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

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Japan International Cooperation Agency (JICA)

Tokyo Electric Power Services Co., Ltd.
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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

PART I   PRINCIPLE OF THE MASTER PLAN

Chapter 1 PSMP2016 Summary

1.1 Abstract

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

1.2 Background and Purpose

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

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

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

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

After the commencement of this survey, Bangladesh started considering also a specific plan to expand power import from neighbouring countries such as India, Bhutan and Nepal. Usually, international cooperation in power system is oriented toward direct cooperation by means of alternate current and, to do so, quality of electricity is required to be equivalent or better than that of counterpart countries. It is therefore necessary for the promotion of international cooperation to improve the quality of electricity.

Since this issue will be a concern to the entire power sector in revising PSMP, it was also decided to add to this survey collection of additional basic information and examination of feasible measures responding to the specific needs of quality improvement.

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

1.3 Vision Paper

VISION 2041: POWER SYSTEM MASTER PLAN 2016

Value-up Plan 1 Robust Infrastructure for Primary Energy Import

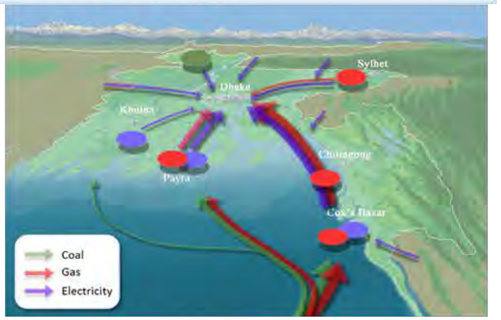
Value-up Plan 2 Domestic Energy Resource Development and Efficient Use

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

Value-up Plan 4 Advanced Deployment of Green Energy

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

PSMP2016 Structure



Abstract

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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

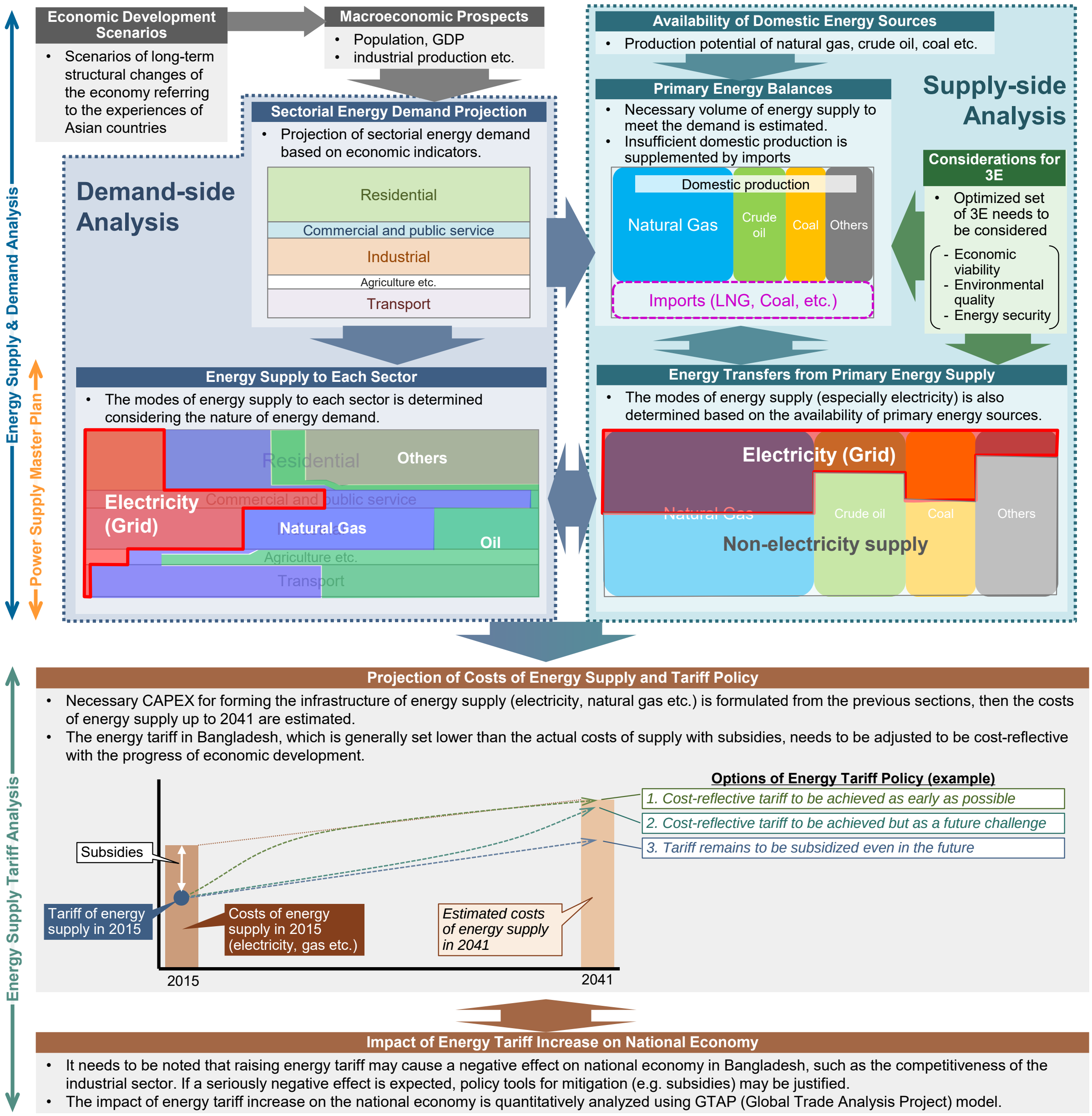
The table below shows the relationship between "the five key policy viewpoints" mentioned above and the components of the master plan. The master plan is composed of a policy for the economic growth, a plan on the primary energy balance, a plan on the power balance mainly based on the power development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

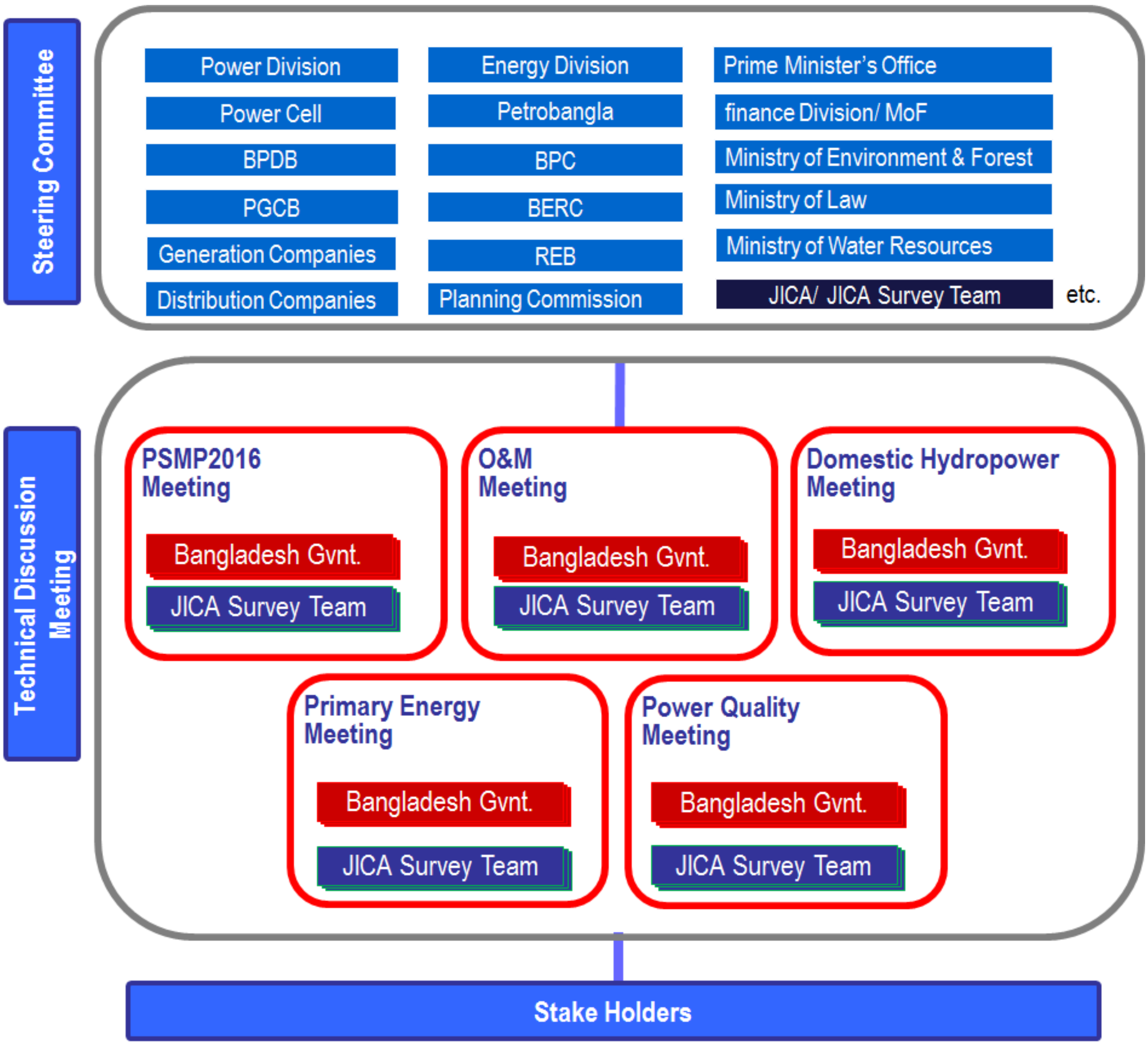
The Hydropower Development Working Group members include PD of MPEMR, MWR, and BPDB. Technical discussion meeting will discuss the impacts and countermeasures downstream due to the planned dam construction, and issues related to the executing agencies.

(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



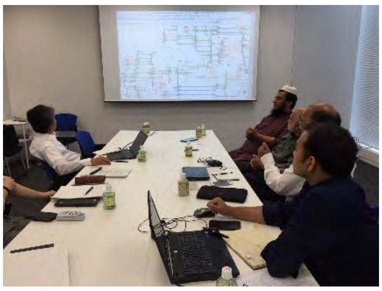
(6) 4th Seminar (4th Steering Committee)

- ■ 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



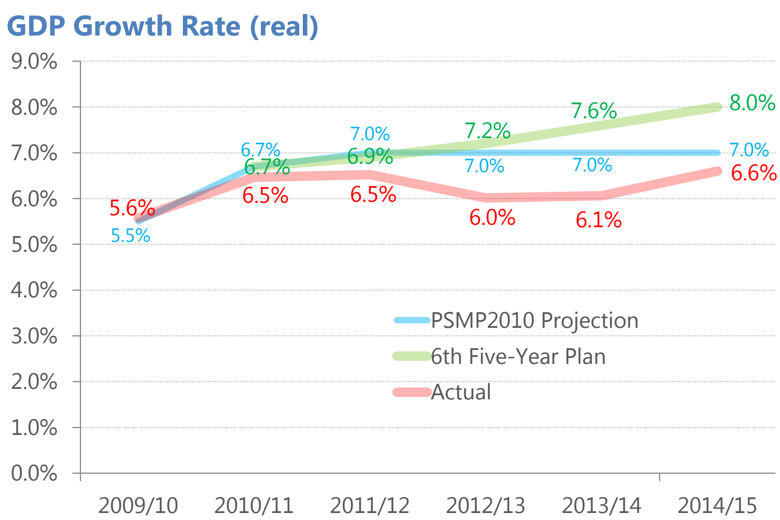
Technical Focal Poits

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 (1st-5th) and the result implies that the country started taking a path of rapid economic growth.
However, the economic growth rate still underperformed the target of the Sixth Five-Year Plan (average 7.3% growth) every year and the gap was widened in the later years. The actual growth rate was also lower than the projection of PSMP2010 that expected the Bangladesh economy to attain 7% growth. The main factor of this gap is supposed to be the delay of economic reforms for inducing further economic growth. The country may not be able to fully reap the opportunity of economic development and the growth rate may continue underperforming the government's expectation unless economic policies to promote the development are not in place as planned.

Table 1-3 PSMP2010 Review (Economic Development)

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

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



Source: JICA Survey Team

Figure 1-3 PSMP2010 Review (Economic Development)

(2) Domestic Coal Production

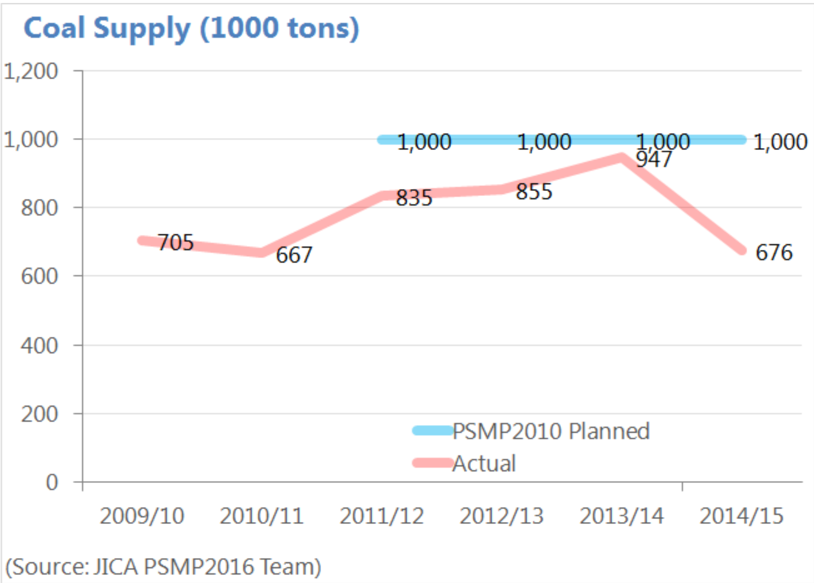
Table 1-4 shows the performance and the forecast of coal production in PSMP2010 and Figure 1-4 shows them by chart. Annual production of 1 million tones will be possible using existing facilities.

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

Table 1-4 PSMP2010 Review (Coal Supply)

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

Source: JICA Survey Team



Source: JICA Survey Team

Figure 1-4 PSMP2010 Review (Coal Supply)

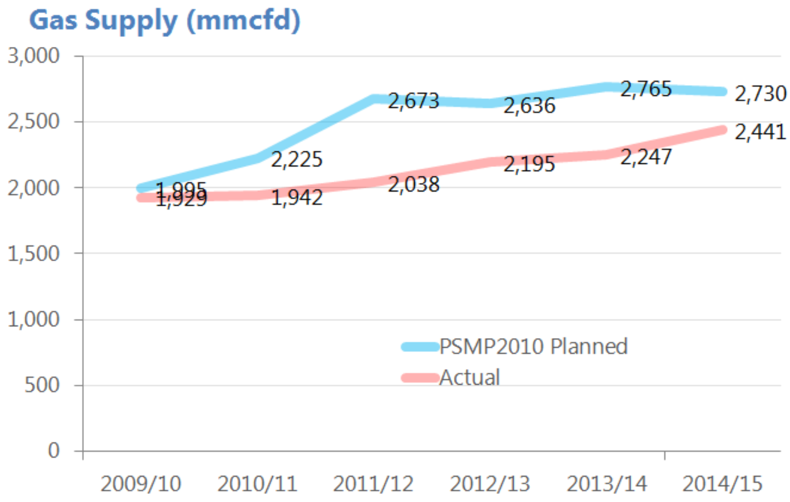
(3) Gas Supply

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

Table 1-5 PSMP2010 Review (Gas Supply)

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

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



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

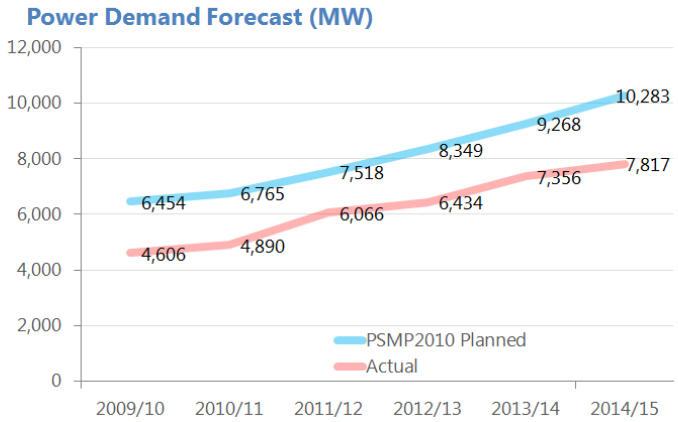
Figure 1-5 PSMP2010 Review (Gas Supply)

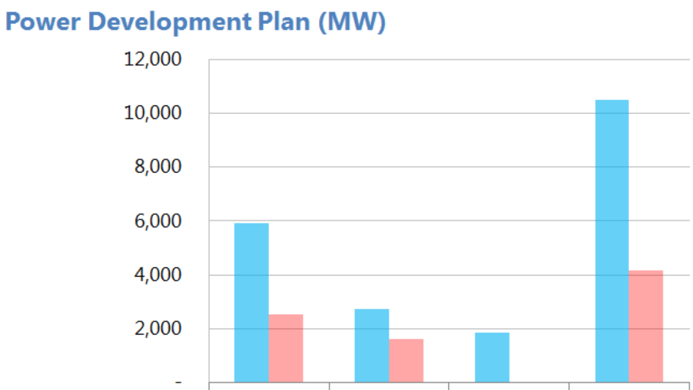
(4) Power Demand and Power Development Plan

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

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

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





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

Source: JICA Survey Team

Figure 1-6 PSMP2010 Review (Power Development Plan)

