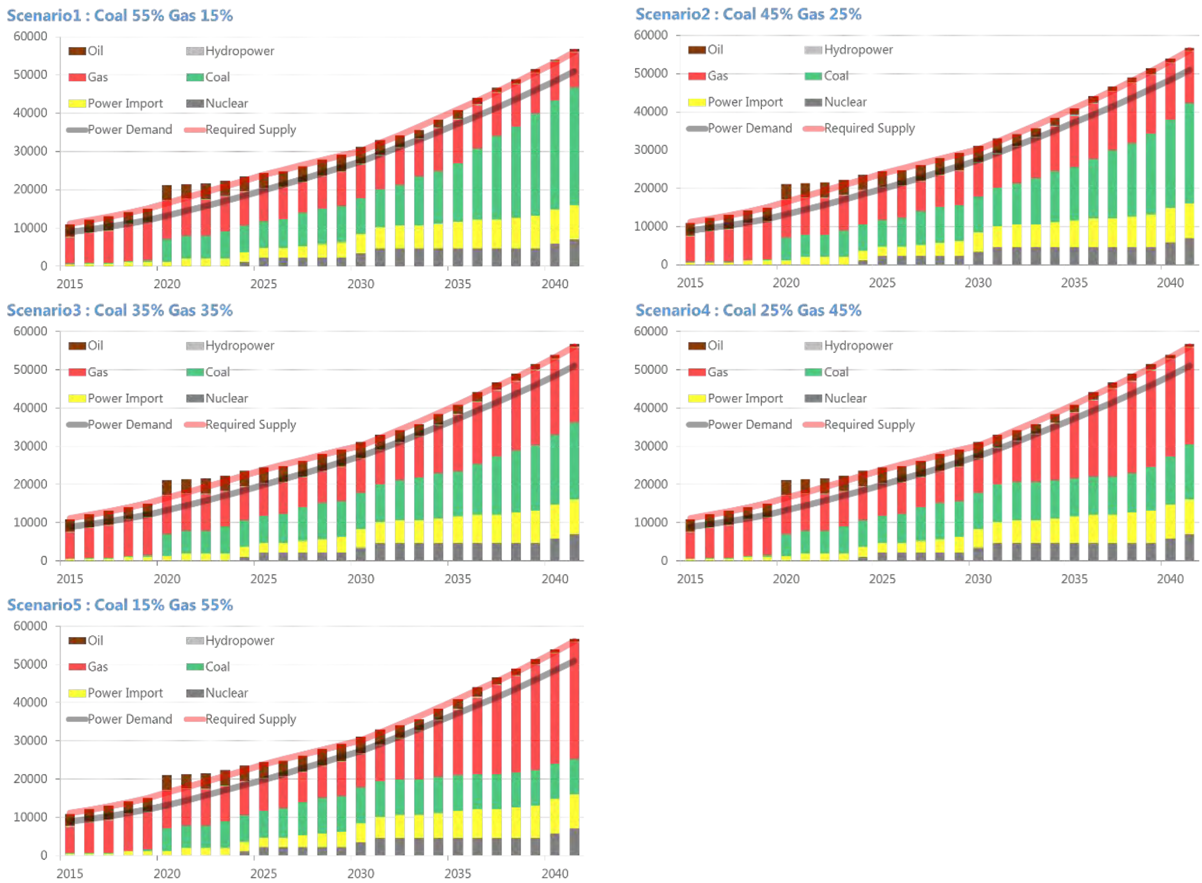
Figure 1-26 Generation pattern in 2041

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

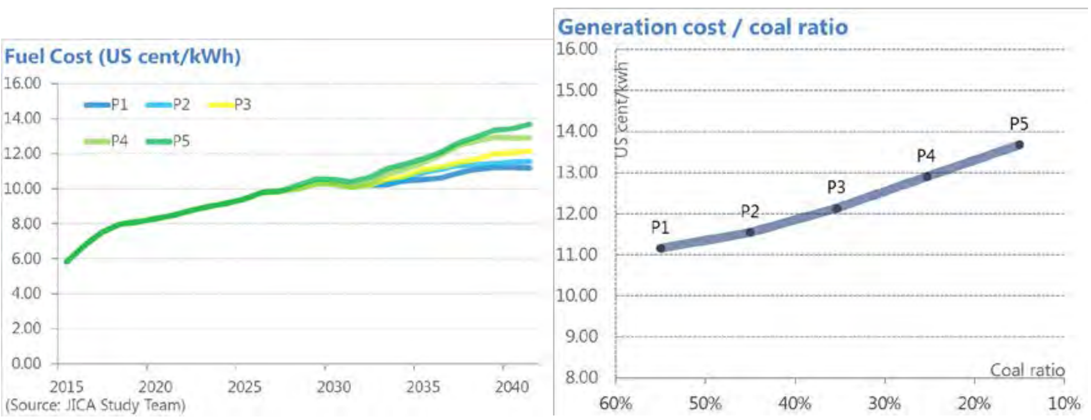


Source: JICA Survey Team

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

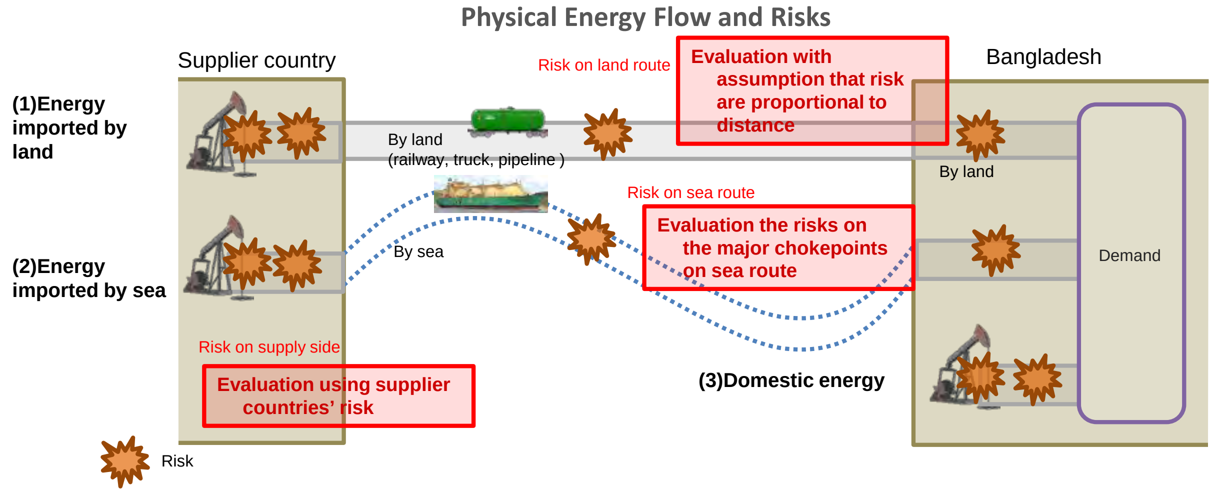
Energy security covers many concepts and there are no common approaches to evaluate it unlike previous two values. Here, we focused on risk of sudden shortage in energy supply quantity, which would directly damage Bangladesh economic activities. The difference ratio of coal and gas among power development 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:

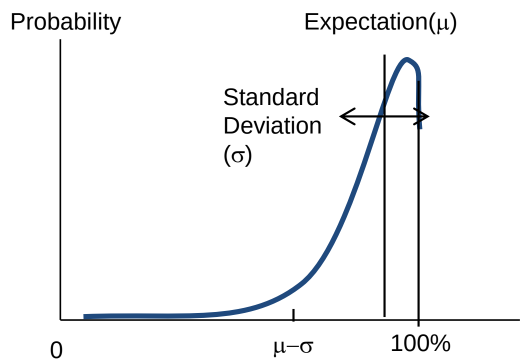
export suspension risk, blockage risk on land route, and blockage risk on sea route. We ignored the risks to deliver domestic energy.



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.

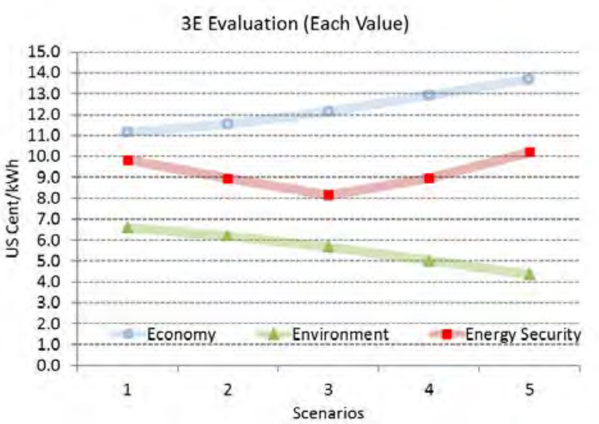
A quantitative evaluation of the 3E values in 2041 of each of the power development scenarios proposed in the previous section conducted for the selection of the most recommendable scenario is described in this chapter.

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

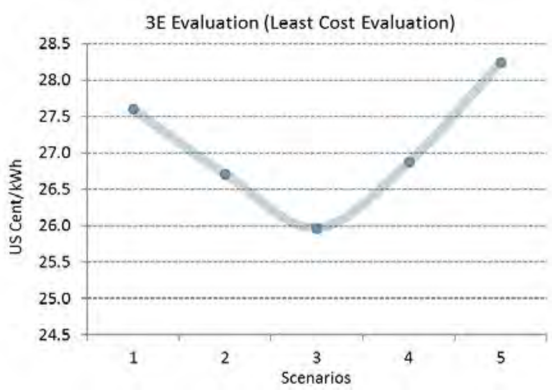
	Composition (MW base)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	11.2	6.6	9.8	27.6
Scenario 2	Gas 25%, Coal 45%	11.6	6.2	8.9	26.7
Scenario 3	Gas 35%, Coal 35%	12.1	5.7	8.2	26.0
Scenario 4	Gas 45%, Coal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

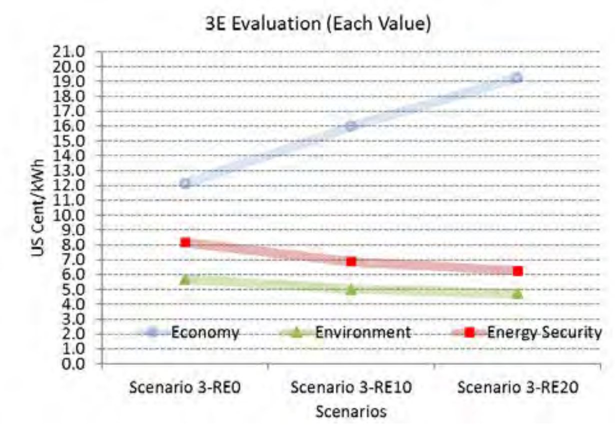
As mentioned above, after determining the optimum share of gas and coal in the enrgy mix, as Step2, changing the share of renewable energy in the energy mix should be considered. In this study, RE10 scenario increasing 10% Renewable energy and RE20 scenario increasing 20% reneawable energy is considered.

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

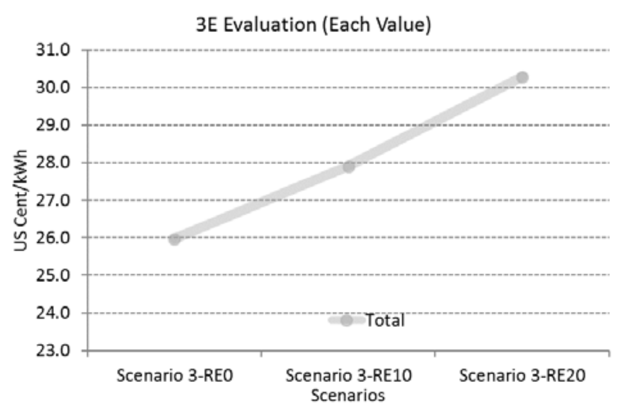
Composition (MW base)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]	Composition (MW base)
Scenario 3	Gas 35%, Coal 35%	12.1	5.7	8.2	26.0
Scenario 3 RE10	Gas 35%, Coal 25%	16.0	5.0	6.9	27.9
Scenario 3 RE20	Gas 25%, Coal 25%	19.2	4.7	6.2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

Source: JICA Survey Team



Source: JICA Survey Team

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

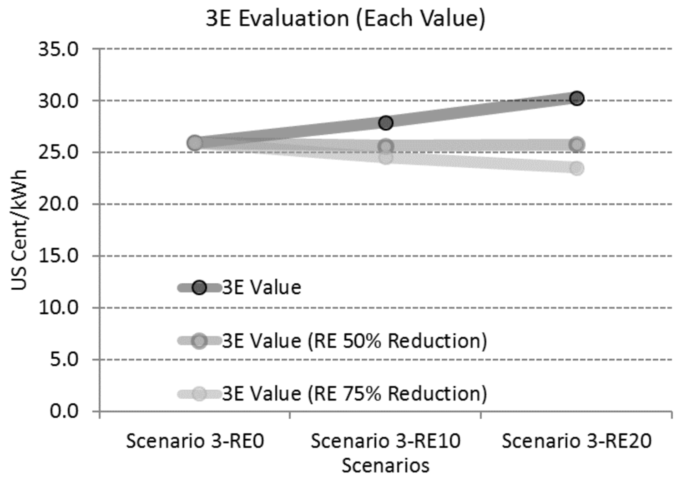


Source: JICA Survey Team

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)

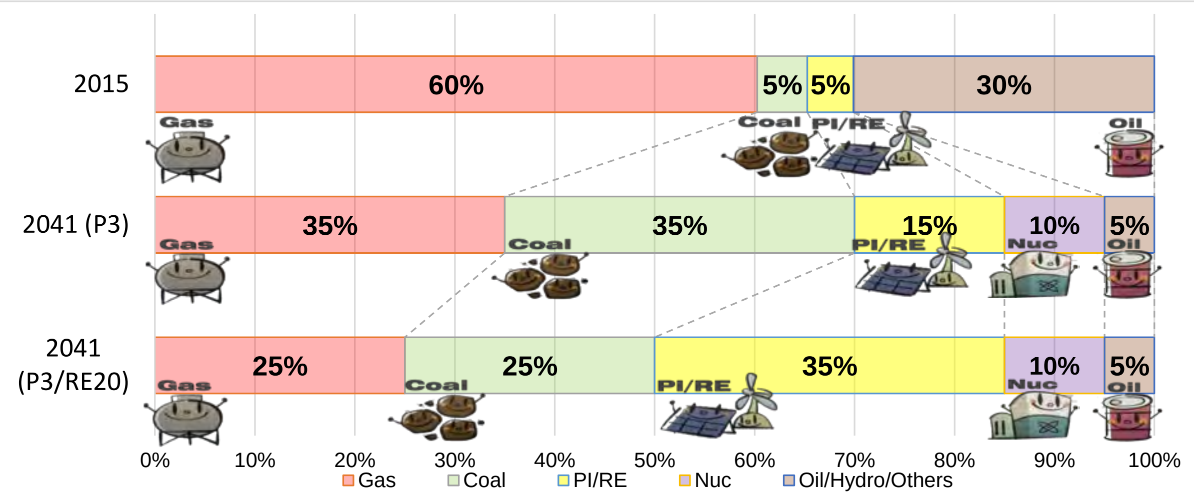
- Breaking away from the dependence on costly petroleum and rental power generation
- Promotion of PPP investment in power generation projects
- Reform of O&M of power plants and revision of electricity rates

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 CO_2 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.

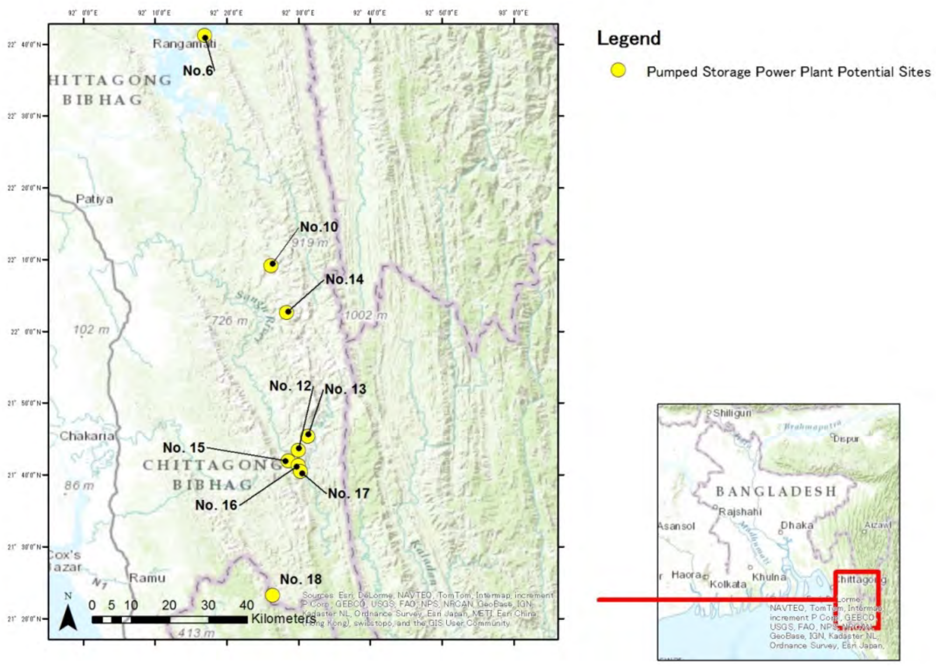


Figure 1-39 Location Map of Potential PSPP Sites

(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.

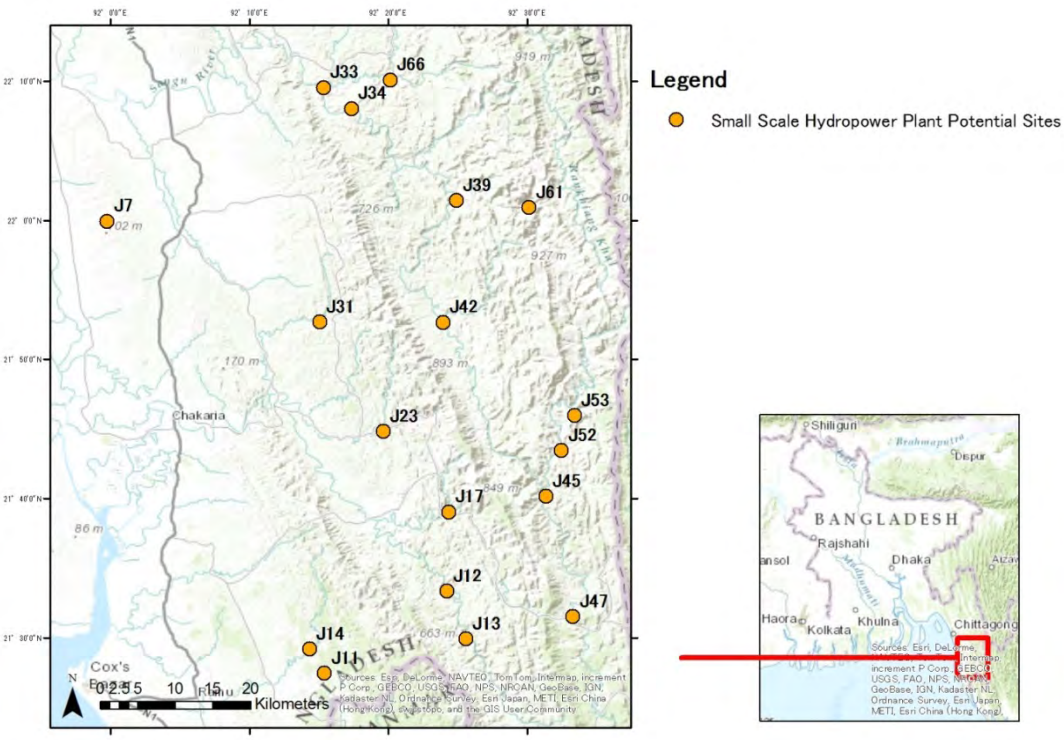


Figure 1-40 Location Map of Potential Sites for Ordinary and Small Scale Hydropower

(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 gas demand, has great potential as home cooking fuel. Considering LPG's expensive price, biogas could

[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.