1.6.2 Economic Development Policy

(1) Current Status and Issues

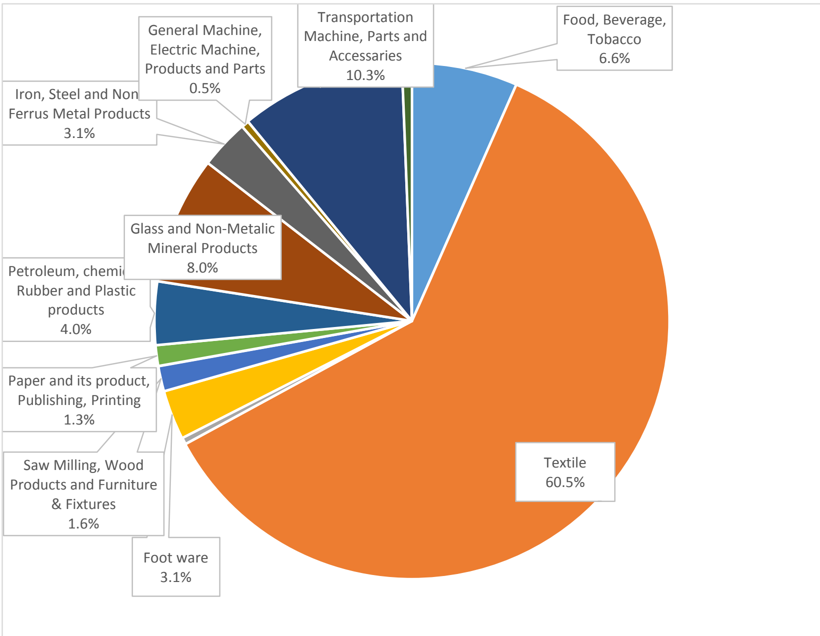
Bangladesh's economy has seen steady growth since independence was declared in 1971. GDP per capita has been steadily expanding since the 1990s, when the ready-made garments (RMG) sector emerged as a major export industry for the country. GDP annual growth rate during the Sixth Five-Year Plan from 2011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

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

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

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

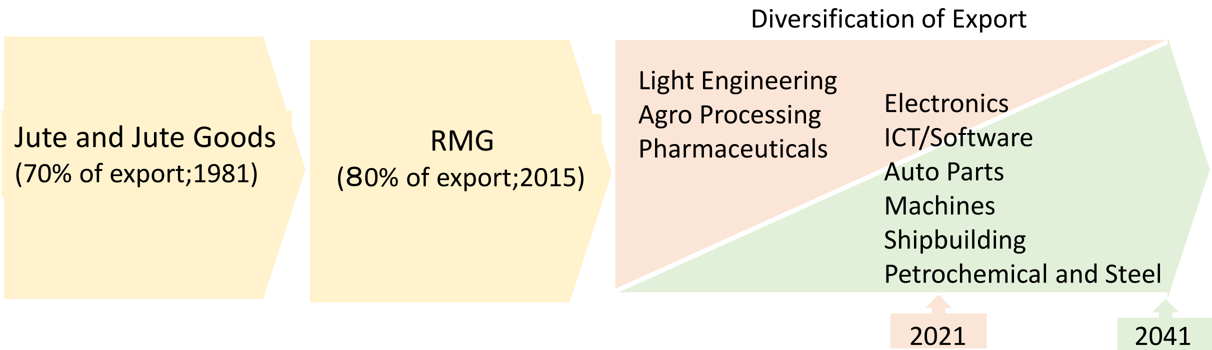
Until now, Bangladesh's economic growth has been maintained by labor-intensive industries such as the garment industry. However, heavy dependence on these industries is not sufficient to sustain further economic growth on a long-term basis. It is necessary to achieve industrial structural changes in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



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

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

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



Source: JICA Survey Team

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

(2) Targets to Achieve

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

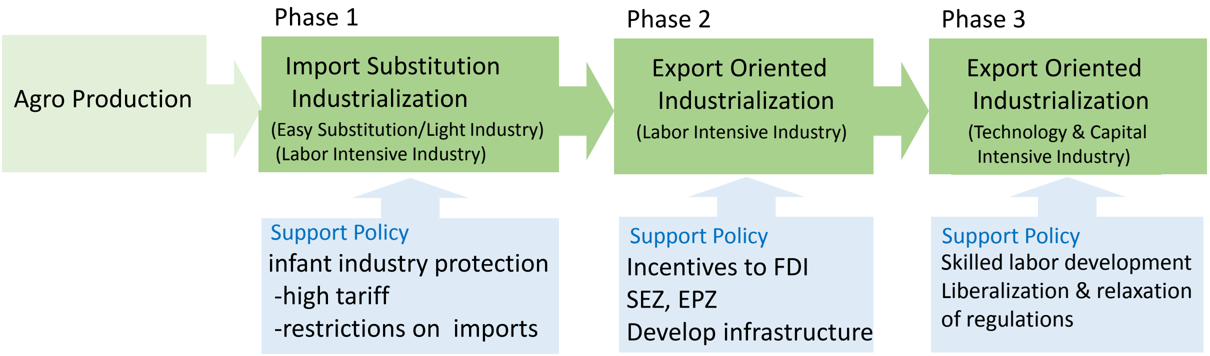
high-income economies (at a GNI per capita of 12,736 US$ or more) by 2041.

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

(3) Roadmap

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

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



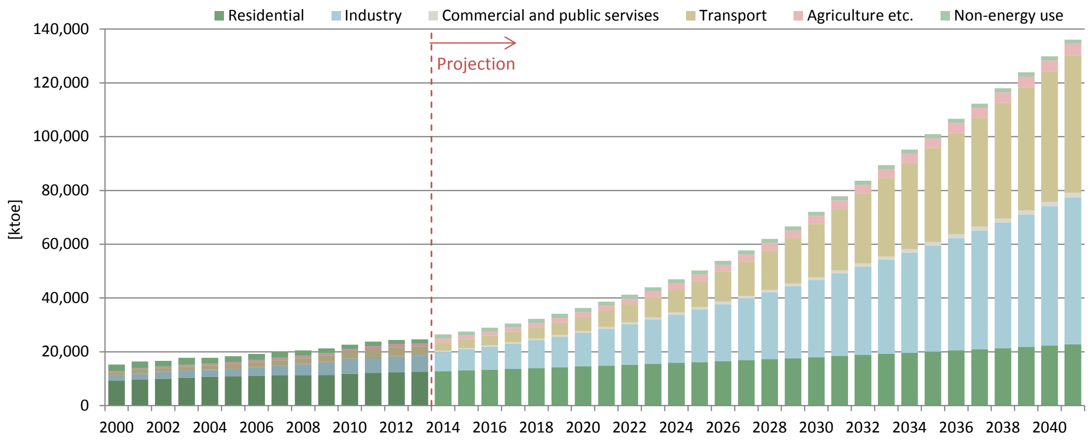
Source: JICA Survey Team

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

1.6.3 Primary Energy

(1) Current Status and Issues

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

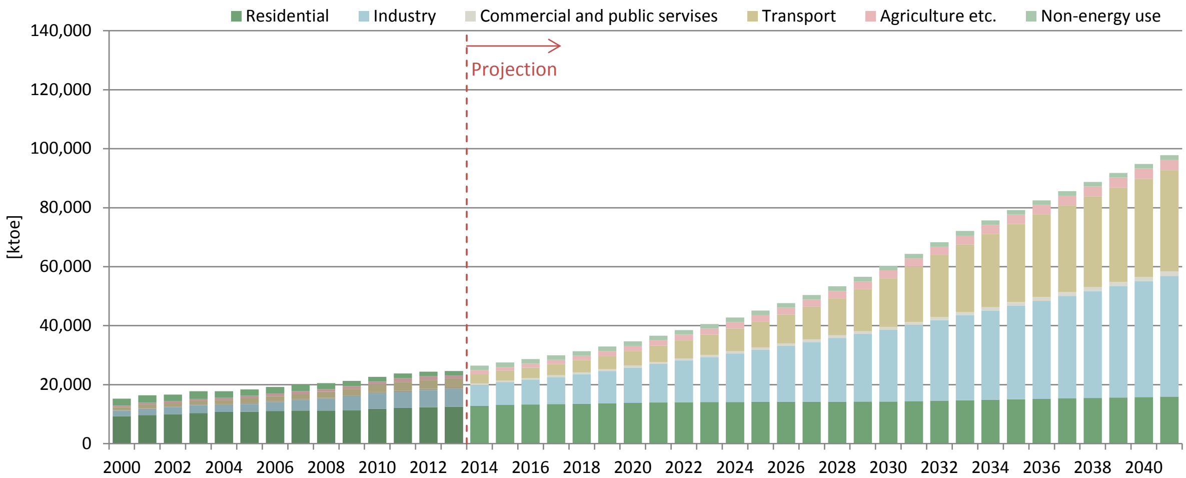


Source: JICA Survey Team

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

With the rapid advancement of industrialization in Bangladesh, it is expected that there will be a shift in the industrial sector from labor-intensive industries like RMG to energy-intensive industries. As a result, energy consumption in the industrial sector is expected to increase rapidly. In addition, in the transport sector, as growth in GDP per capita is expected to facilitate vehicle ownership from the middle of the 2020s onward, it is estimated that energy consumption in the transport sector will significantly exceed that of the residential sector in the future.
It is estimated that the average annual growth rate of total final energy consumption including the aforementioned two sectors will be 6.3% between 2014 and 2041. According to this BAU scenario, the growth in energy consumption will slightly exceed the GDP growth rate (annual average real GDP growth rate is 6.1%). Though total energy consumption per GDP tends to decrease until the middle of the 2020s, it is expected to turn upward and, in 2041, reach the same level as the actual figure in 2014 (3.42 toe/million BDT).
For the purpose of relieving rapid growth in energy consumption in Bangladesh in the future, "Energy Efficiency and Conservation Master Plan up to 2030" (EECMP) was formulated in March 2015, supported by JICA. In light of the survey results from EECMP and based on the assumption that measures proposed in the Master Plan will be properly implemented, it is estimated that total energy consumption per GDP will decrease as follows in the Energy Efficiency Scenario. The difference between the figure in this Scenario and the target set in the EECMP (energy consumption per GDP in 2030 is -20% compared to 2014) was due to the difference in definition. For example, calculation in this Scenario considered the transport sector, which was not included in the EECMP's calculation. If calculation is carried out on the basis of the same definition, energy consumption per GDP in 2030 is -20% and that in 2041 is -23% compared to 2014.

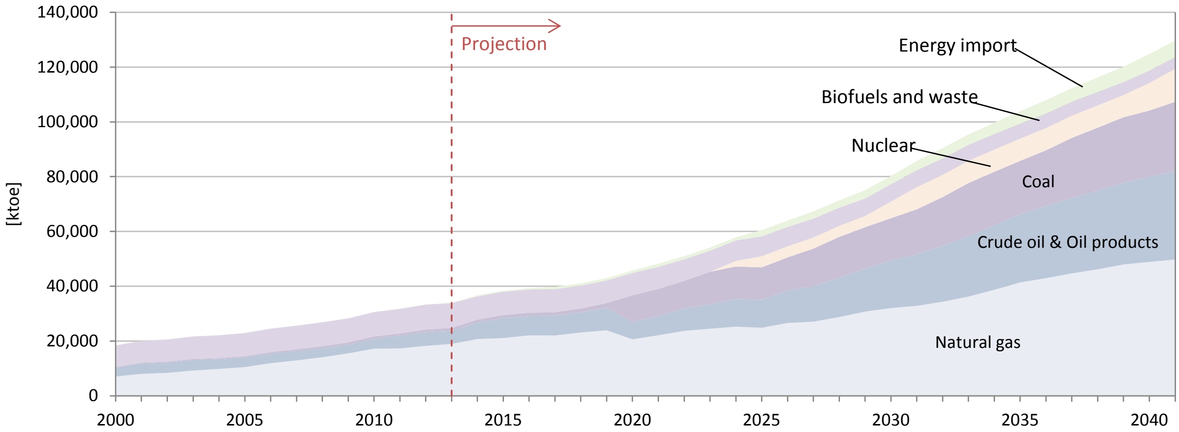
- 2.65 toe/million BDT as of 2030 (decrease of 23% compared to 2014)
- 2.56 toe/million BDT as of 2041 (decrease of 25% compared to 2014)



Source: JICA Survey Team

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

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



Source: JICA Survey Team

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

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

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

Source: JICA Survey Team

(2) Targets to Achieve

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

(3) Roadmap

To implement the Action Plans proposed in the EECMP.

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

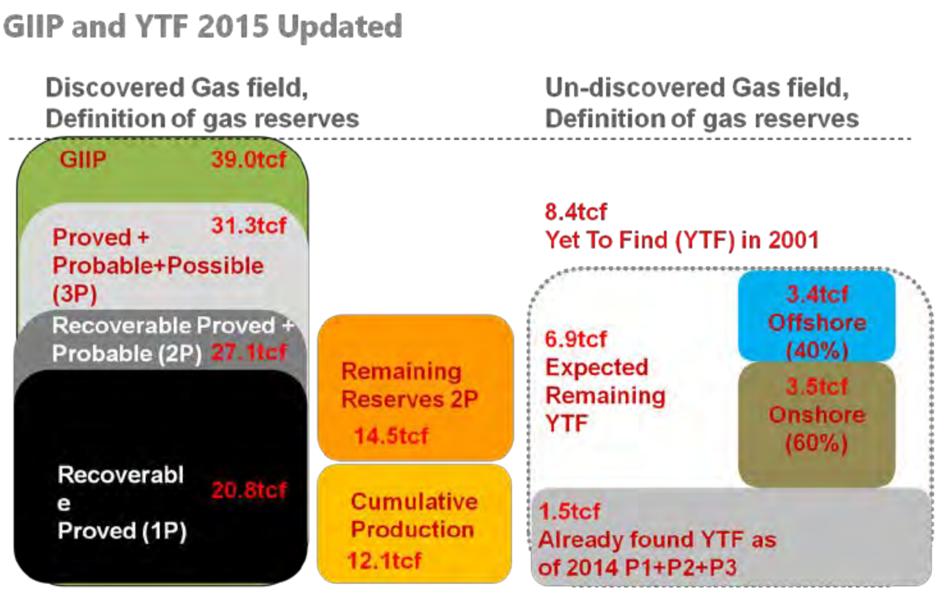
In the transport sector, not only the improvement of fuel consumption efficiency for passenger vehicles but also the improvement of traffic conditions in urban areas (within Dhaka city), which are affected by chronic heavy traffic congestion, needs to be considered.

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

1.6.4 Natural Gas (Domestic)

(1) Current Status and Issues

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



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

Figure 1-13 Gas Resource Balance

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

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

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

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

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

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

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

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

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

(2) Targets to Achieve

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

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

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

(3) Roadmap

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

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

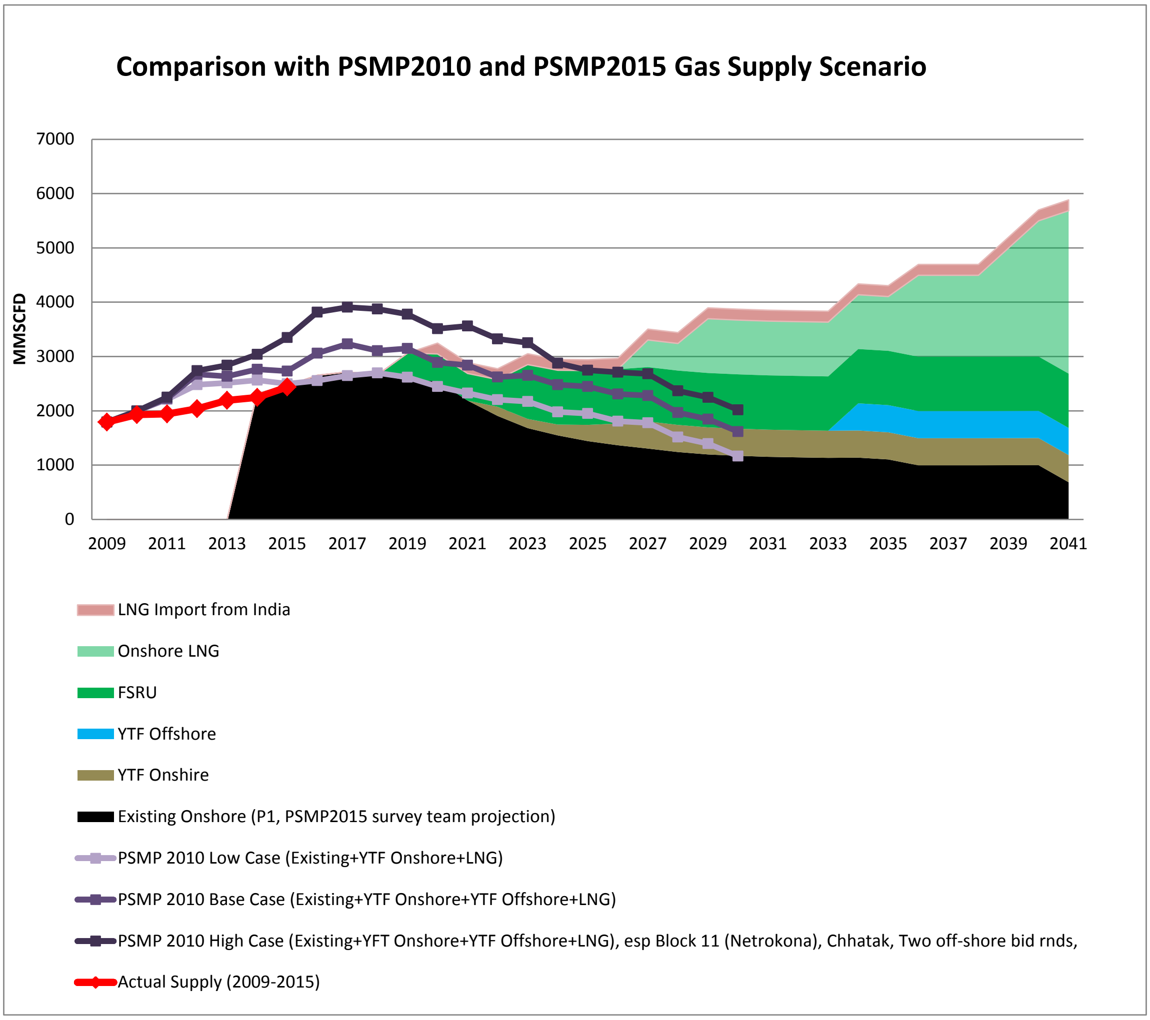
- Legal framework to enhance gas efficiency to be in place by 2019
    - Efficiency to be enhanced to the international level and discourage the use of substandard facilities.

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

1.6.5 Natural Gas (LNG Imports)

(1) Current Status and Issues

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



Source: JICA Survey Team

Figure 1-14 Gas Supply Forecast 2016~2041

Under these circumstances, gas (LNG) import infrastructure, including an LNG Import and re-gasification terminal, and connecting pipeline to the existing transmission and distribution infrastructure, needs to be constructed urgently to fill the supply and demand gap.