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.

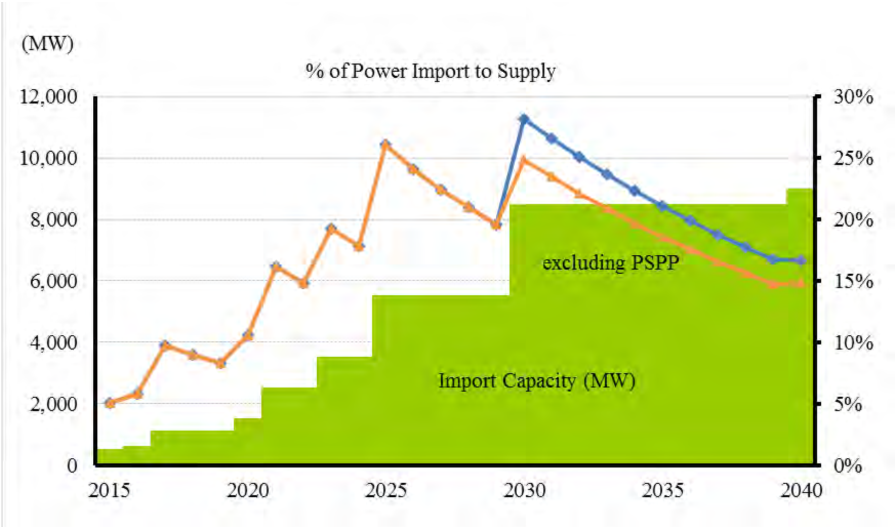
(iv) Mutual Interference due to Grid Accidents

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.



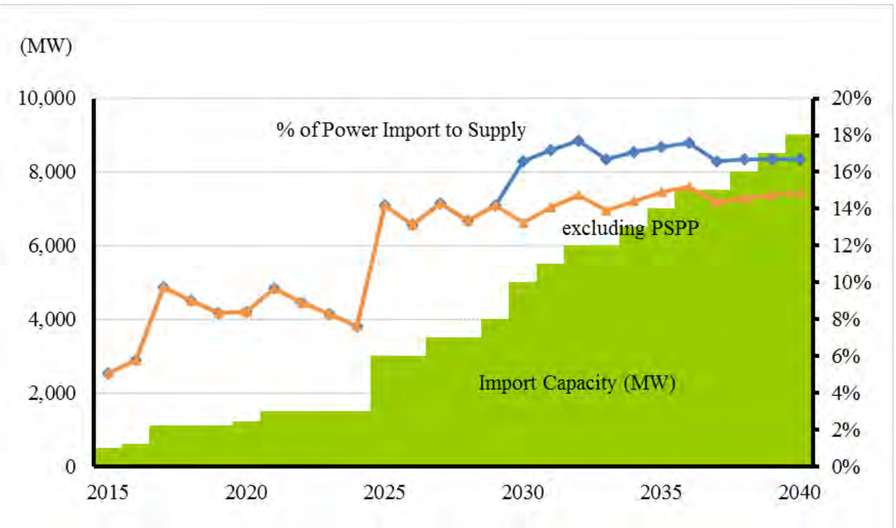
Source: JICA Survey Team

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.

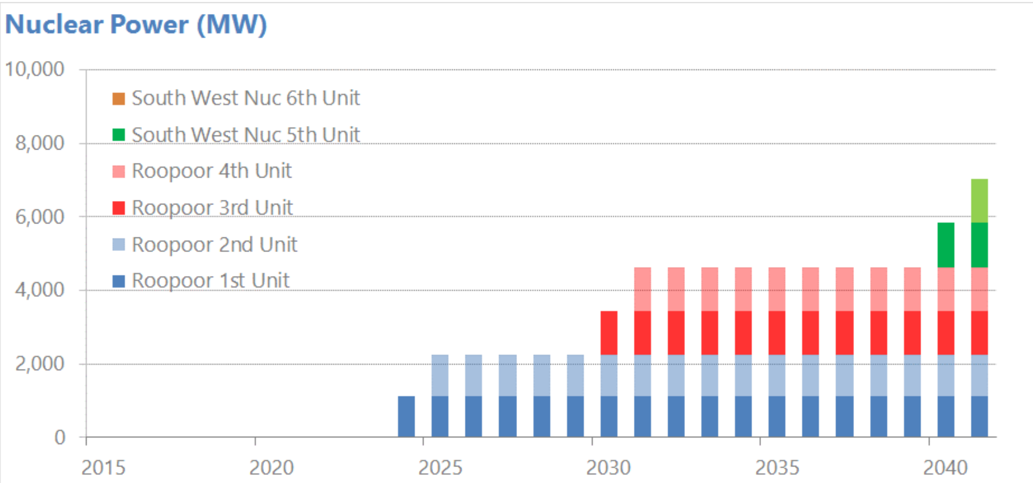
1.6.12 Nuclear Power

(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.

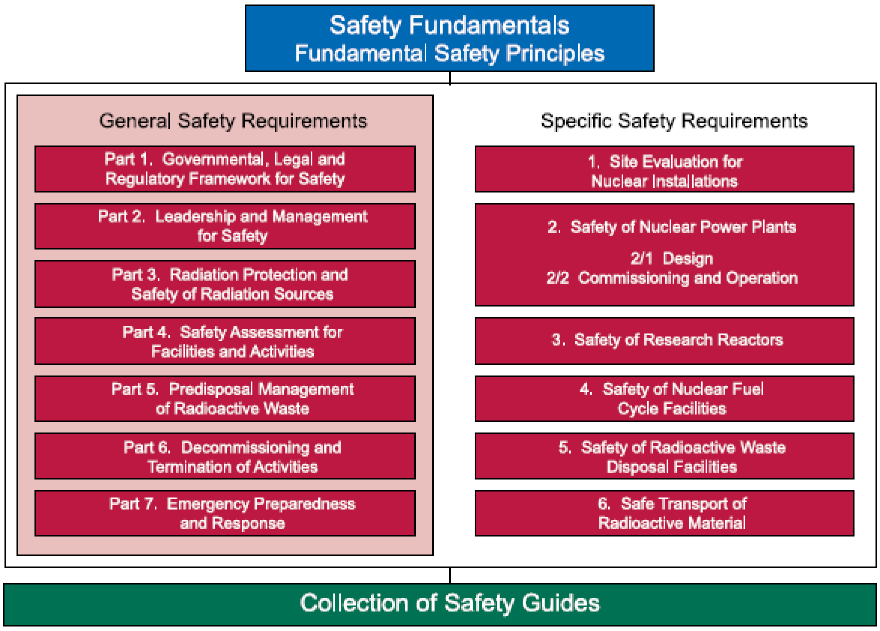
(i) Meeting IAEA safety standards2

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

[2] IAEA Safety Standards homepage

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.

(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

[3] IAEA Country Nuclear Power Profiles, 2016 update

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 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

[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

(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

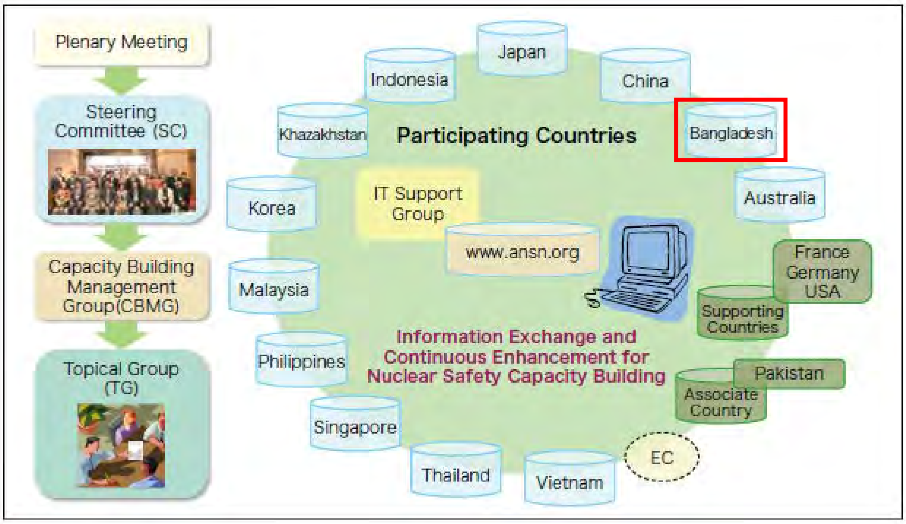
In addition, the government is preparing the Multi purpose information center around Rooppur NPP site to strengthen public communication strategy with public and media. Expected PR-program is as follows;

- 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 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.

[5] Asian Nuclear Safety Network homegage

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)

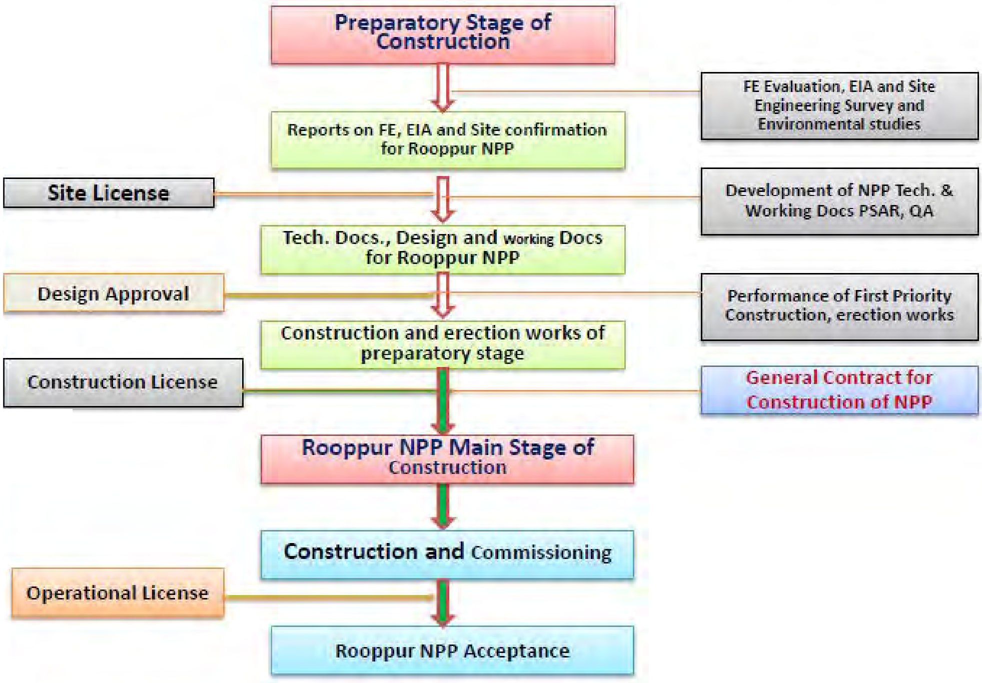
(3) Road Map

(i) Construction

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.

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



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.

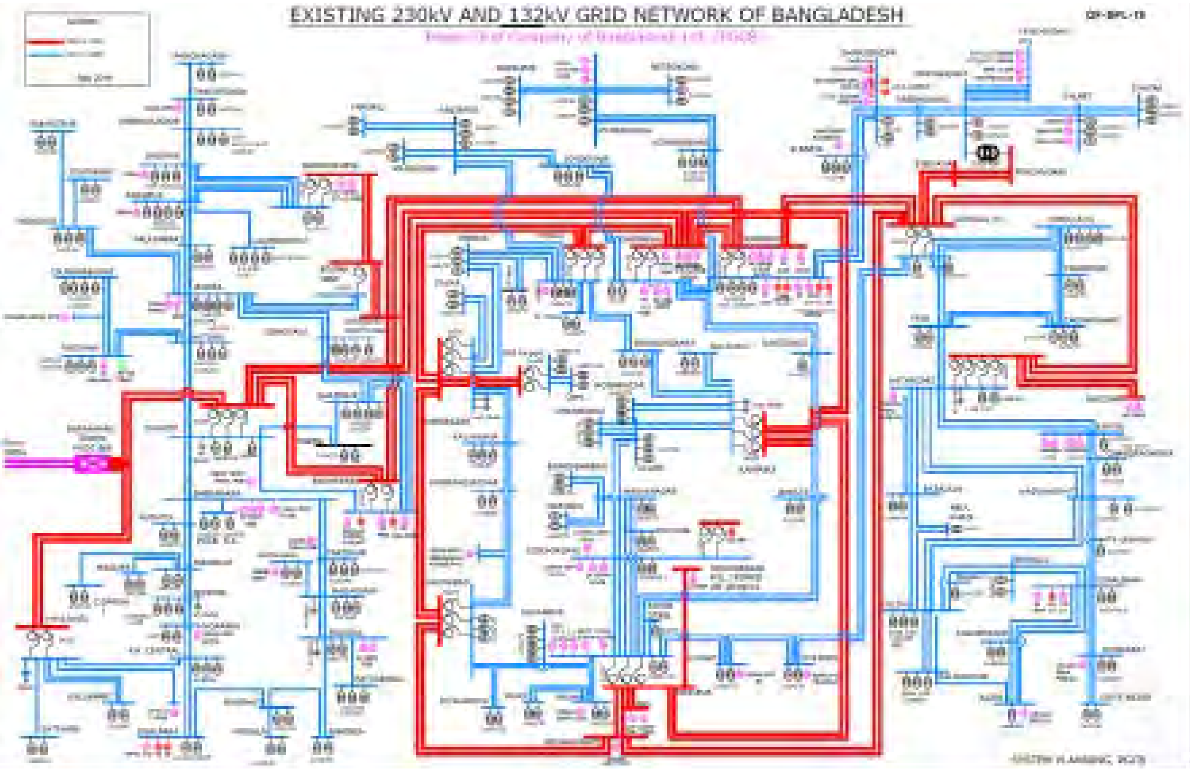


Figure 1-48 The Existing Bulk Power Network System of Bangladesh (2014)

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.

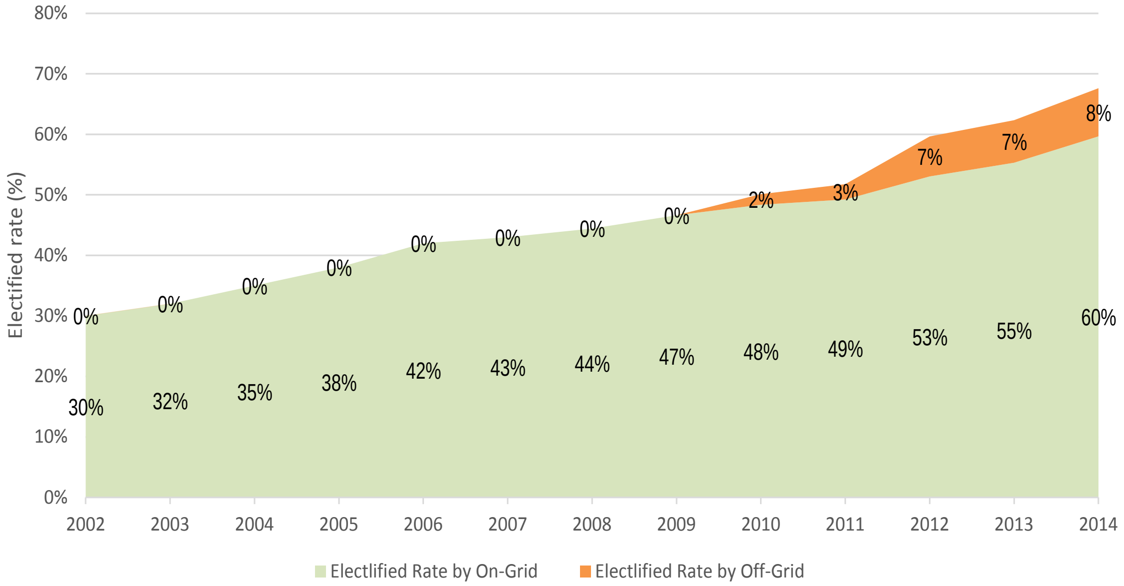
*2 It assumes that the number of people per off-grid connection (renewable) is 4 (-2014) or 5 (2013-). This is based on the assumption that a household using SHS has fewer family members than a grid-connected household.

---

[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.

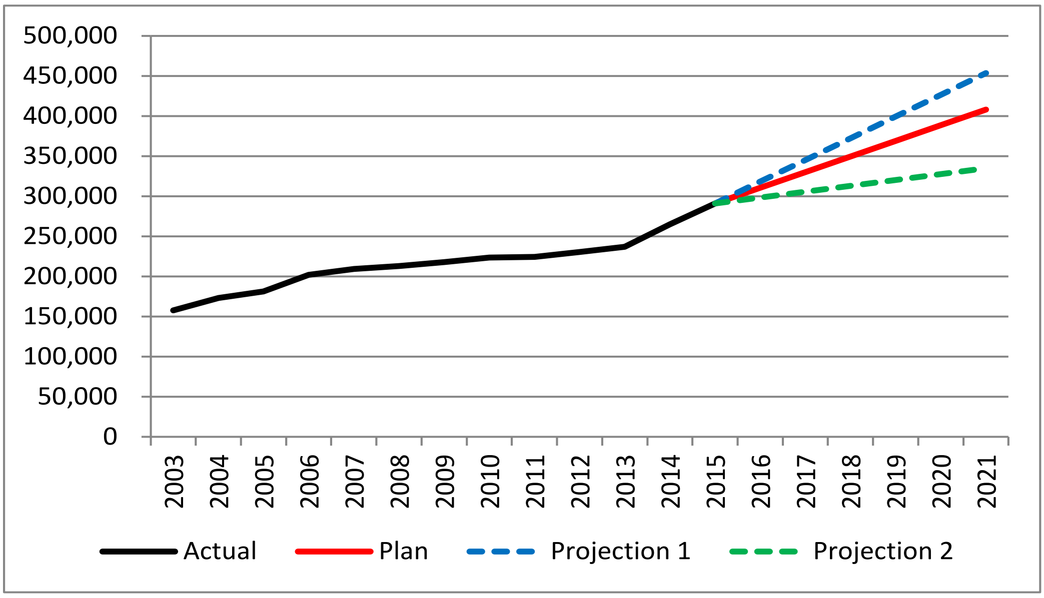


Source: JICA Survey Team, based on the data provided by BPDB

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).