Currently, introduction of LNG via FSRU, initiated by Petrobangla, is underway, and concurrently, construction of a land LNG terminal by Power Cell is also under discussion. It is important to understand the difference in these systems in view of economics, construction schedule and operational risk, and it is advisable to prepare in the Master Plan the introduction of LNG to Bangladesh.

The economics of a land LNG Terminal require large upfront investment for land acquisition and infrastructure construction; however, gas handling capacity can be increased with the increase in demand with minimum cost and schedule. Unit operation cost will be lower with the increase of handling volume. It is also important to note that larger size tankers can be used for LNG delivery and this will benefit the land LNG Terminal by reducing the unit transportation cost.

In view of the construction schedule, a Land LNG terminal requires 10 years including land acquisition and the associated re-settlement plan. FSRU requires less than 3 years for commercial operation.

It should be noted, however, that the current FSRU project in Bangladesh would require more than 60 times' the LNG delivery using Ship to Ship Transfer, and would be vulnerable to weather conditions.

LNG Terminal Capacity will be expanding and transmission capacity of the pipeline infrastructure from LNG terminals to the existing distribution infrastructure may need to be studied in advance. Sending out gas pressure at the terminal should be studied to allow the use of higher pressure for gas transportation, eliminating booster compressors downstream. Higher pressure in the system will impact existing gas systems and well head separation performances. The LNG Master Plan should be prepared to optimize and solve potential operational issues.

Fluidization of LNG supply has started already and the inflexible Take or Pay Contract has been an old legacy in US and Europe. On the other hand, Asia has suffered from an expensive gas pricing system known as the Asian Premium. It is important to tie up with other LNG importing Asian nations and consider the introduction of spot procurement, and discuss product exchange (trading) among the LNG importing nations. It is advisable to own a slightly larger storage capacity and loading facility for re-export. Terms of sales/purchase agreements for LNG are not simple. It is important to set up a strategy taking the above into consideration.

It should be noted that the current LNG price is about ten times higher than that for Bangladesh's domestically produced and marketed gas, where the current gas price for the electric power sector is 1.02 USD/Mcf and that for the fertilizer sector is 0.94 USD/Mcf. In the near future the dependence on LNG over the total gas supply will sharply increase, and the dependency on LNG is projected to exceed 70% of the total gas supply in the year 2041. Domestic Gas prices need to accommodate the LNG price. Under these circumstances, existing fertilizer manufacturing facilities will not be able to produce economically competitive product and the power price from old existing facilities will not be able to compete economically with higher efficiency facilities. Similarly, more attention should be given to gas leaks and system loss from gas transmission and distribution infrastructure to prevent economic loss, i.e., "the lost opportunity cost".

It is very important to review the integrity of the existing infrastructure, and swiftly introduce an electronic mapping system with object orientated features as a first step.

(2) Targets to Achieve

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

(3) Roadmap

- Master Plan for LNG Introduction to be prepared and completed by end of 2017, covering economic analysis, construction schedule, operational risks, energy security, and international cooperation (including joint LNG infrastructure operation)

- Initial land-based LNG terminal commences operation in 2027, supplying 500mmscfd of natural gas. The terminal is expanded to supply 3,000 mmscfd gas in 2041.
- FSRU Phase 1 and connecting pipeline to be completed and start supplying 500 mmscfd of gas in 2019
- Impact of LNG introduction on existing gas infrastructure and gas field facilities to be investigated and reinforcement plan to be prepared by 2019
- LNG Procurement Strategy to be prepared by 2018.

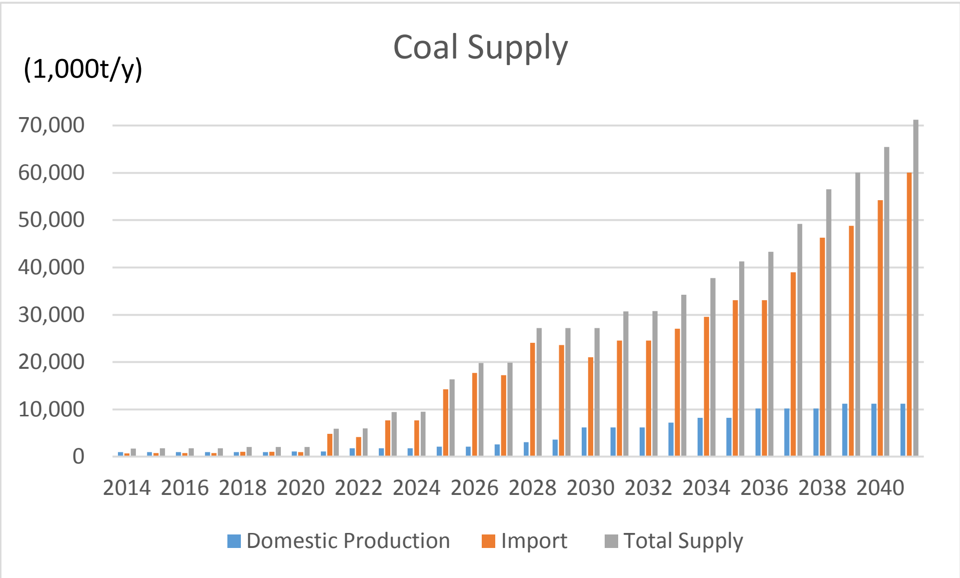
1.6.6 Coal

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

(1) Current Situation and Issues

(a) Infrastructure for import coal

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



Source: JICA Survey Team

Figure 1-15 Forecast of Coal Demand and Supply

(b) Domestic coal development

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

(2) Targets to Achieve

(a) Infrastructure for import coal

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

(b) Domestic coal development

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

(3) Roadmap

(a) Infrastructure of import coal

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

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

(b) Domestic coal development

1) Because it will take about 10 years to develop a new coal mine and start production, production will begin in 2025 at the earliest even if it is prepared now. Therefore, it is necessary to carry out the required preparation from a position of being able to do this now due to as much utilization of the excellent domestic resources as possible.

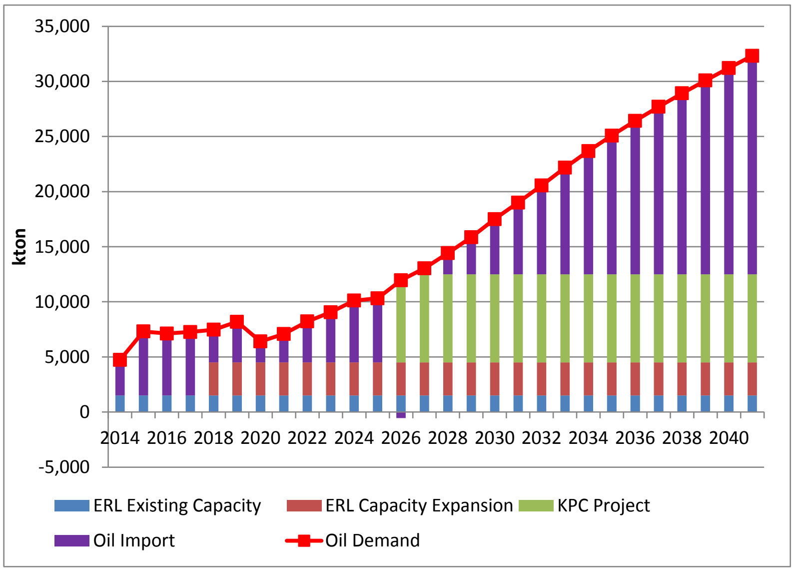
2) Unfortunately, the production of Barapukuria coal mines in 2015 was 0.68 million tons and did not reach 1 million tons as planned, but 1.1 million tons from U/G in 2020 and a total of 3.2 million tons (1.2 million tons from U/G and 2 million tons from O/C) from 2030 to 2041 are assumed.

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

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

1.6.7 Oil and LPG

(1) Current Status and Issues
Bangladesh's current oil annual demand is around 5 million tons, and the self-sufficiency rate is only 5%. However, Bangladesh expects continuous economic development, and the industry sector and transport sector demand will lead drastic oil demand growth: 6 times higher in 2041 than in 2016 (average growth rate 7.4% p.a.), even under the "Energy Efficient and Conservation Scenario".
Bangladesh has several plans to extend or newly develop oil refineries; however, if the oil demand grows as projected, oil imports will be mandatory to meet the demand and keep increasing.



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

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

Furthermore, Bangladesh's LPG demand is only 2% of total oil demand, and less than 0.01% of the total energy demand. However, LPG consumption is expected to grow drastically as an alternative for households' cooking fuel (currently domestic natural gas) and transportation fuel.
The current price of LPG is two to three times higher than that of the pipelined gas, and may not be affordable for average households in Bangladesh. While Bangladesh rural households spend 4-7 % of their monthly income on traditional solid biomass, LPG at the market price would be 25%. If the government seriously intends to pursue universal access to modern energy, LPG may not be a good solution or may need some policy countermeasures. Subsidy of LPG may work to some degree to increase affordability; however, without sound consideration of the side effects and an exit strategy, LPG subsidy would create huge pressure on the national coffers, given the projected future demand.

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

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

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

1.6.8 Power Development Plan

(1) Current Status and Issues

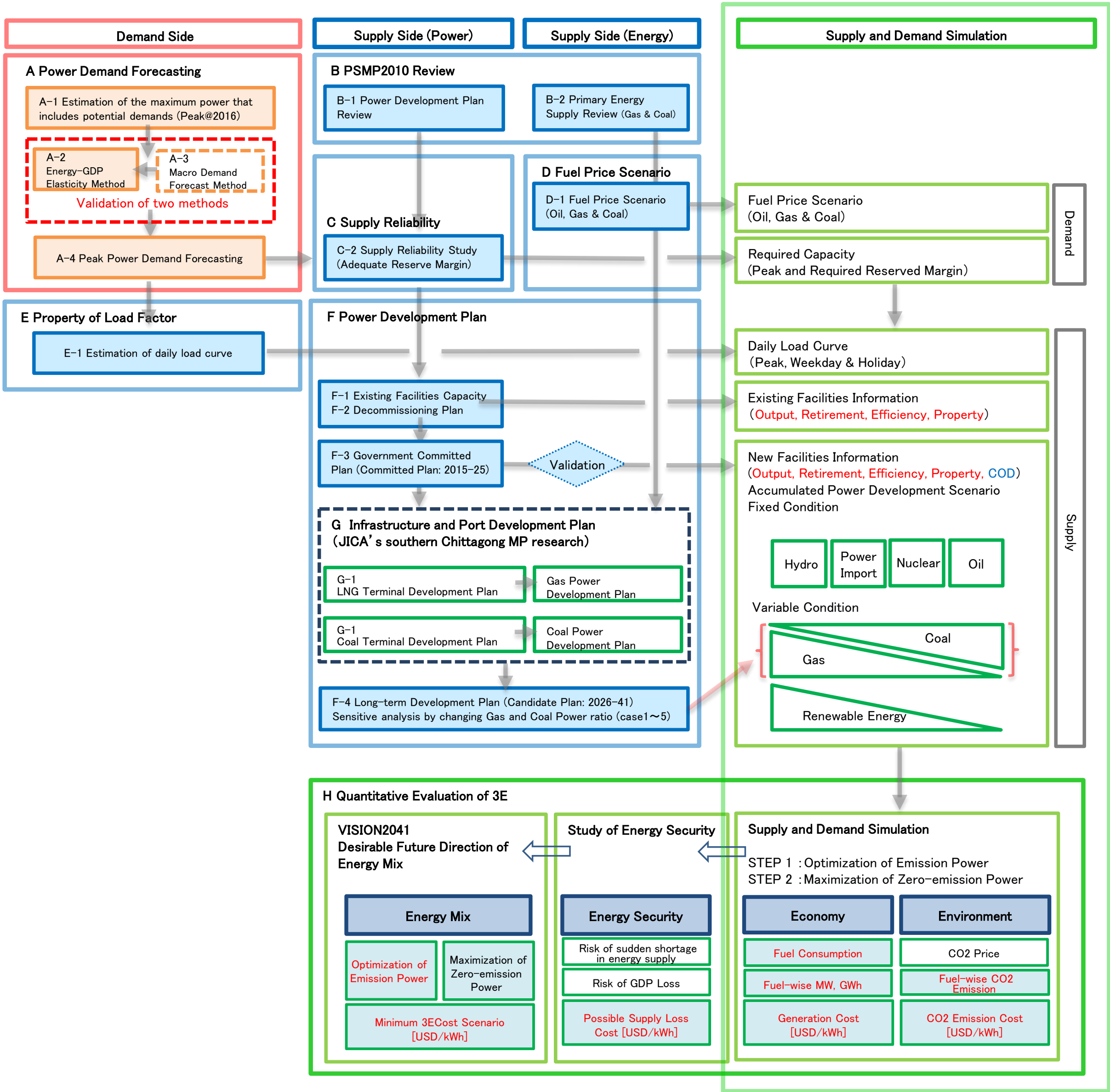
As mentioned in Chapter PSMP2010 review, five-year power demand by PSMP2010 and its actual performance had remained in about 8,000MW which is about 80% level of the plan, because it was delayed power plant construction which had been planned and necessary infrastructure such as port which is essential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

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

(2) Targets to Achieve

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

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



Source: JICA Survey Team

Figure 1-17 Power Development Planning Flow

1) Peak Power Demand Projection

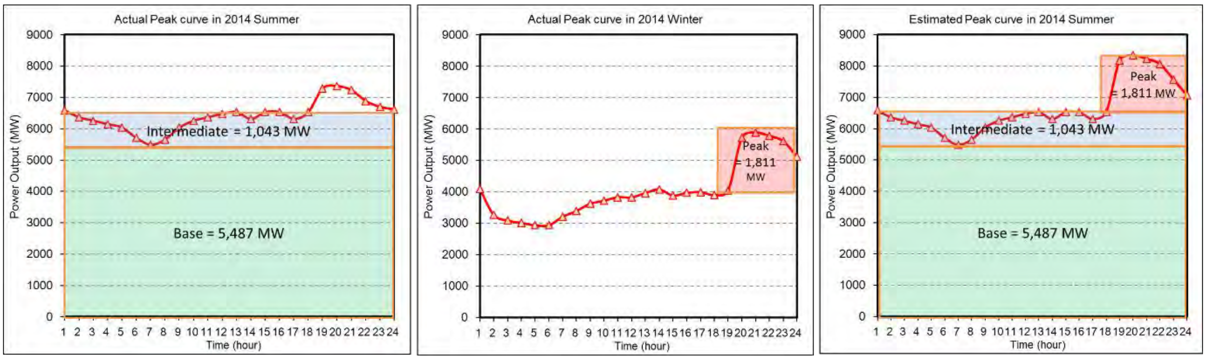
As for the methodology of peak demand projection for PSMP2016, this study adopted the "GDP elasticity method", which is an easier approach and thus easy for technology transfer to local counterpart agencies who are expected to take over the work in a rolling plan. However, it has to be noted that this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

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

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

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

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

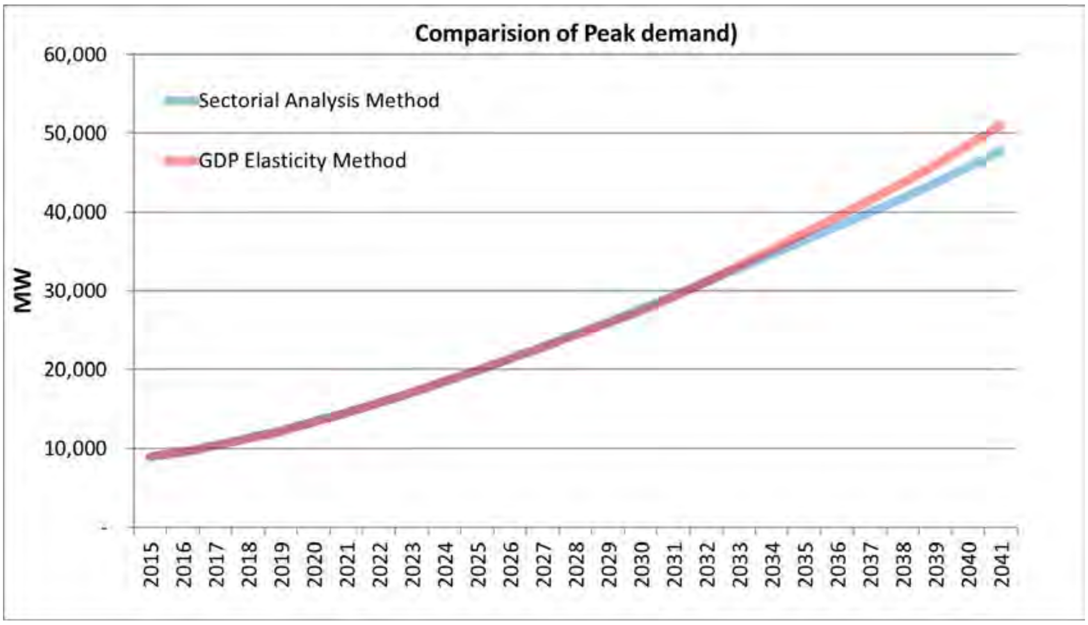


Source : JICA Survey Team

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

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

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



Source: JICA Survey Team

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

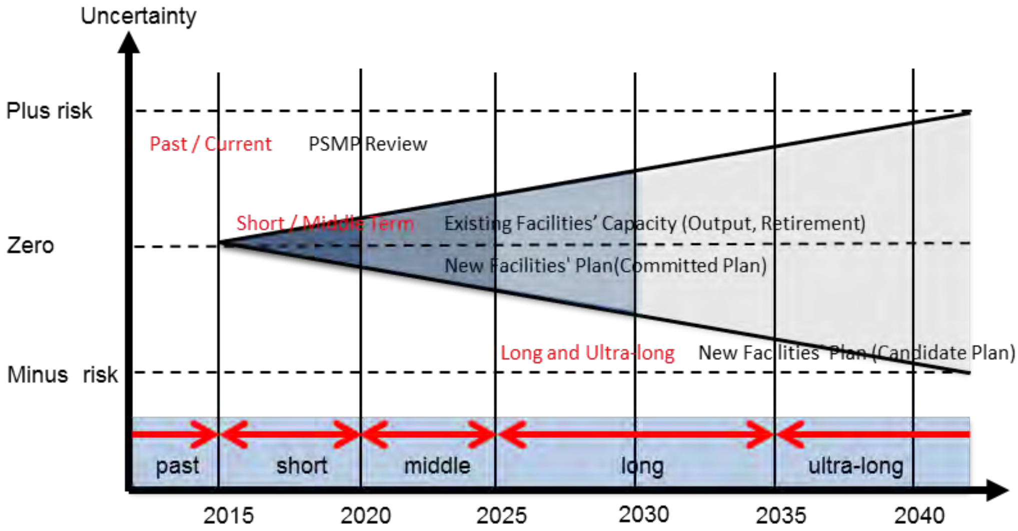
(d) Integration of Peak Power Demand Projection and Energy Supply-Demand Projection

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

2) Power DevelopmentPlan

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

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



Source：JICA Survey Team

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

(a) Existing plants

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

(b) Retirement Plan

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

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

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

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

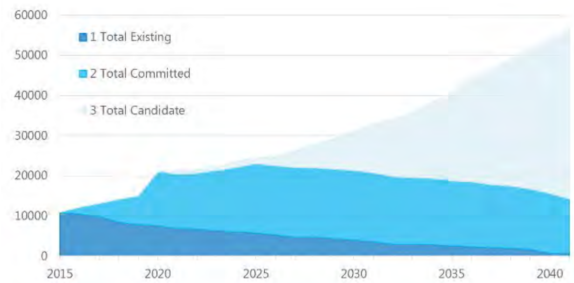
Guarantee of the long-term stability of the fuel supply is a very important factor in the formulation of a power development plan. The existence of a port infrastructure required for the importing of fuels including gas and coal during operation has to be a precondition for the decision on the CODs of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

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

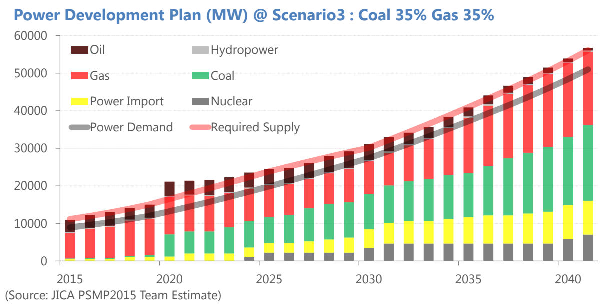
A study on increasing the power sources by changing the ratios of the gas and coal power generation in accordance with the progress in the infrastructure and port development planned in JICA's Southern Chittagong MP Survey is to be conducted for the formulation of the candidate plan. In this section,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

(f) Summary of Power Development Plan

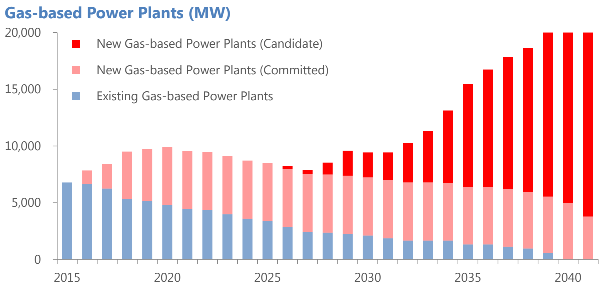
The figure below shows the power supply plan formulated by adding the capacity of the existing plants estimated with the retirement plan in the plan for the existing facilities taken into consideration (existing capacity), the capacity of the plants mentioned in the Committed Plan to be constructed by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



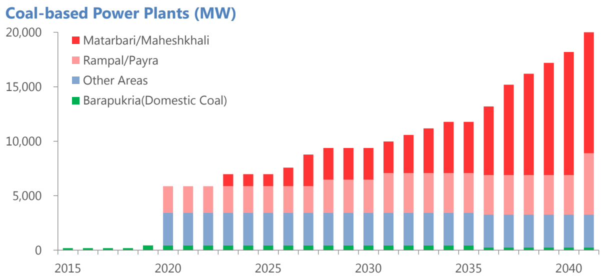
PowerDevelopment Plan (Base case)



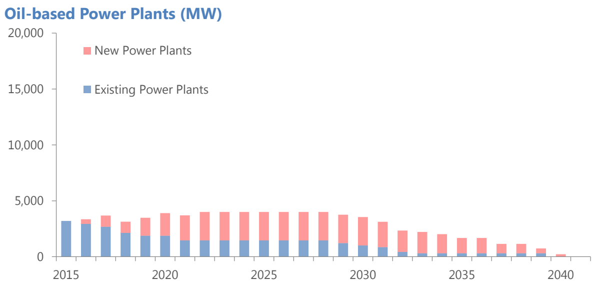
Power Development Plan (Base case)



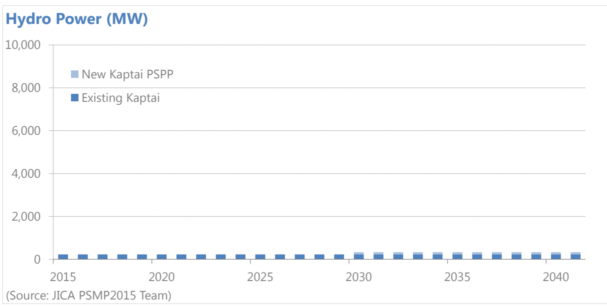
Gas



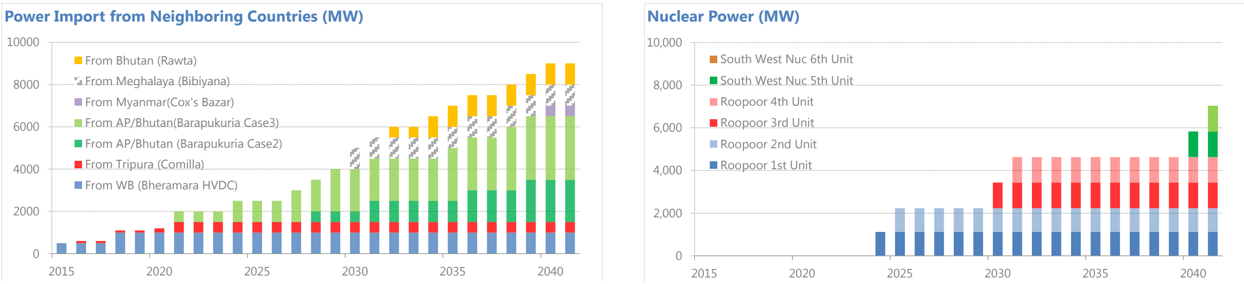
Coal



Oil



Hydro



Power Import Nuclear

Source：JICA Survey Team

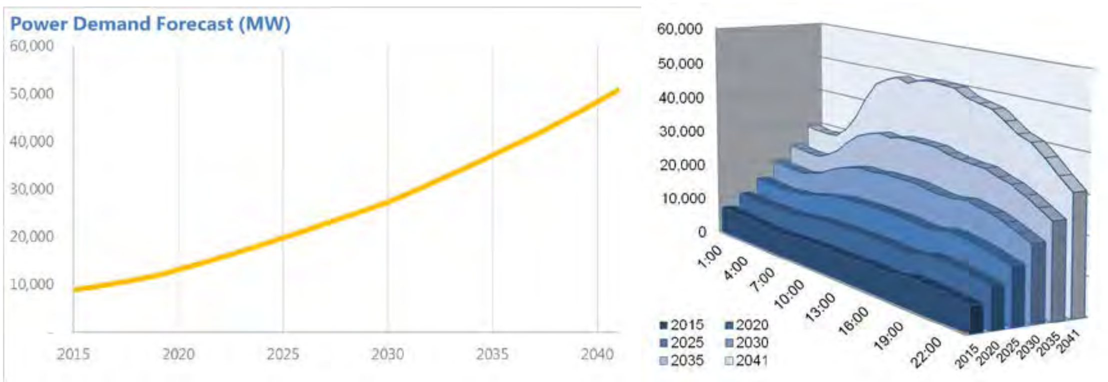
Figure 1-21 Annual Trend of Each Power Plants（MW）

3) Simulation of Supply/Demand Operation

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

(a-1) Daily load curve

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

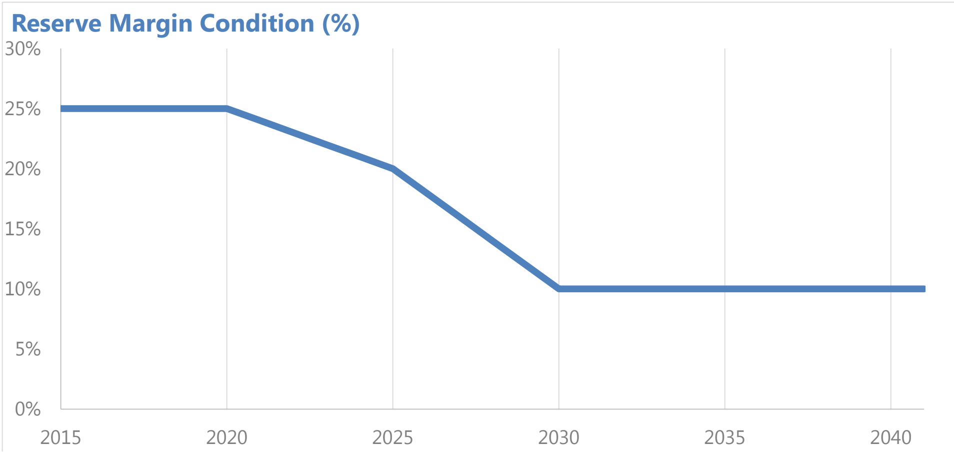


Source: JICA Survey Team

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

(a-2) Power supply reliability

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



Source：JICA Survey Team

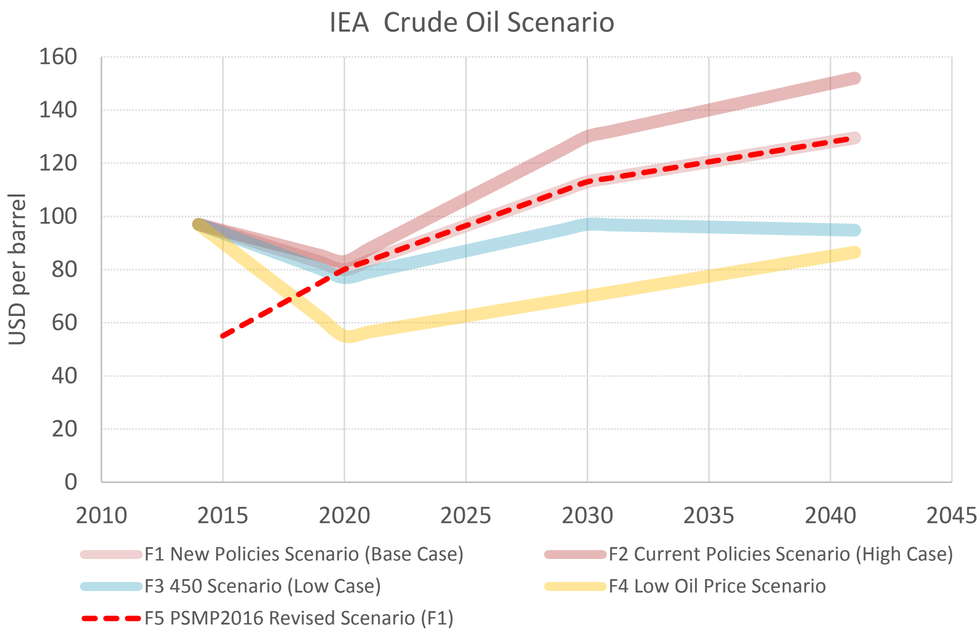
Figure 1-23 Reserve Margin

(a-3) Fuel Price Scenarios

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

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

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



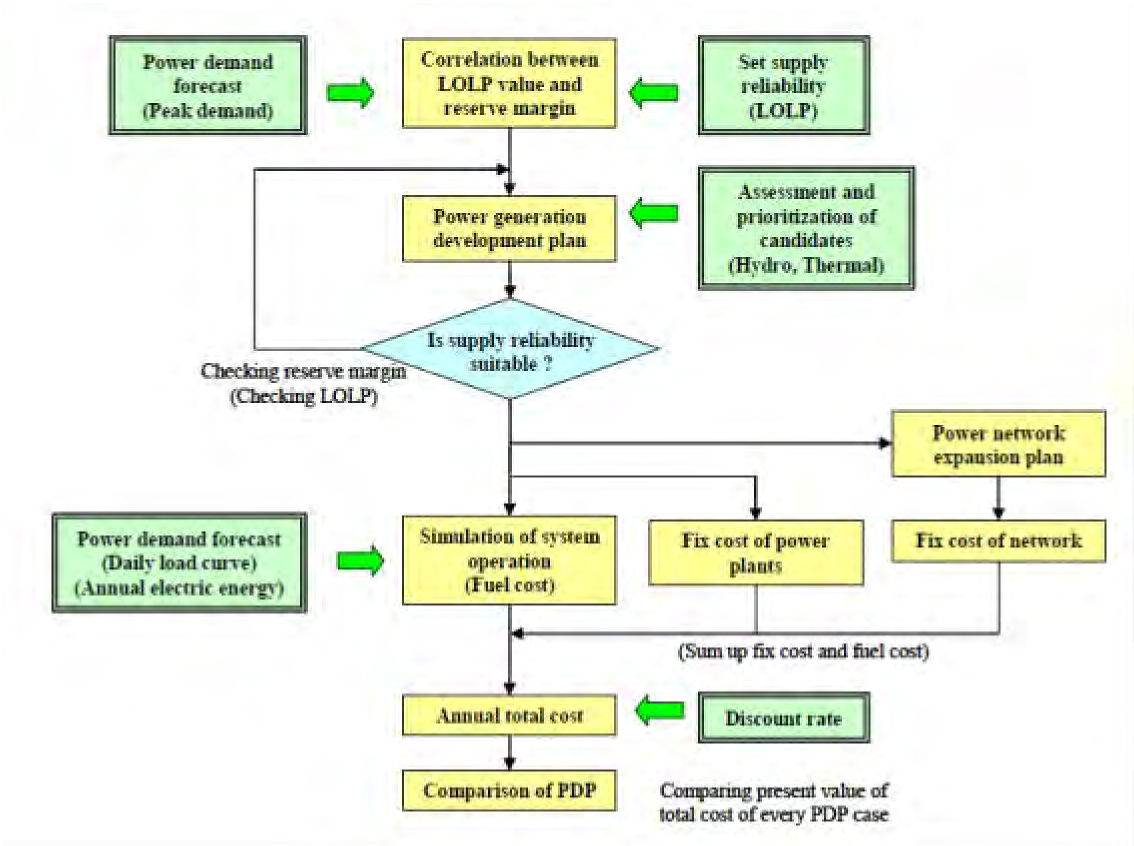
Source: JICA Survey Team

Figure 1-24 IEACrude Oil Scenario

(b) General description of Supply/Demand Operation Simulation

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

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

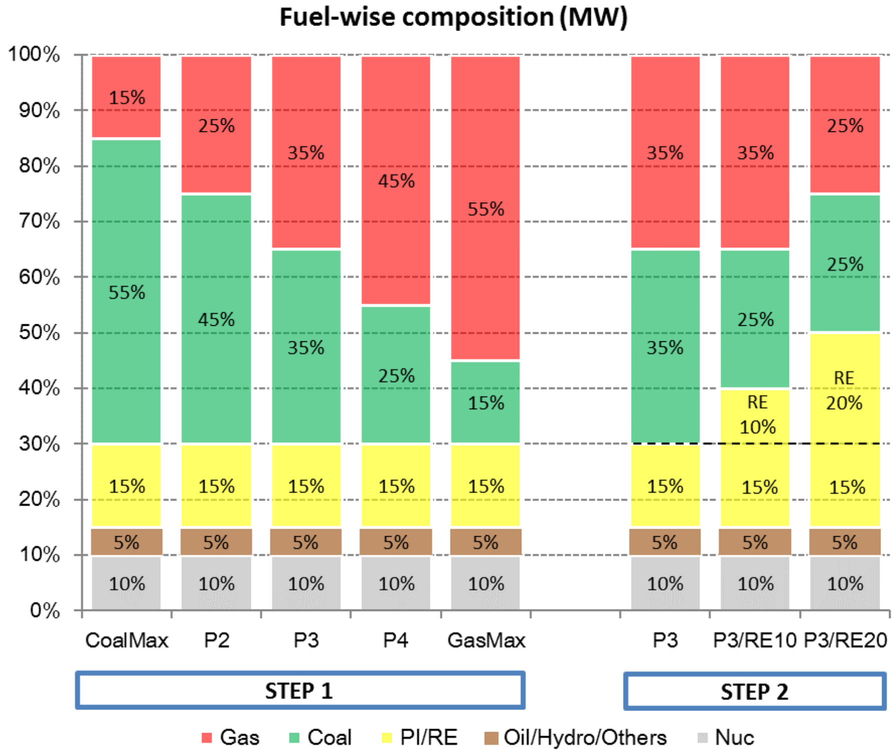


Source: JICA Survey Team

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

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

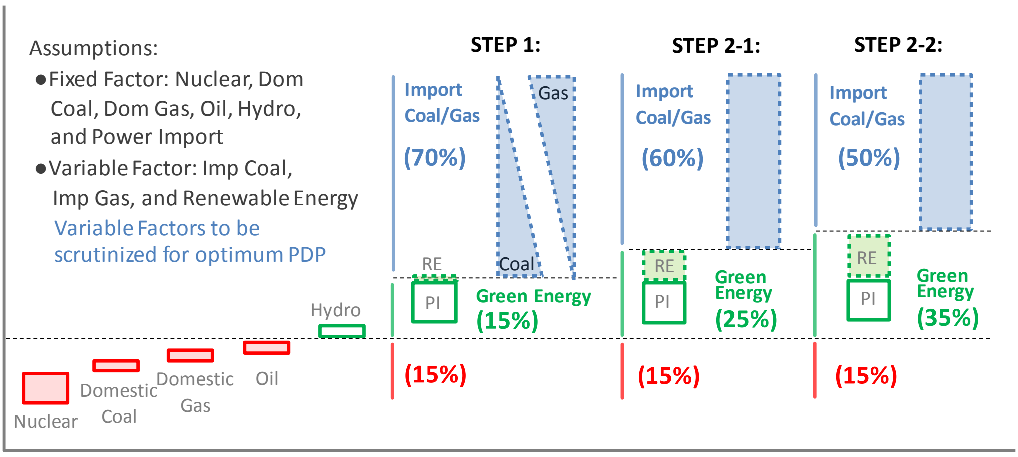
In this case, the share of oil and other fuels in the energy mix should not change in each scenario. The energy mix by fuel type from 2015 to 2041 in each scenario is as shown in the following figure.