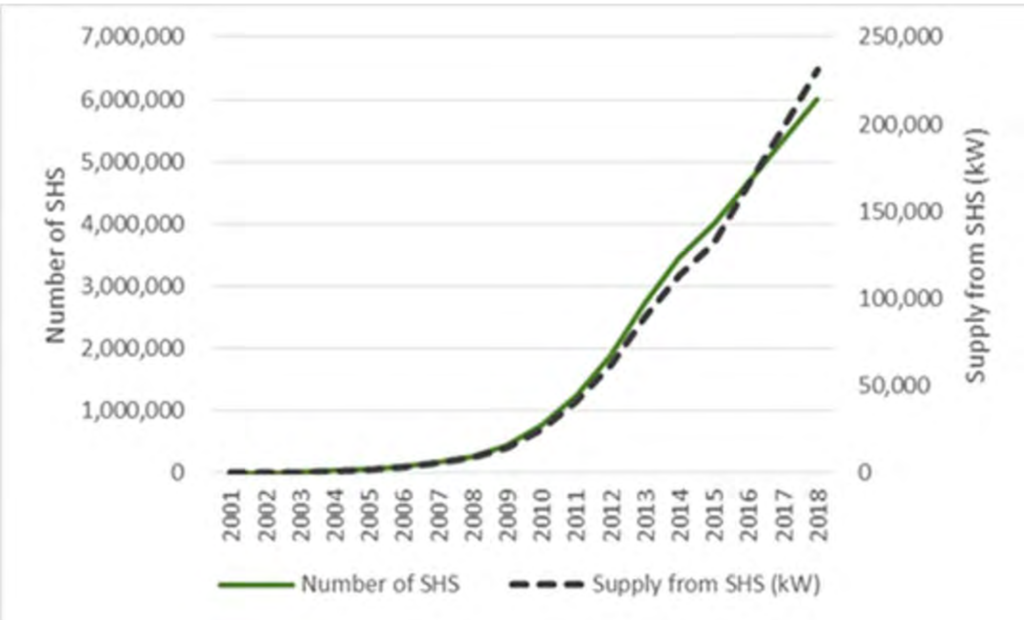
It should be noted that BREB made a great improvement in grid extension implementation between 2014 and 2015, when it substantially increased the grid extension speed compared with the past (between 2003 and 2013). The dotted blue line (Projection 1 in the Figure) means that if BREB keeps the implementation 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).



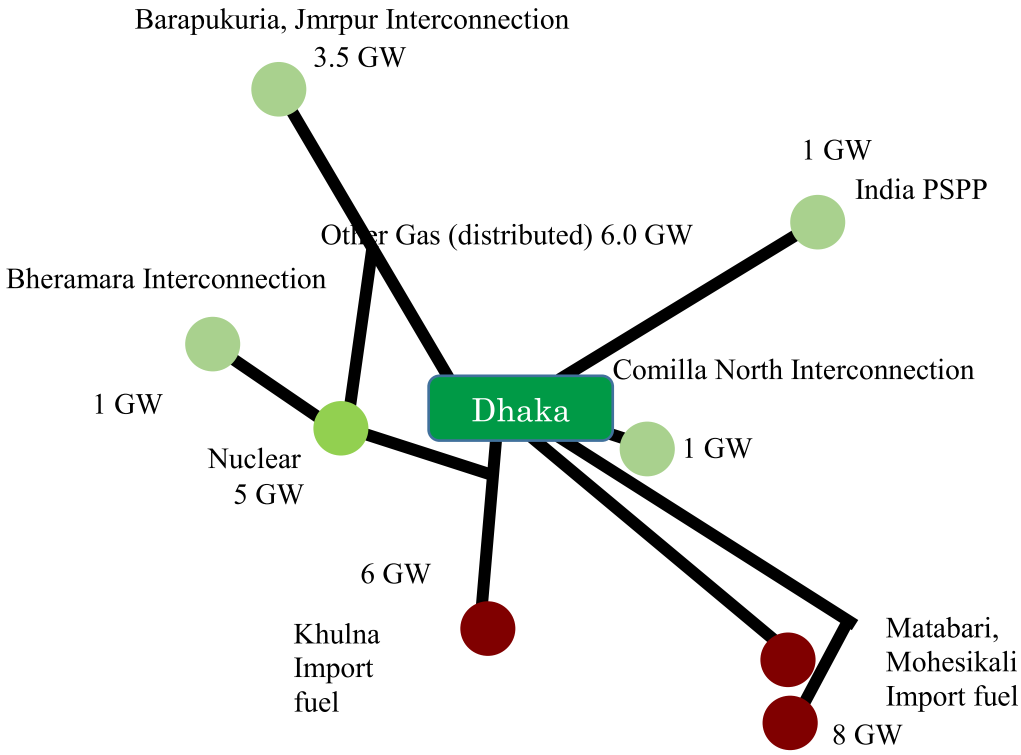
Source: JICA Survey Team

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:

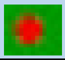
- There is almost no remaining power which can be offered for frequency control due to a significant deficiency in power sources. That is, all generators have no other choice except to keep their outputs at the maximum of available capacity.
- Grid Code in Bangladesh seems to have most of the necessary 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

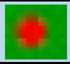
<u>Regulation by the Electricity Acts</u>

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	-

<u>Regulation by independent regulatory organization</u>

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

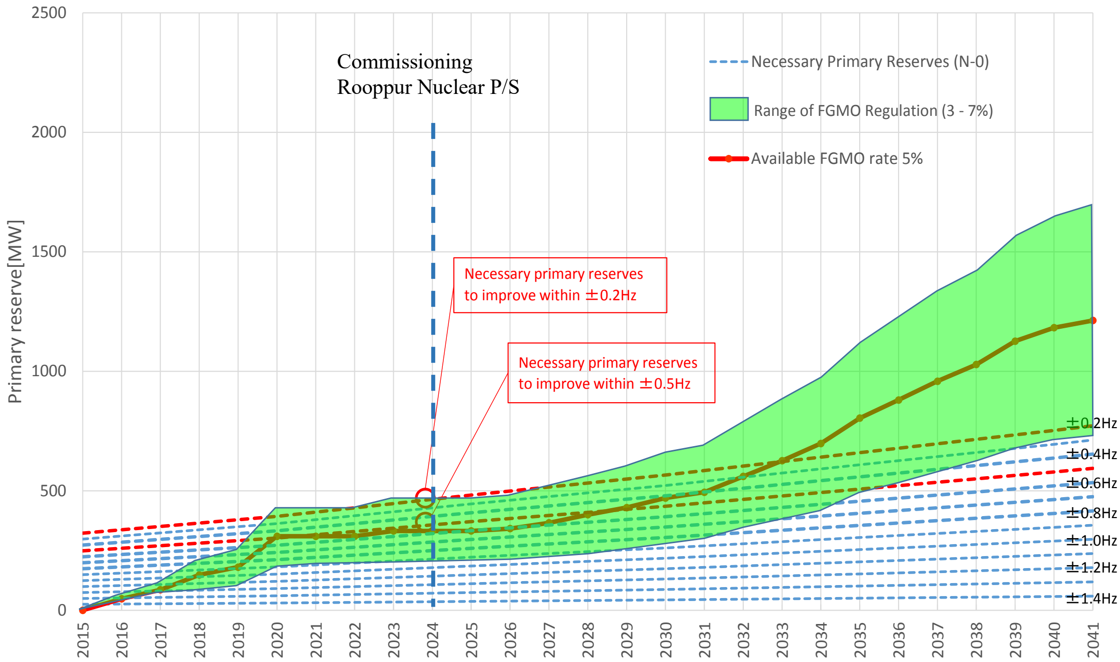
Frequency regulation control is usually realized by a combination of FGMO (Free-governor mode operation) and LFC (Load frequency control).
In this study, the JICA survey team conducted a trial calculation for future frequency improvement when the regulation control is performed by FGMO only, because:

- 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.

<u>Power frequency quality improvement in the N-0 Case (Normal Conditions)</u>

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:



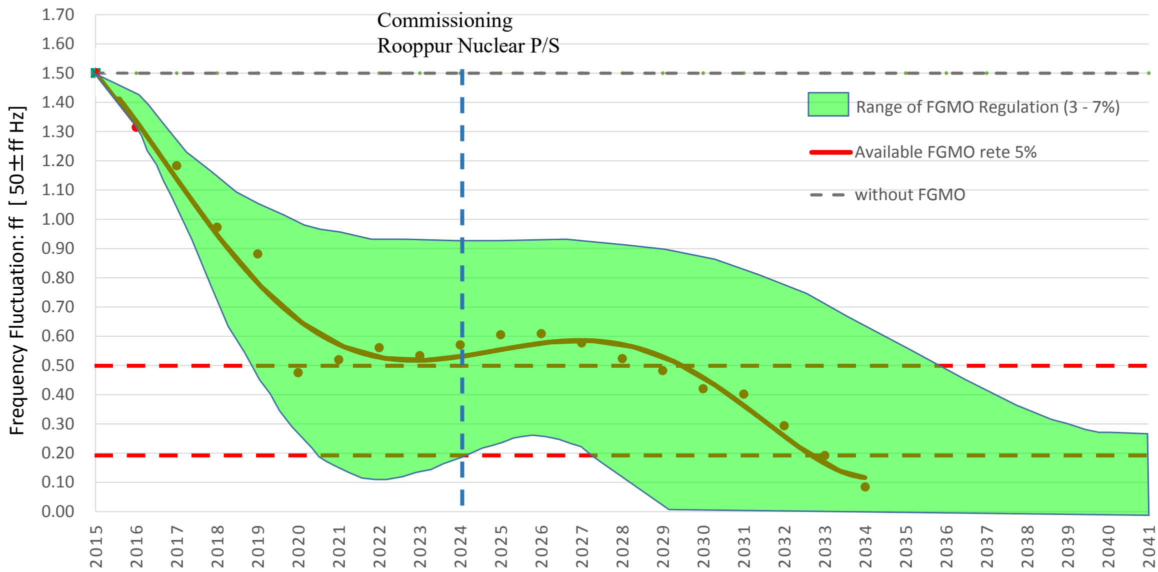
Source: JICA Survey Team

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

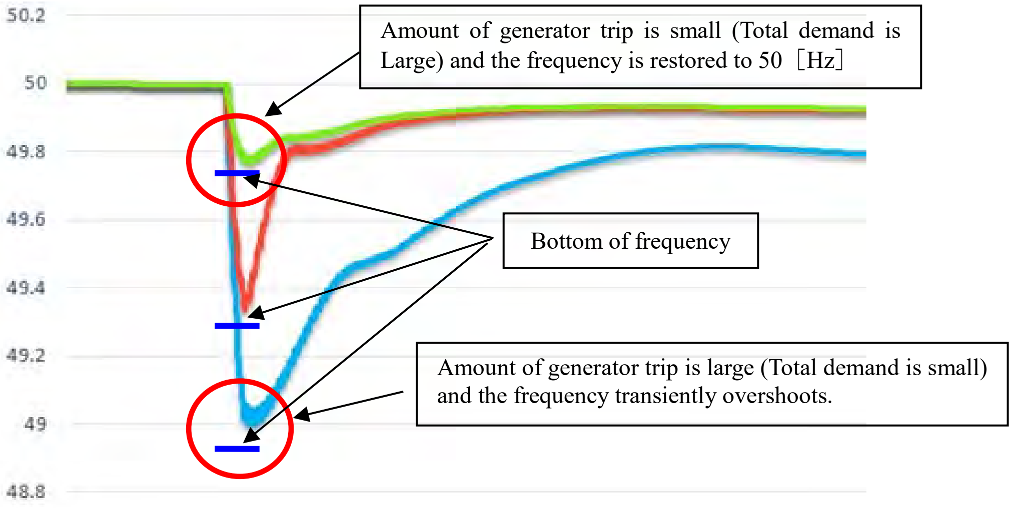
Figure 1-54 Trend of Power Frequency Quality Improvement

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

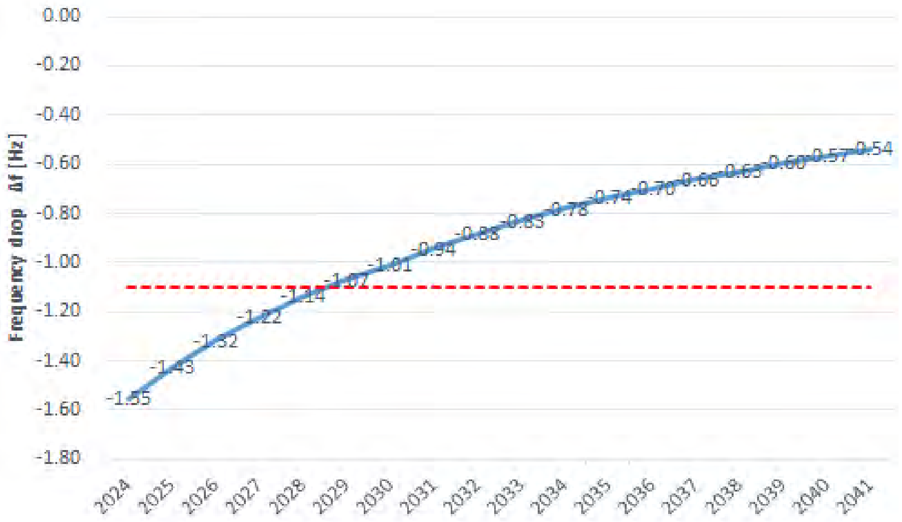
Overshoot of frequency immediately after the generation trip can be regulated only by FGMO and the inherent characteristics of the flywheel effect in load. Therefore, urgent preparation for FGMO is required in Bangladesh. The large capacity generator (power source) trip events which should be taken into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

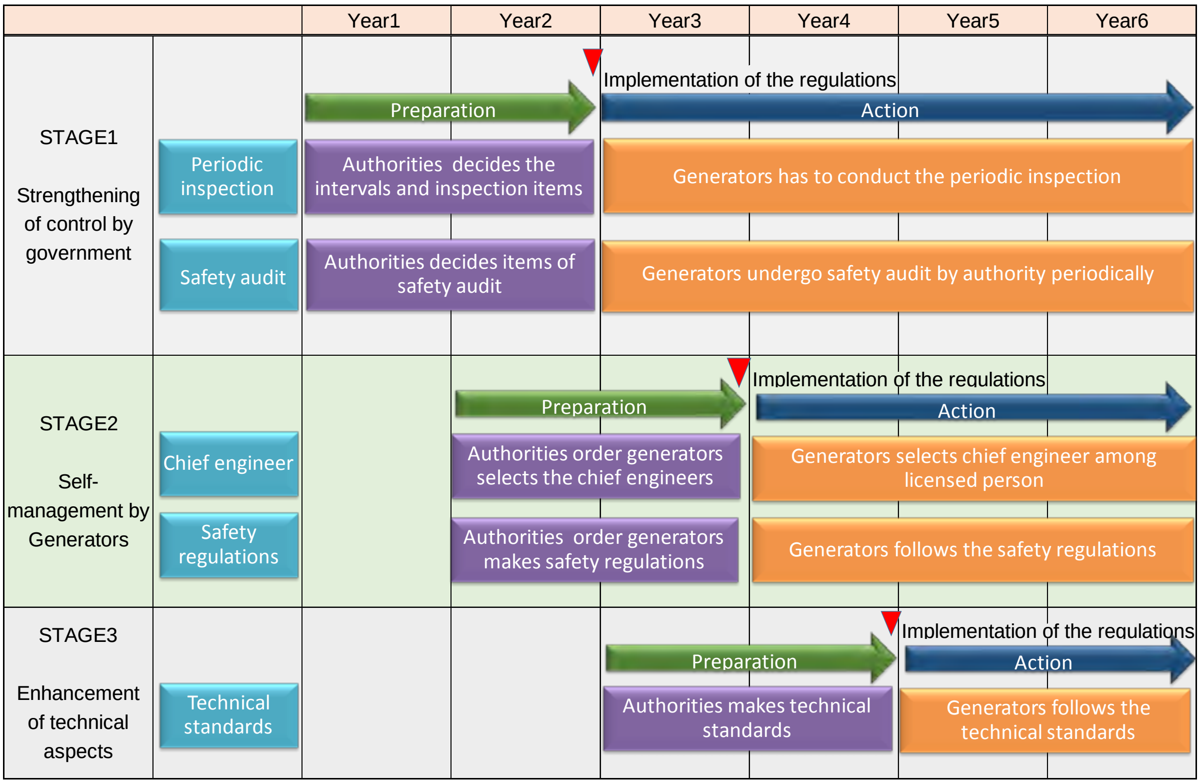


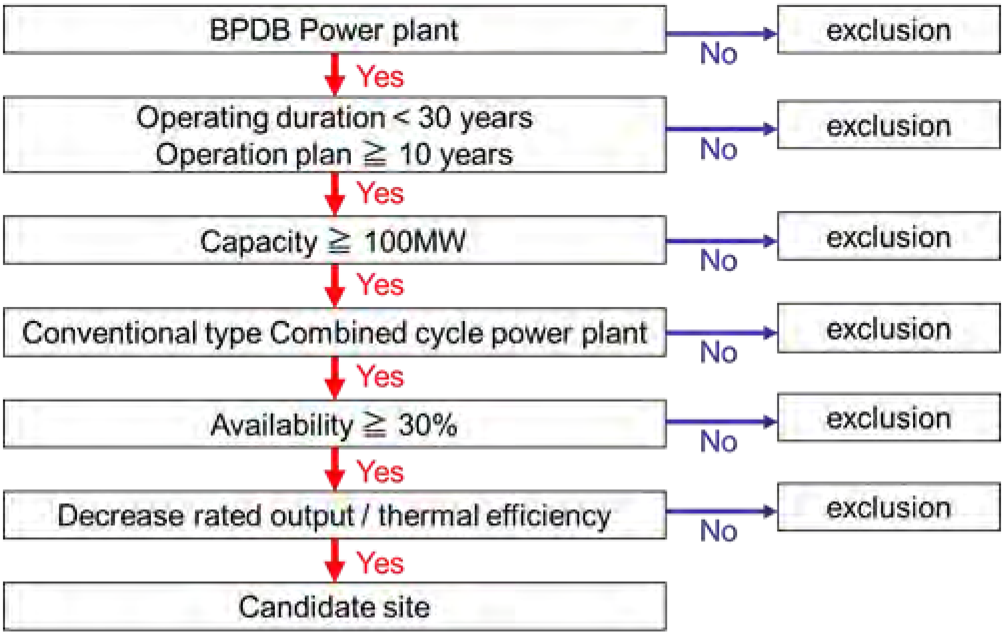
Figure 1-57 Schedule for Legal Reform

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.

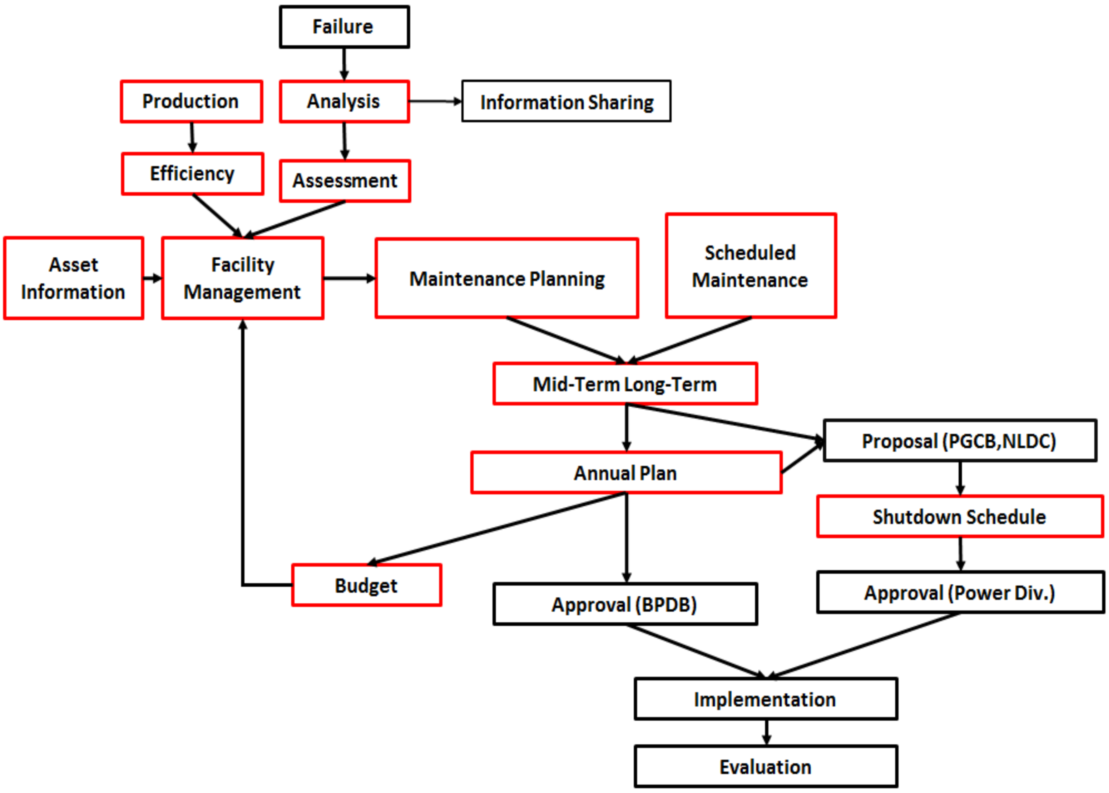
The implementation items of the proposed solutions are shown in the table below.