Source: JICA Survey Team

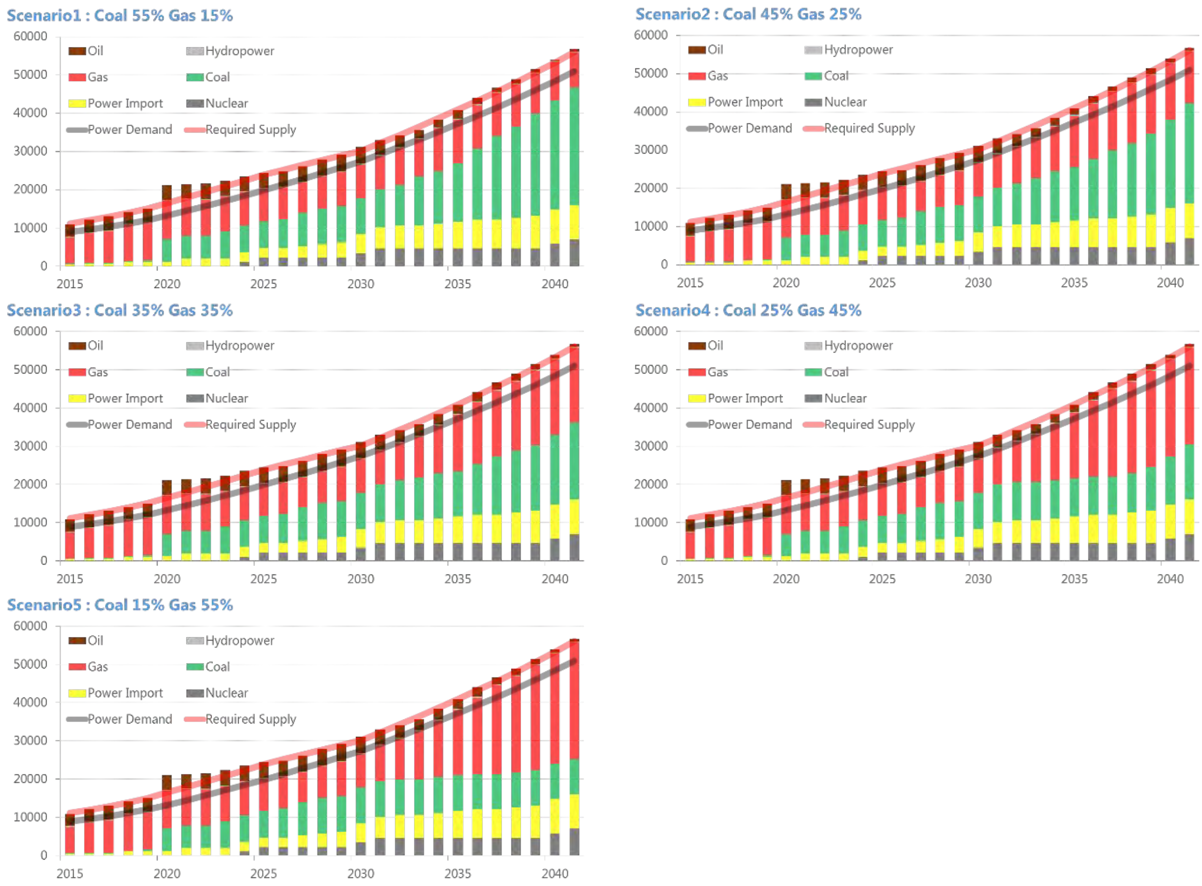
Figure 1-26 Generation pattern in 2041

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



Source: JICA Survey Team

Figure 1-27 Image for demand and supply simulation

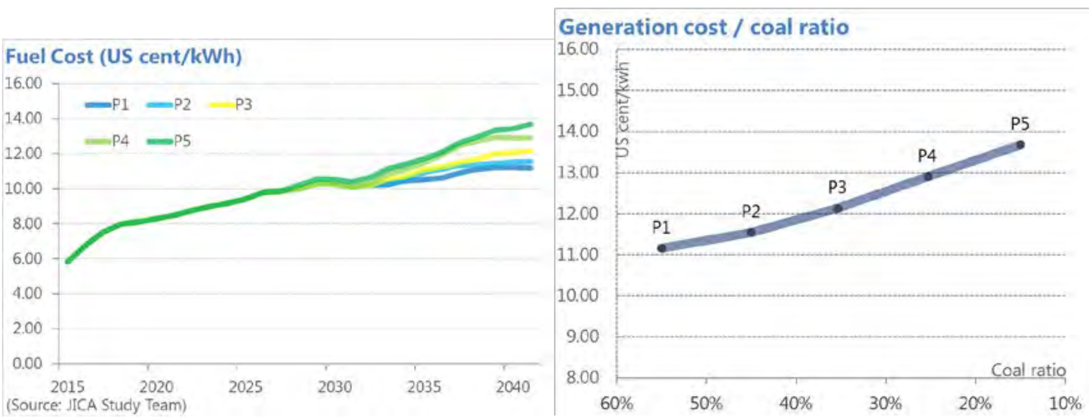


Source: JICA Survey Team

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

(c) Estimation of Economic Value

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



Source: JICA Survey Team

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

(d) Estimation of Environmental Value

CO_2 emissions in different scenarios are shown in the figure below. The CO_2 emissions in 2041 are the highest (0.82 CO_2 kg-C/kWh) in Scenario P1, with a high share of coal in the energy mix, and the lowest (0.55 CO_2 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 CO_2 emissions. This study employed CO_2 cost per unit of electricity generated to evaluate the environmental value of each power development scenario. CO_2 cost is calculated by multiplying CO_2 emissions and CO_2 price. In this study, 125 USD/tCO_2 is used for the CO_2 price, referring to the assumption in the 450 scenario of IEA World Energy Outlook 2015.

(e) Estimation of Energy Security Value

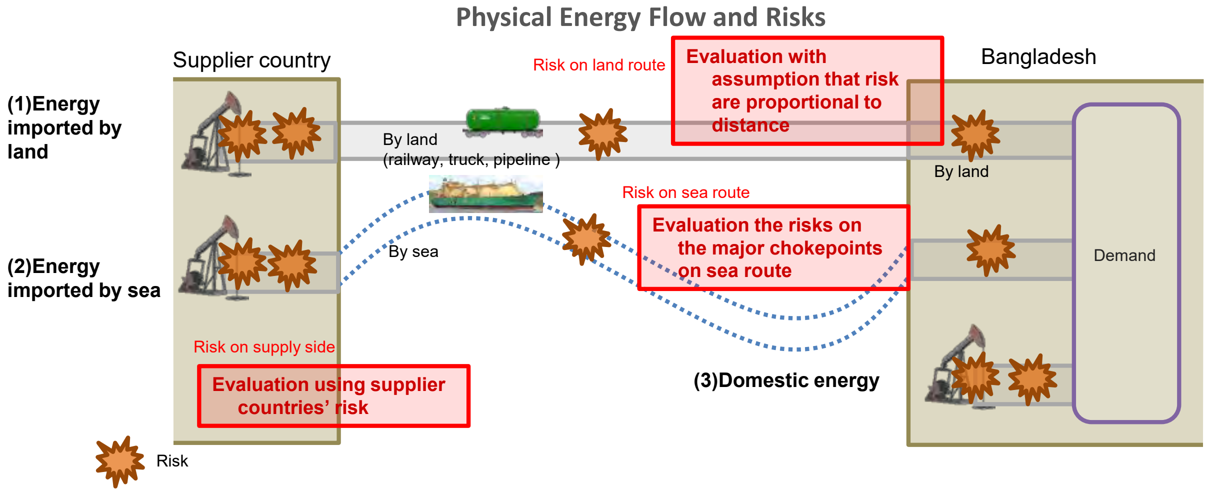
Energy security covers many concepts and there are no common approaches to evaluate it unlike previous two values. Here, we focused on risk of sudden shortage in energy supply quantity, which would directly damage Bangladesh economic activities. The difference ratio of coal and gas among power development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

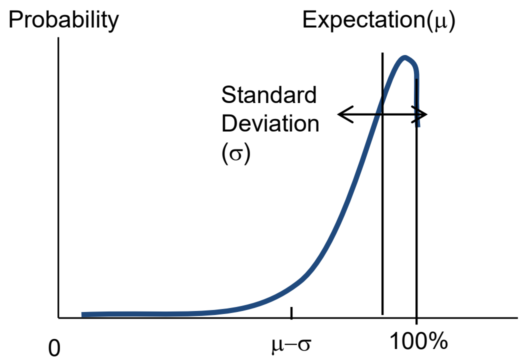
export suspension risk, blockage risk on land route, and blockage risk on sea route. We ignored the risks to deliver domestic energy.



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.

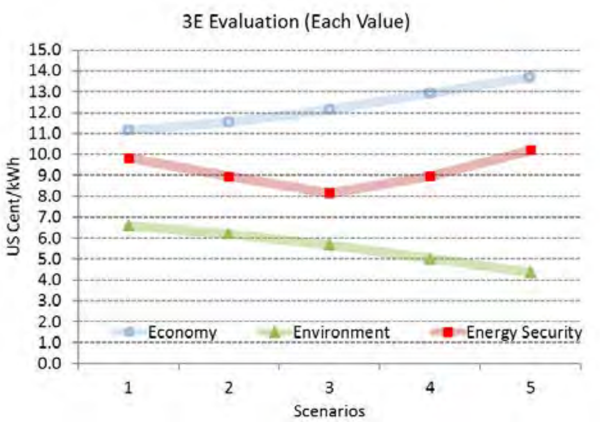
A quantitative evaluation of the 3E values in 2041 of each of the power development scenarios proposed in the previous section conducted for the selection of the most recommendable scenario is described in this chapter.

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

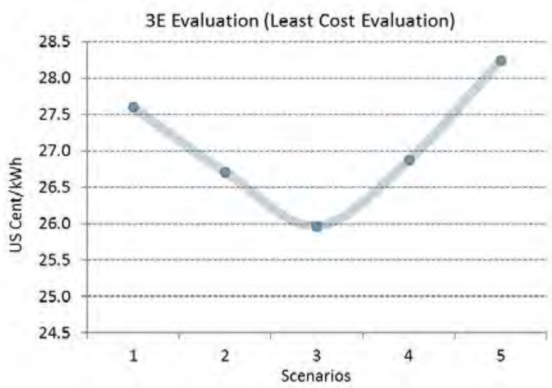
	Composition (MW base)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	11.2	6.6	9.8	27.6
Scenario 2	Gas 25%, Coal 45%	11.6	6.2	8.9	26.7
Scenario 3	Gas 35%, Coal 35%	12.1	5.7	8.2	26.0
Scenario 4	Gas 45%, Coal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

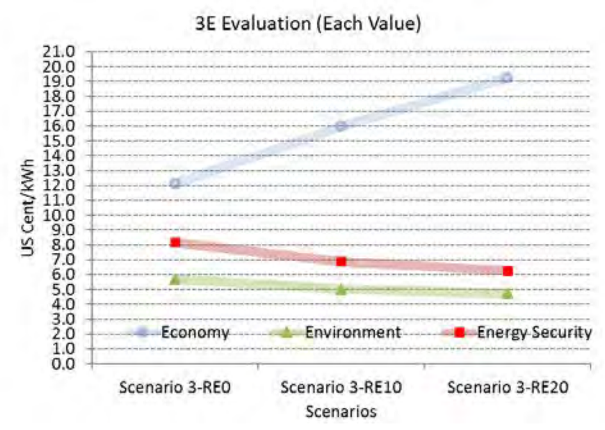
As mentioned above, after determining the optimum share of gas and coal in the enrgy mix, as Step2, changing the share of renewable energy in the energy mix should be considered. In this study, RE10 scenario increasing 10% Renewable energy and RE20 scenario increasing 20% reneawable energy is considered.

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

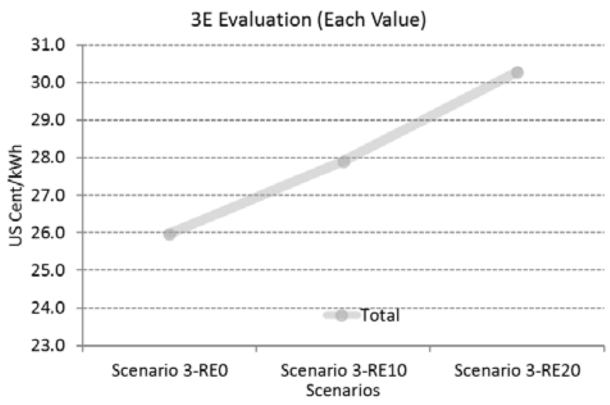
Composition (MW base)	Economy [US cent/kWh]	Environment [US cent/kWh]	Energy Security [US cent/kWh]	Total [US cent/kWh]	Composition (MW base)
Scenario 3	Gas 35%, Coal 35%	12.1	5.7	8.2	26.0
Scenario 3 RE10	Gas 35%, Coal 25%	16.0	5.0	6.9	27.9
Scenario 3 RE20	Gas 25%, Coal 25%	19.2	4.7	6.2	30.2

Source: JICA Survey Team



Source: JICA Survey Team

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

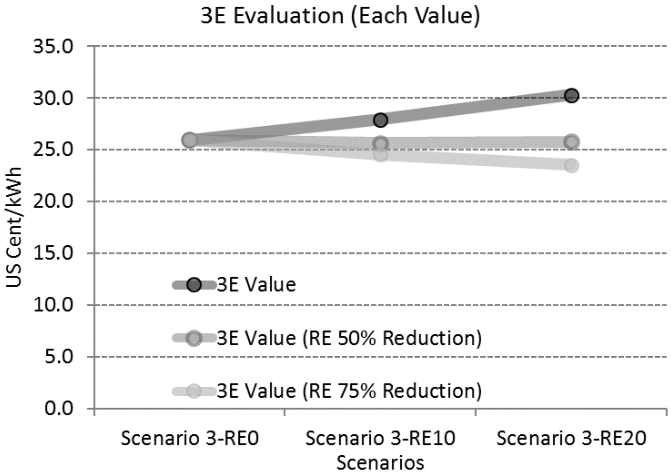


Source: JICA Survey Team

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)

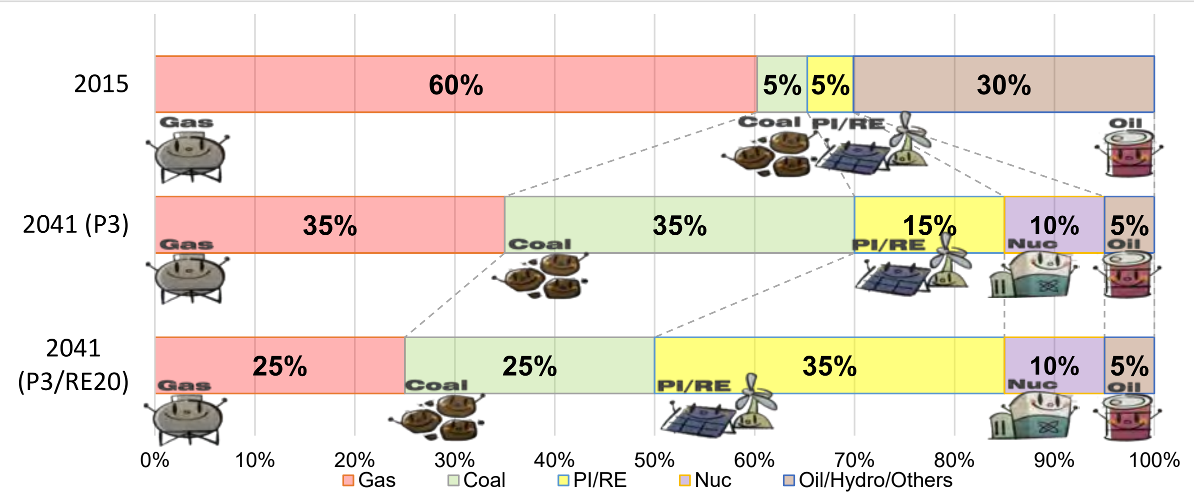
- Breaking away from the dependence on costly petroleum and rental power generation
- Promotion of PPP investment in power generation projects
- Reform of O&M of power plants and revision of electricity rates

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.

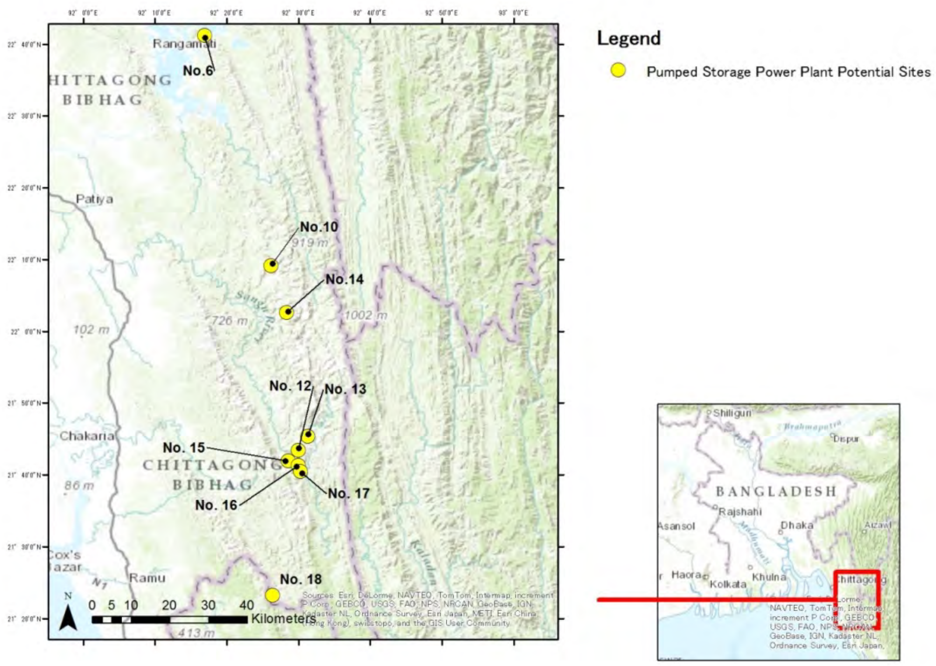


Figure 1-39 Location Map of Potential PSPP Sites

(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.