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

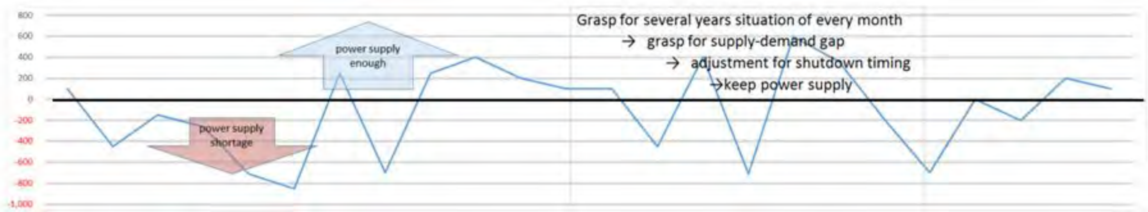
If BPDB has managed to establish a system for the centralized management of the data on the operation and the plans and records of repair of all the plants under its control, as a financial measure, it will be able to estimate the budget for the entire organization and to plan for the suspension of the 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 (12.4%/year in nominal BDT in consideration of average inflation rate from 2010 to 2014) 1.5%/year from 2022

[8] Source: World Bank data site

Scenario	Annual Increase in real USD
	(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 infrastructure 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 investment 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			
Power Balance	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			
	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

Chapter 2 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.

2.1 Capacity building for master plan revision

2.1.1 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.

2.1.2 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.

2.1.3 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.

2.1.4 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.

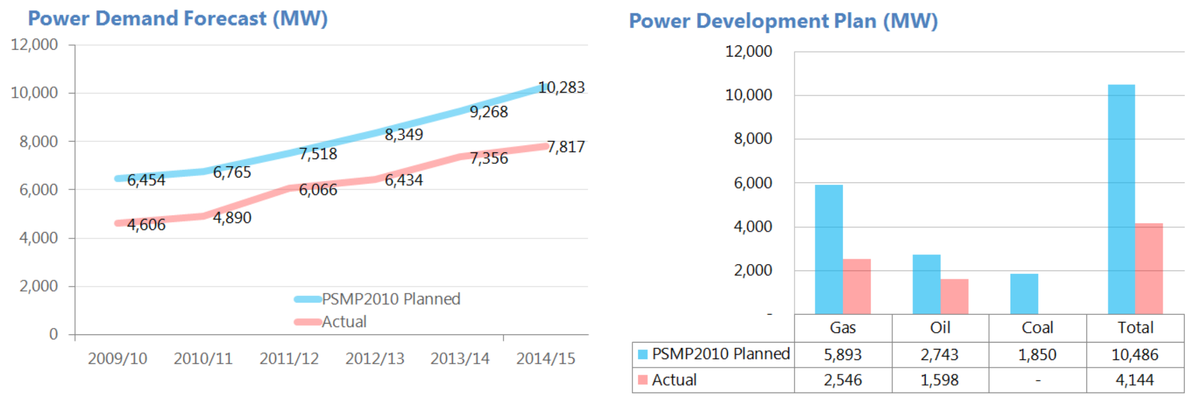
2.2 Measures to Facilitate Improvement of Investment Climate

2.2.1 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.

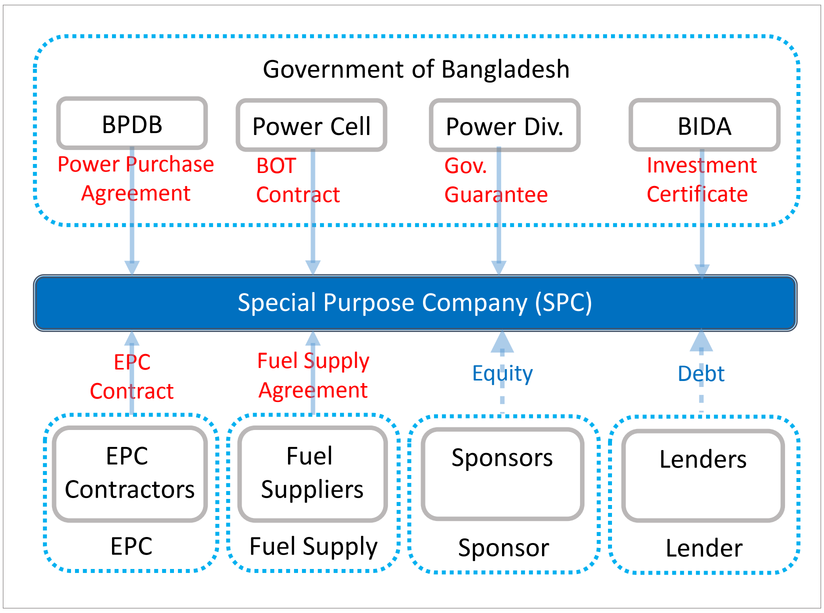


Source: JICA Survey Team

Figure 2-1 PSMP2010 Review (Power Development Plan)

2.2.2 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 2-2 Organization 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)

2.2.3 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.

2.2.4 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.

2.2.5 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.

2.3 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).

2.4 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.

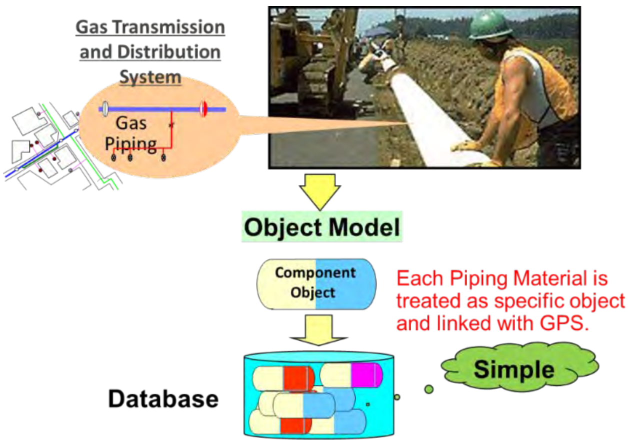
Industrial structure and lifestyle of people will be changing with development of economy. Role of gas based electric power generators will be changing from base load generation to middle/peak shaving generation, and numbers of new gas power plants will be constructed near metropolitan area (Dhaka). 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 2-3 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.

2.5 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.

2.6 Renewable Energy [Introduction of energy storage technology]

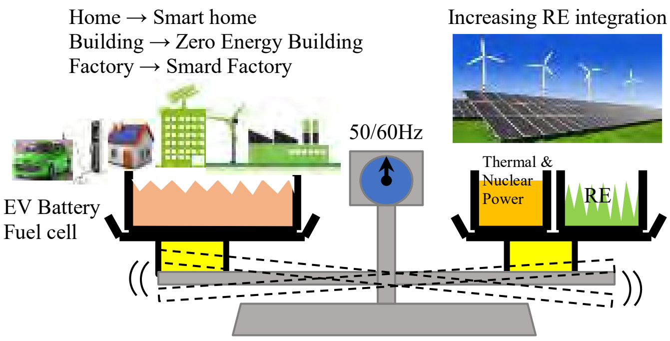
(1) Infrastructure

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 2-4 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.

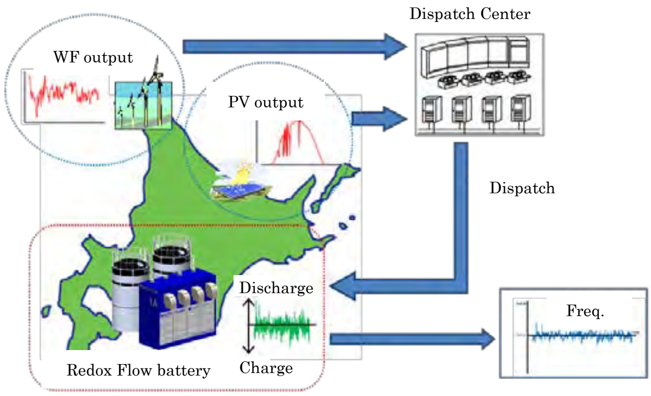
Redox Flow battery is one of the most well-known large-scale and safe energy storage technologies. Some of the application samples can be shown as follows.