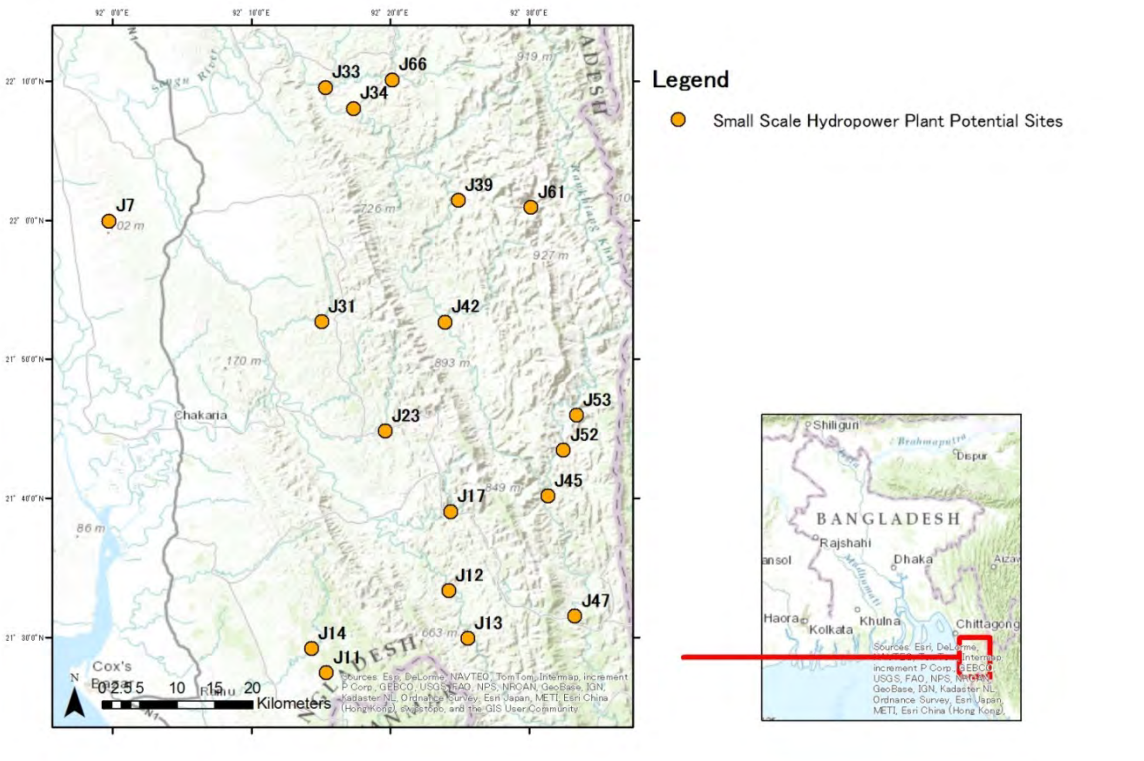


Figure 1-40 Location Map of Potential Sites for Ordinary and Small Scale Hydropower

(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.

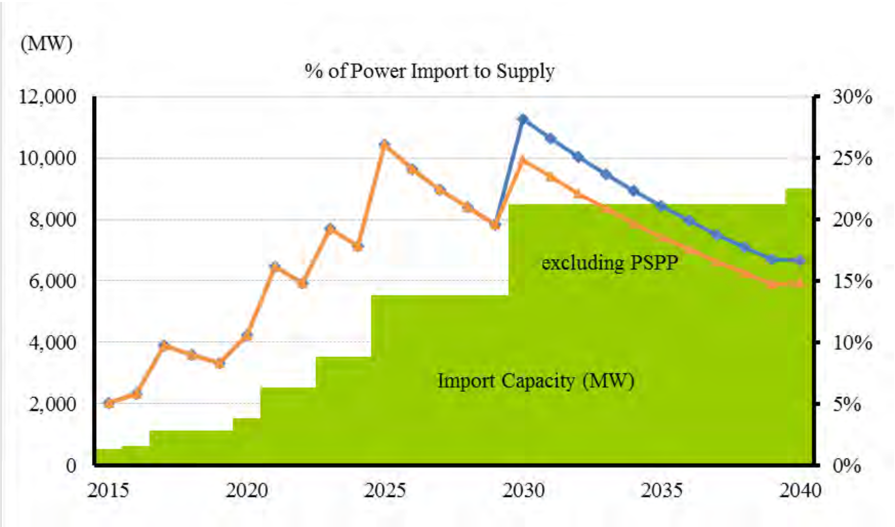
(iv) Mutual Interference due to Grid Accidents

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.



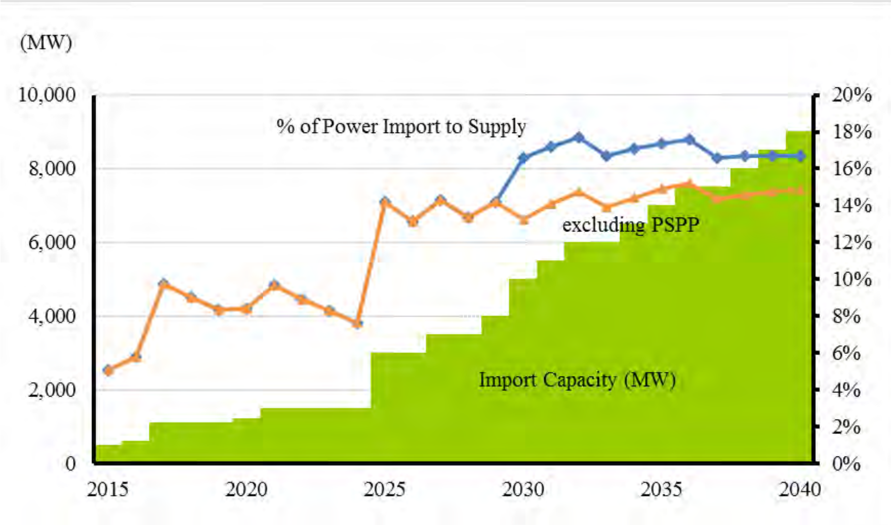
Source: JICA Survey Team

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.

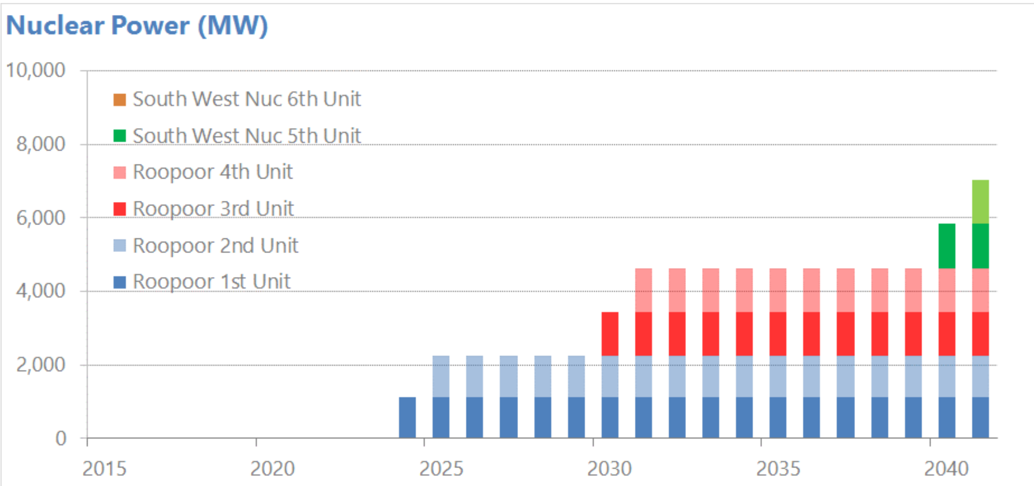
1.6.12 Nuclear Power

(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

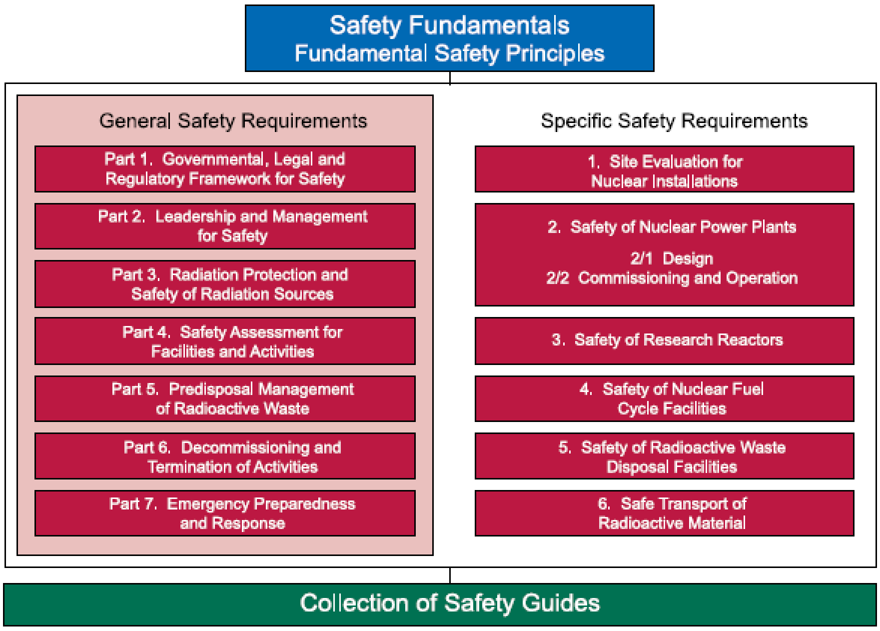
(2) Targets to Achieve
Realization of development of nuclear generation facilities, many challenges shall be solved.

(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

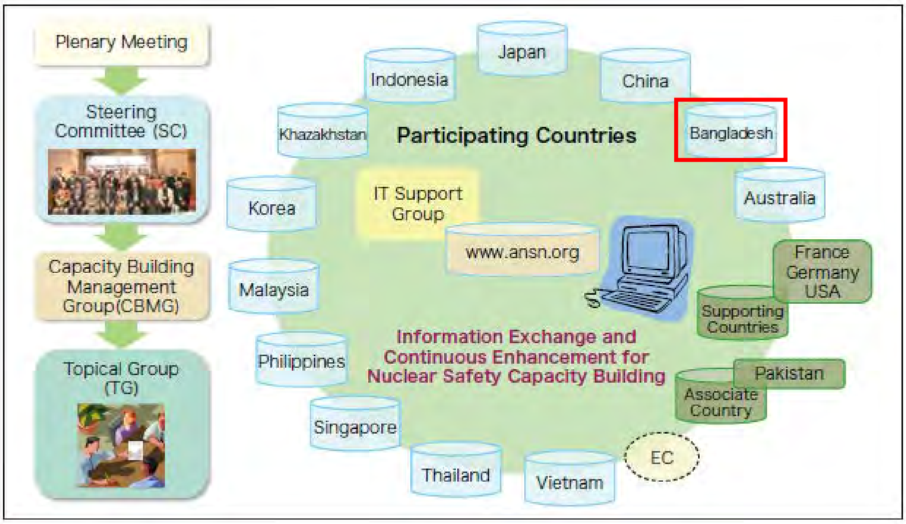
In addition, the government is preparing the Multi purpose information center around Rooppur NPP site to strengthen public communication strategy with public and media. Expected PR-program is as follows;

- 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 followered.

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

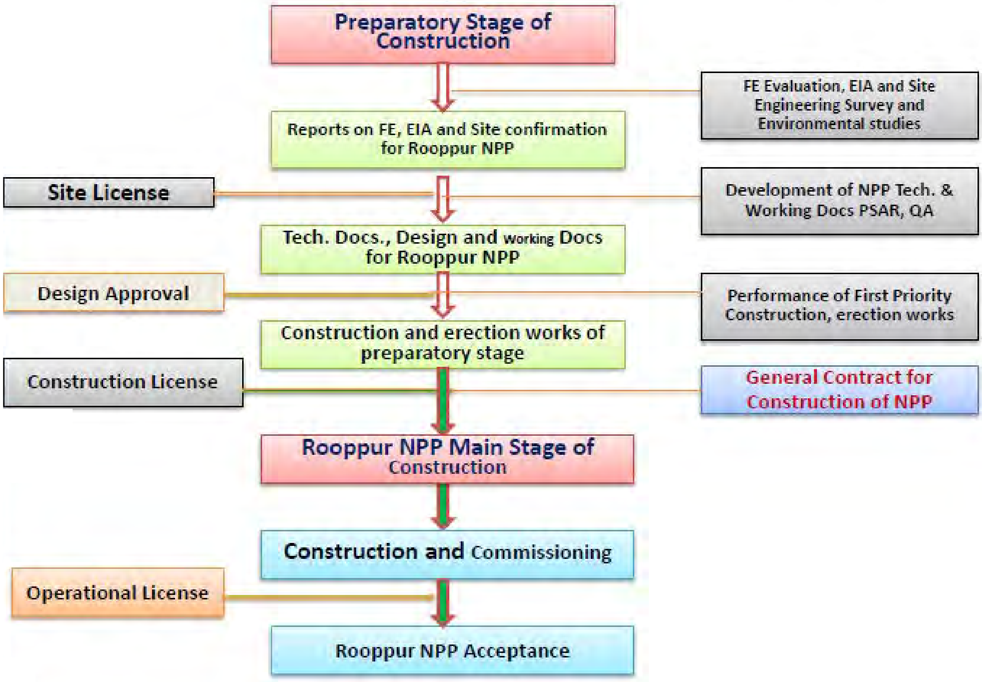
- Nuclear power planning integrated into the part of power & energy planning, such as alternative generation capacity in case of outage of nuclear power plant, reliability of the power supply system
- Development of science technology experience within the country
- Emergency planning
- Protection of 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: 1^{st} and 2^{nd} units
- 2030/31 3^{rd} and 4^{th} units
- 2040/41 5^{th} and 6^{th} 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.

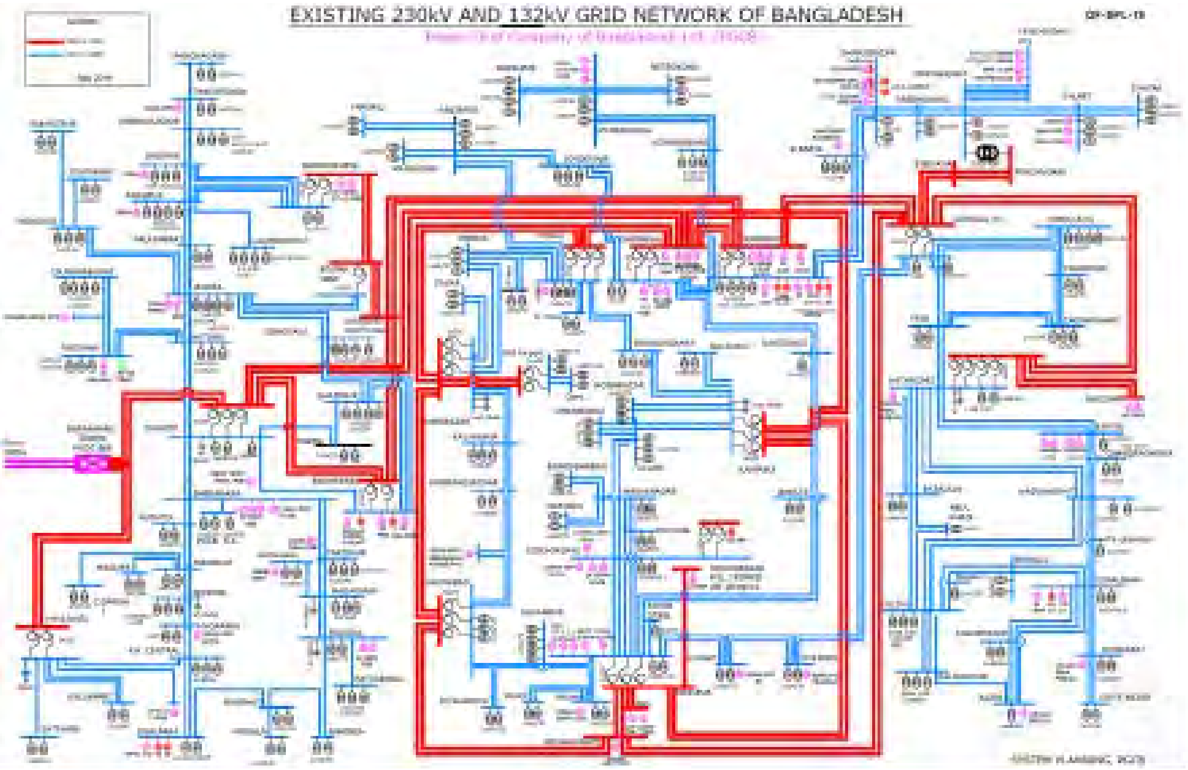


Figure 1-48 The Existing Bulk Power Network System of Bangladesh (2014)

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

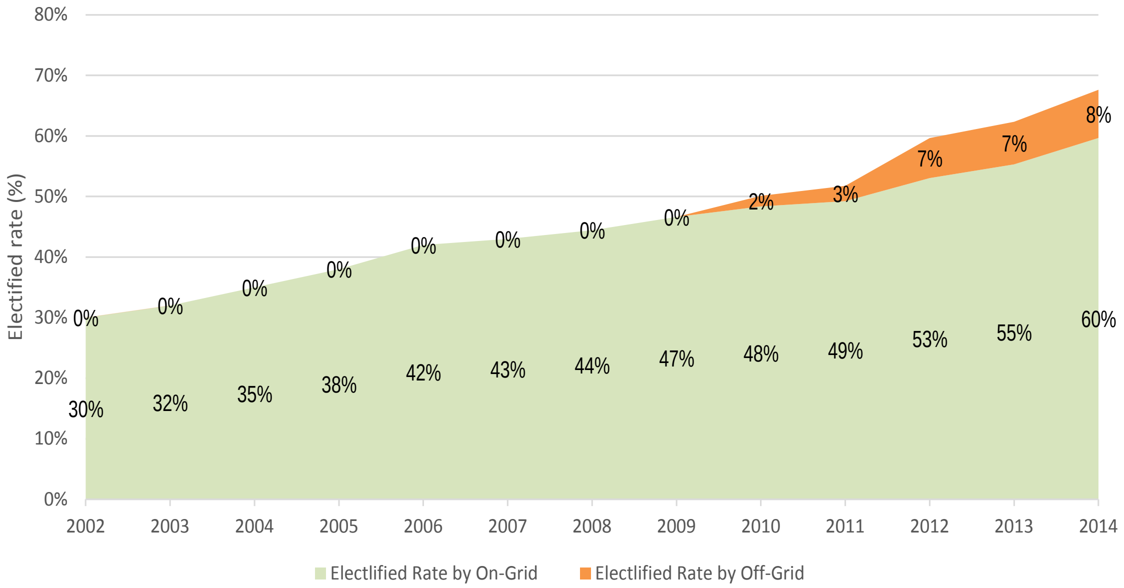
*1 It assumes that the number of people per grid connection (per household) is 7. Household: Husband, wife, children x 2, father, mother + 1. There are big customers such as hospitals, so 1 is added.

*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.

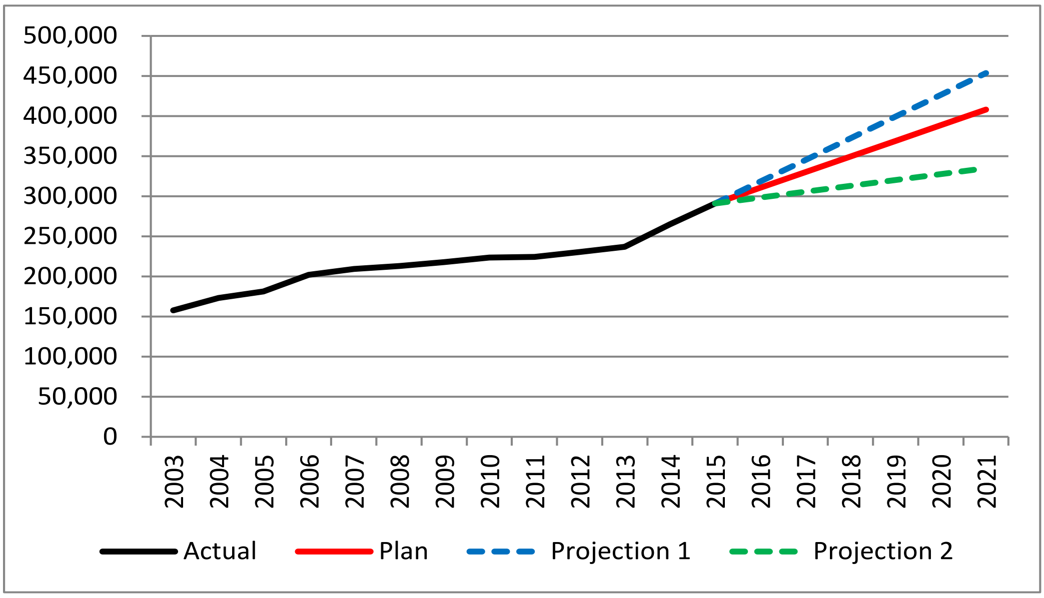


Source: JICA Survey Team, based on the data provided by BPDB

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).

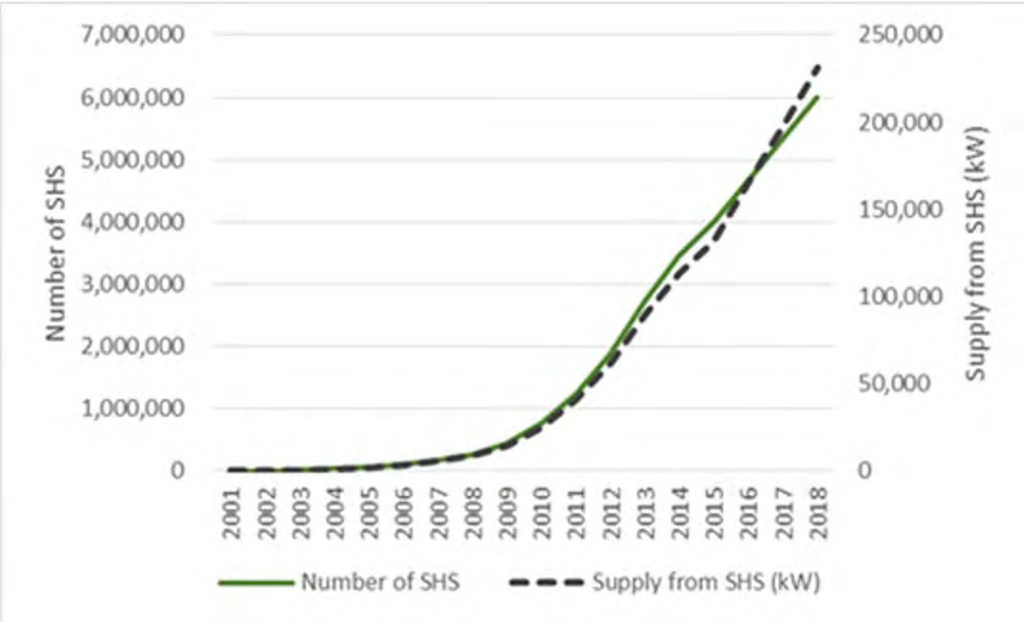
It should be noted that BREB made a great improvement in grid extension implementation between 2014 and 2015, when it substantially increased the grid extension speed compared with the past (between 2003 and 2013). The dotted blue line (Projection 1 in the Figure) means that if BREB keeps the implementation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



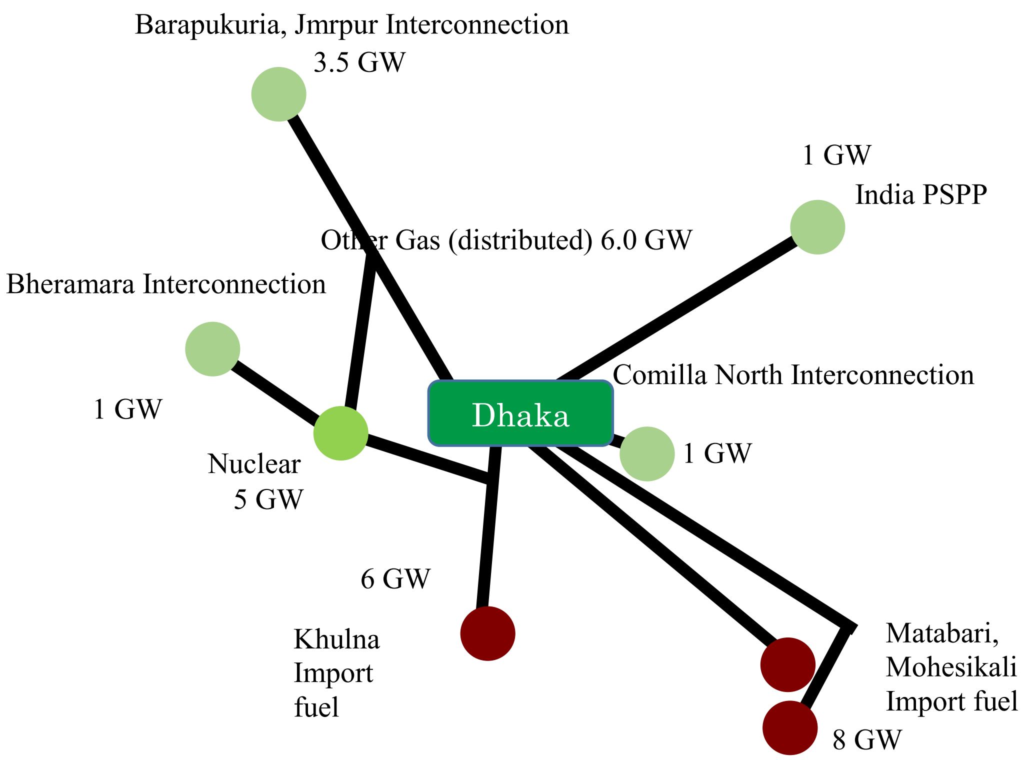
Source: JICA Survey Team

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:

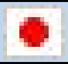
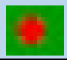
- There is almost no remaining power which can be offered for frequency control due to a significant deficiency in power sources. That is, all generators have no other choice except to keep their outputs at the maximum of available capacity.
- Grid Code in Bangladesh seems to have most of the necessary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

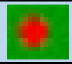
<u>Regulation by the Electricity Acts</u>

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

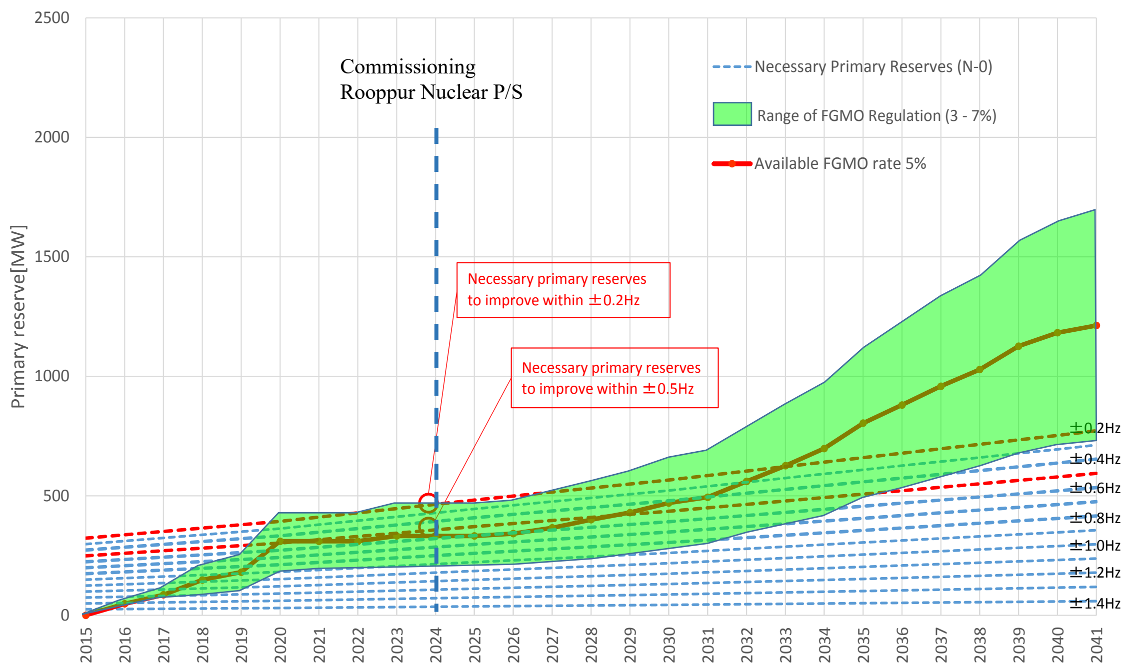
Frequency regulation control is usually realized by a combination of FGMO (Free-governor mode operation) and LFC (Load frequency control).
In this study, the JICA survey team conducted a trial calculation for future frequency improvement when the regulation control is performed by FGMO only, because:

- 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.

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

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

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



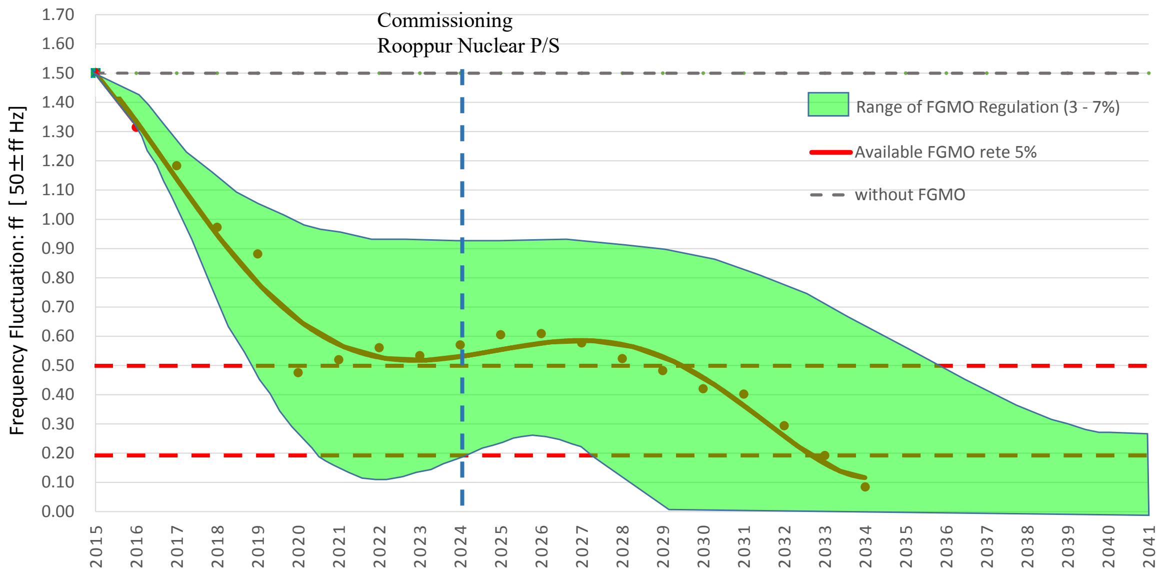
Source: JICA Survey Team

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

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

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

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



Source: JICA Survey Team

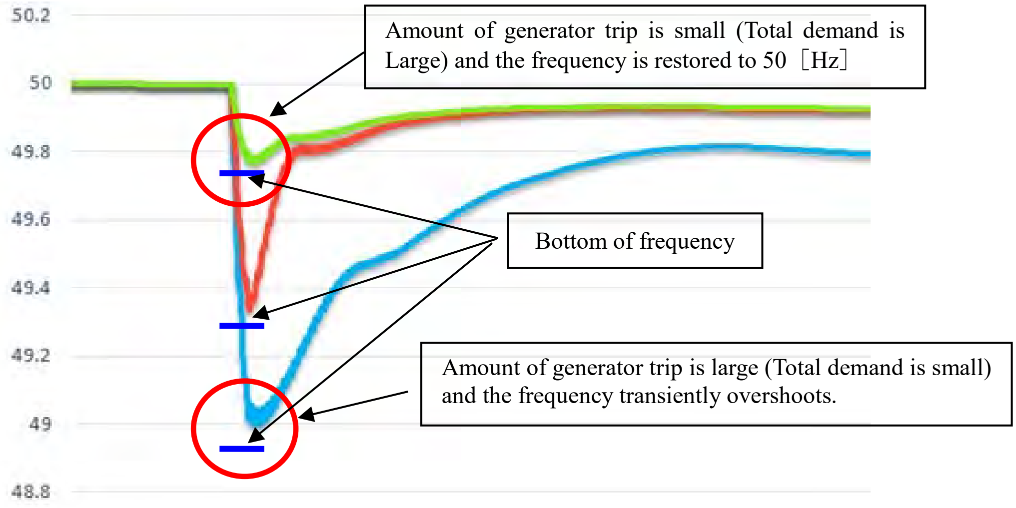
Figure 1-54 Trend of Power Frequency Quality Improvement

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

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

<u>Power frequency quality improvement in the N-1 Case (Emergency Conditions)</u>

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

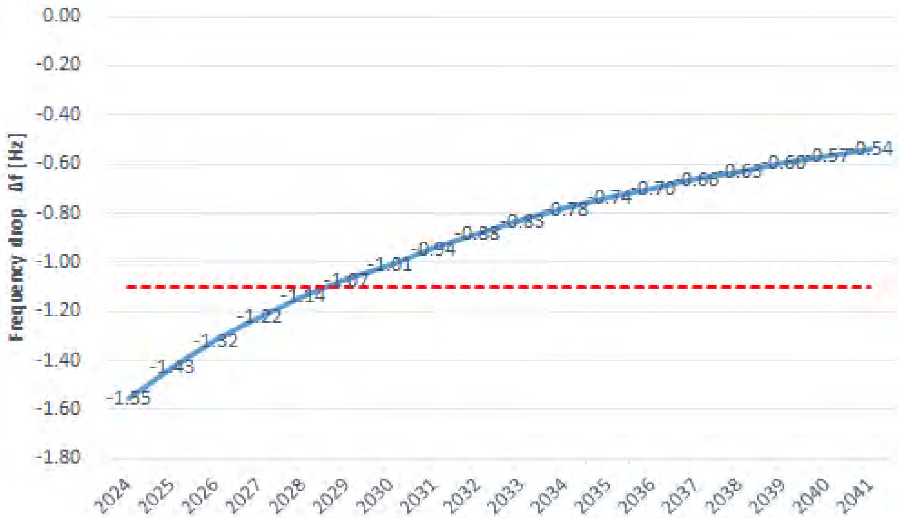
Overshoot of frequency immediately after the generation trip can be regulated only by FGMO and the inherent characteristics of the flywheel effect in load. Therefore, urgent preparation for FGMO is required in Bangladesh. The large capacity generator (power source) trip events which should be taken into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