[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 >



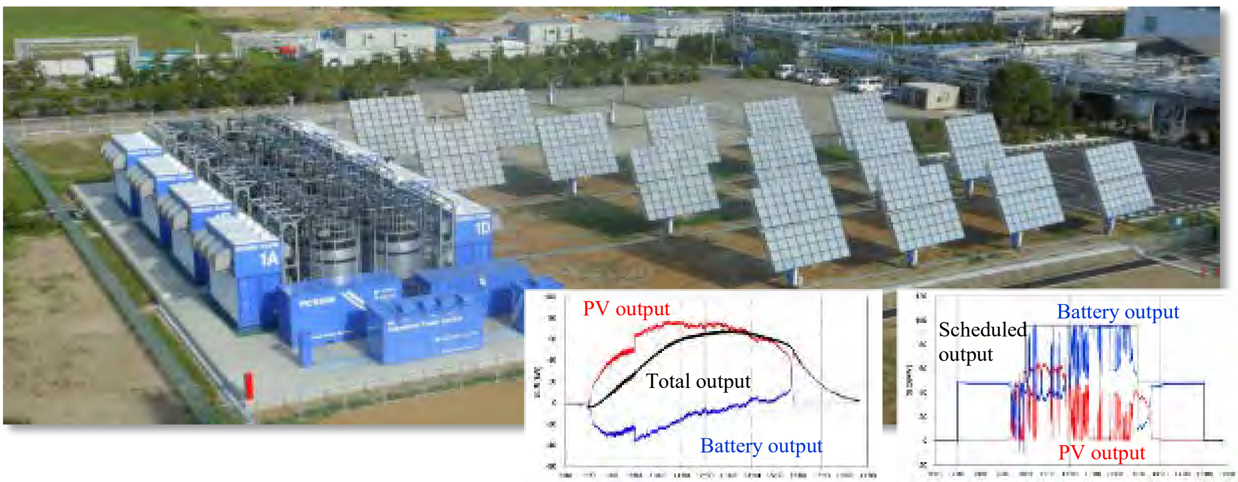
Source: JICA Survey Team

Figure 2-5 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 2-6 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.

2.7 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.

2.8 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.

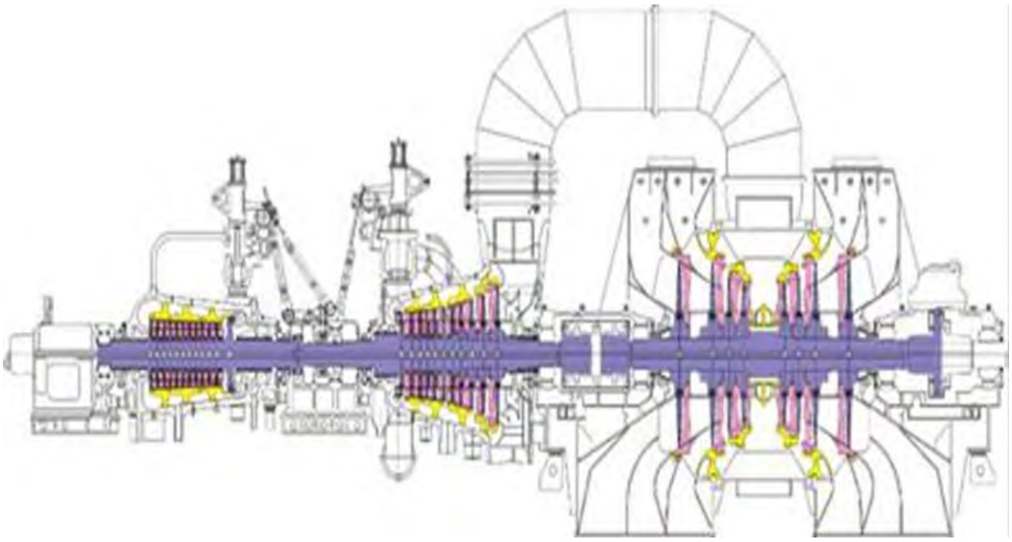
2) Mid/long term
In terms of mid-long term, one of solutions developing human resources is that the members of legislation committee would be dispatched to developed foreign country to learn the real O&M legal framework and actual situation of O&M in a power plant, and the members might bring back knowledge 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.

2.9 Thermal Power Plant O&M [O&M]

(1) Infrastructure

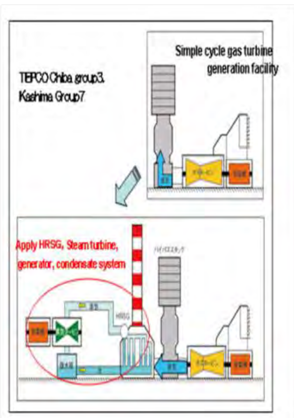
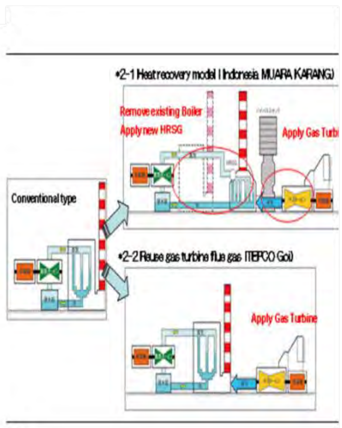
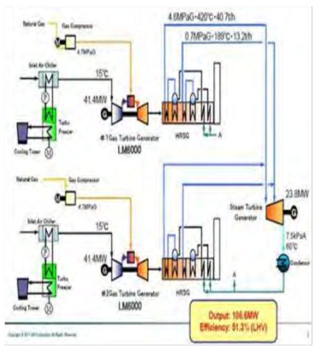
1) Short term

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 2-7 Steam Turbine Rehabilitation Plan

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 2-8 Combined Cycle Power Generation Remodeling Plan

2) Mid/long term

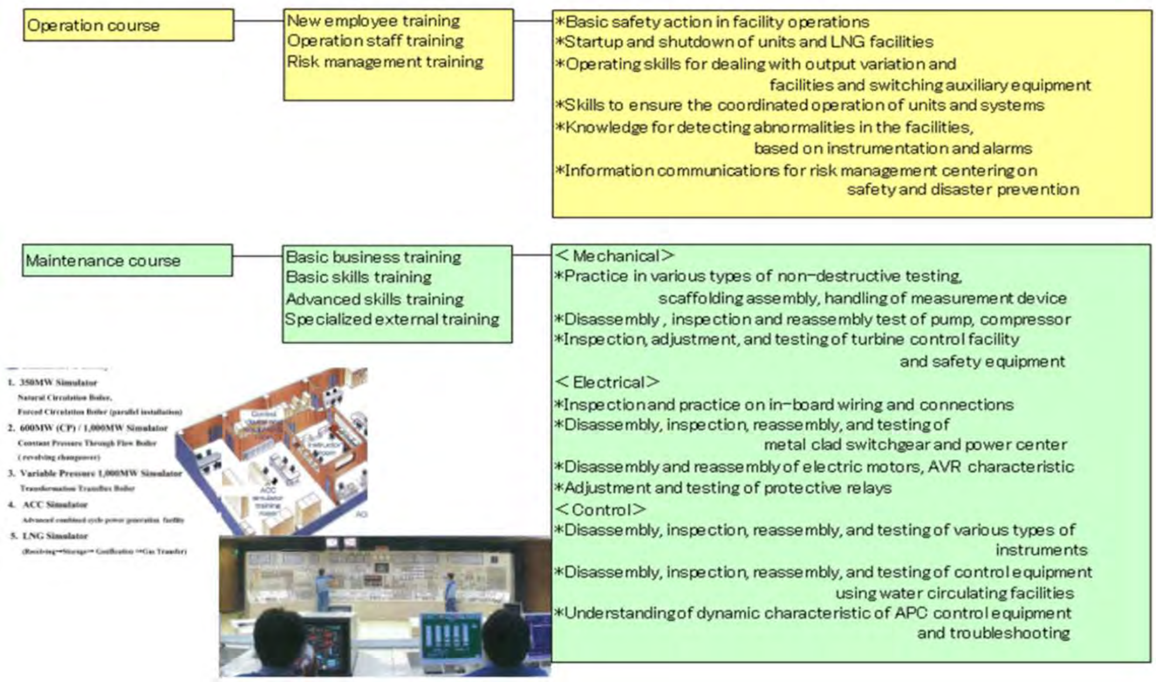
Those proposals mentioned above can be a quick solution to the power shortage problem of Bangladesh for a short time period. After the completion of the remodeling works, application of proper maintenance is a key to successful capacity enhancement.

(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 2-9 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

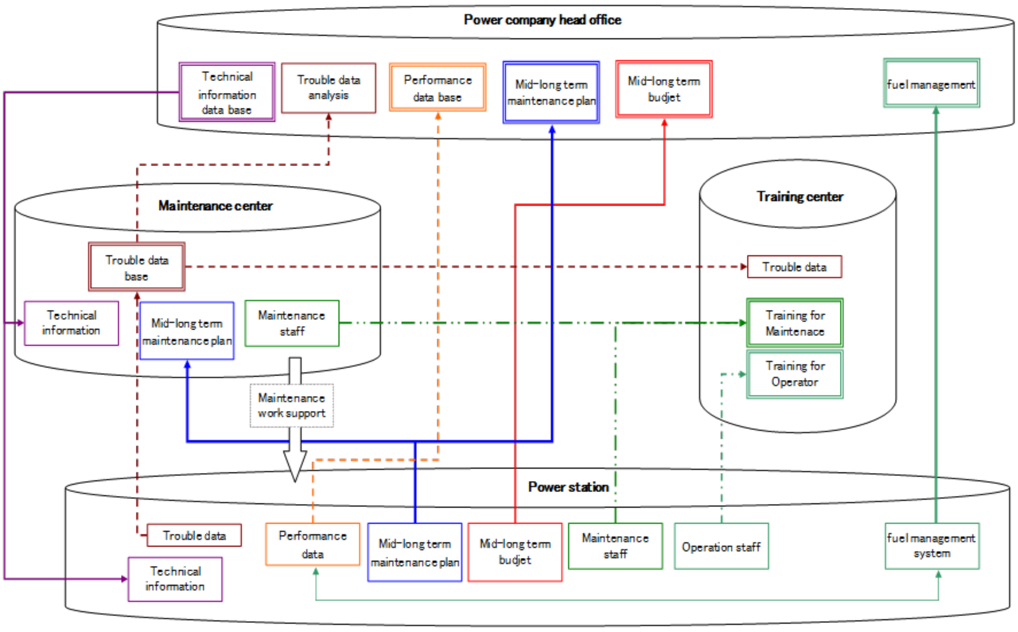
In order to maximize the effectiveness of implementation of information management, a feasibility study is expected to be carried out in pursuit of the following information items.

Table 2-1 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 2-10 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.

2.10 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.

2.11 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.

2.11.1 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 2-2 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

2.11.2 New technologies in the electric power infrastructure sector

Table 2-3Areas 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

2.11.3 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.

jica