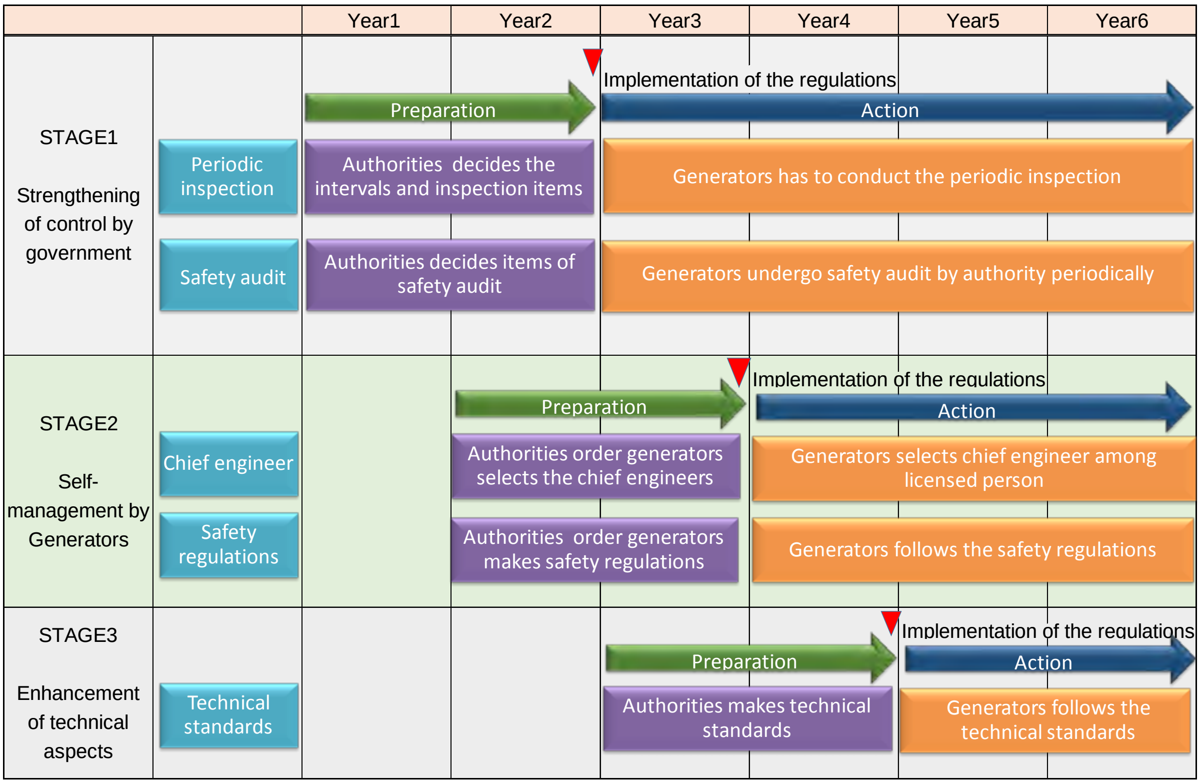


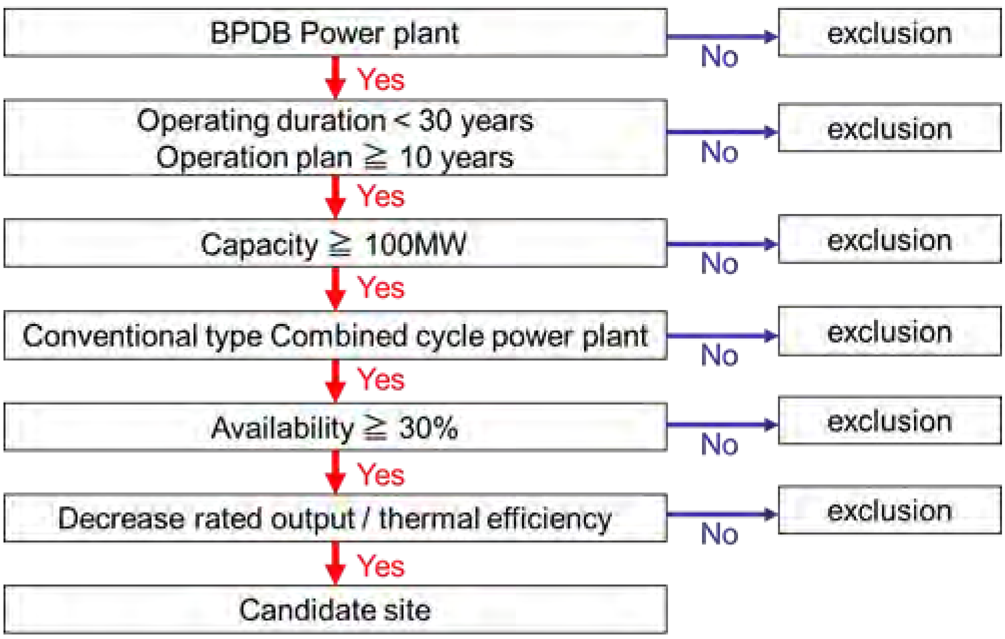
Figure 1-57 Schedule for Legal Reform

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.

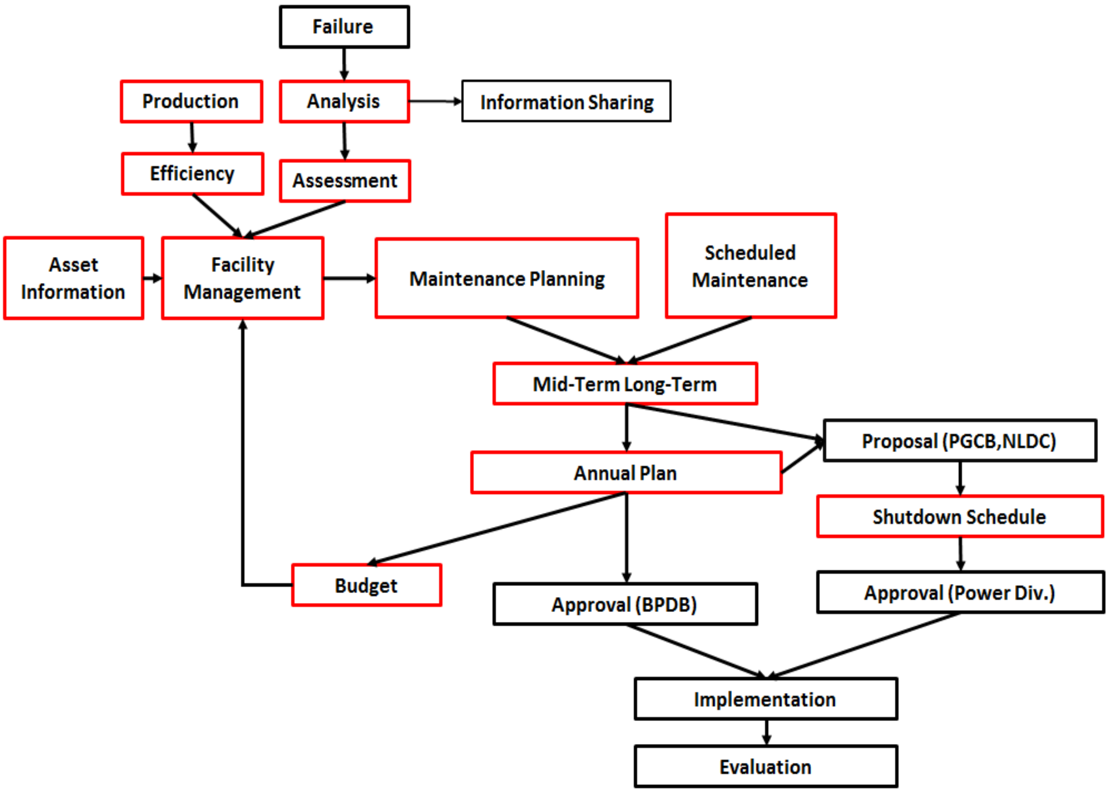
The implementation items of the proposed solutions are shown in the table below.

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

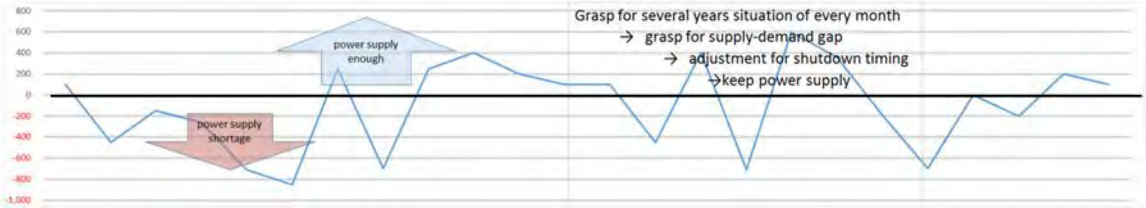
If BPDB has managed to establish a system for the centralized management of the data on the operation and the plans and records of repair of all the plants under its control, as a financial measure, it will be able to estimate the budget for the entire organization and to plan for the suspension of the 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			Maximising RE generation potential under limited land
			Transparent and competitive bidding process			
			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		1&2 Units	3&4 Units, 5&6 Units
			Operation of nuclear power plants			
	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

Part II　POLICY

Chapter 2 Energy and Power Sector Overview

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

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

2.1 Overall Entity

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

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

Source: www.emrd.gov.bd

2.1.2 Bangladesh Energy Regulatory Comission (BERC)

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

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

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

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

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

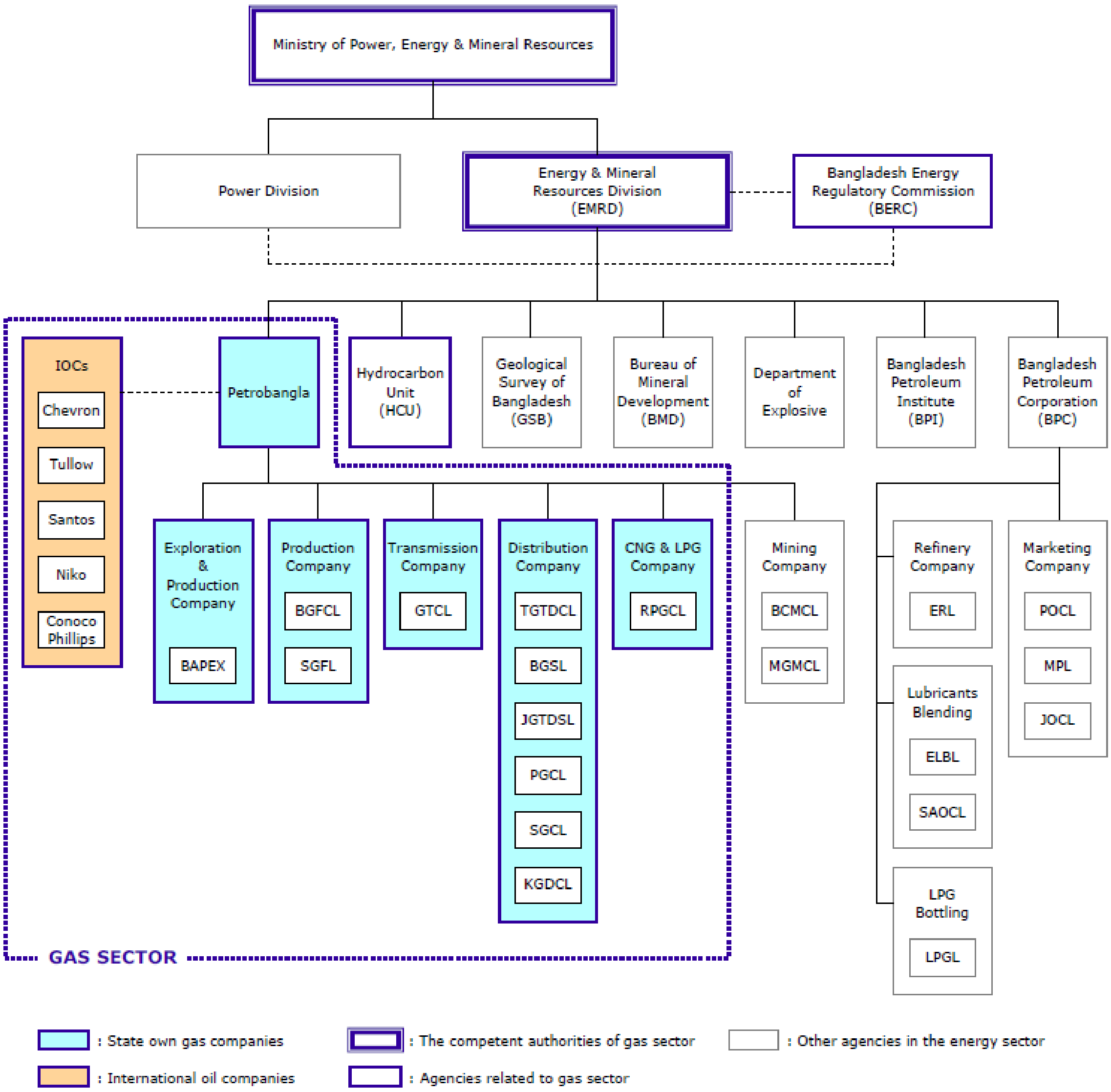
As of December 2015, BERC is drafting Feed-In-Tariff (FIT) to promote renewable energy. More details are discussed in Chapter 13 of this Report.

Furthermore, it should be noted that the Commission has responsibilities of two critical areas namely i) to set codes and standards for quality electricity supply, and ii) to facilitate energy efficiency, energy audit and setting standards for the power plants. These areas have been undermined in power sector operation; however, the strengthening BERC's capability and related regulations are indispensable for the further development of the Bangladesh's power sector hence the PSMP2016 has conducted the in-depth analysis and recommendations of these areas. The detailed are discussed in Chapter 16 and Chapter 17.

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

2.2 Energy Sector Overview

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



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

Figure 2-1 Bangladesh Energy Sector Overview

In addition to the above state-owned entities, International Oil Companies (IOCs) are important players in Bangladesh's gas sector, as they are responsible for more than half of the domestic production. Details are described in Chapter 7.

2.2.1 Energy and Mineral Resources Division (Energy Division)

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

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

2.2.2 Petrobangla

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

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

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

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

Coal operation company under Petrobangla, BCMCL, on the other hand, has own discretion to the negotiation with the foreign operator, although the coal sales pricing requires the government approval. BCMLC produces 3 billion Taka profit each year, and has ample investment capital for investment for machine and equipment[1].

2.2.3 Bangladesh Petroleum Corporation (BPC)

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

BPC used to retail oil products under market (=import) price, and the gap was approximately 10 Taka

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

per litter. As a result, BPC's sales deficit accumulated to 10 billion Taka in FY2010, and reached 86 billion Taka in FY2012, which was equivalent to 0.9% of GDP. BPC received "subsidy" from the government to meet such deficit. In recent years, IMF set the conditions for its structural reform loan, i.e. Extended Credit Facility (ECF); the reduction of BPC's accumulated deficit and the government subsidy. More recently, the decline of oil price from 2014 benefited the BPC's deficit reduction. BPC's domestic retail price becomes in fact higher than the import price, and BPC delivered the profit to the national coffer (more details about the subsidy to BPC are described in Chapter 19).

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

2.2.4 Other State-owned Entities

(1) Hydro Carbon Unit (HCU): HCU was established in 1999, with support from Norway government. HCU's main responsibility is gas field appraisal. ADB also supported the establishment of HCU with a part of its loan in 1993[2]. In 2010 HCU employed a US consulting firm and conducted a reserve evaluation. As mentioned in the previous chapter "PSMP2010 Review", however, the current Petrobangla production scenario does not employ the HCU analysis.

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

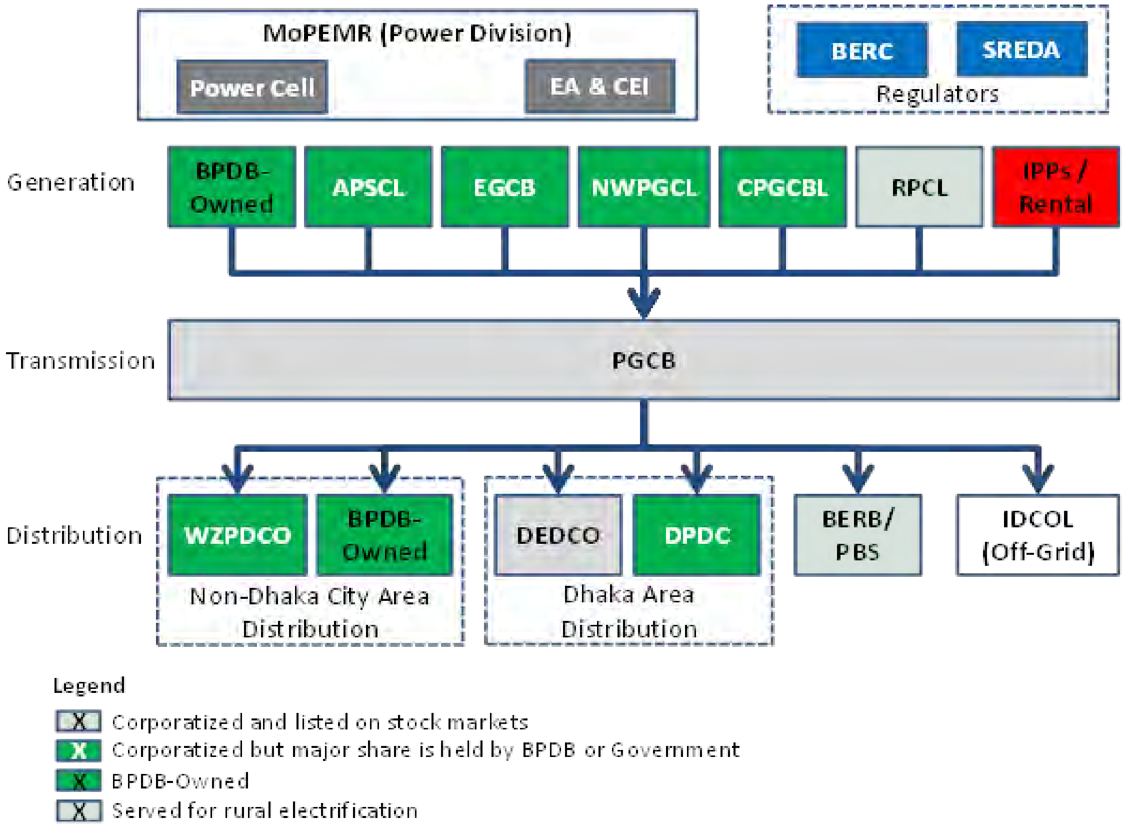
(3) Bureau of Mineral Development (BMD)：Responsible for managing mining concessions.

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

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

2.3 Power Sector Overview

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



Source: JICA Survey Team

Figure 2-2 Overview of Bangladesh Power Sector

2.3.1 Power Division

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

Power Division has below sub-division organizations:

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

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

2.3.2 Sustainable and Renewable Energy Development Authority

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

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

2.3.3 Bangladesh Power Development Board (BPDB)

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

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

in general suffer poor maintenance and low efficiency, which results in the BPDB-own power plants contribute less than 30% of electricity generation). BPDB Board consists of chairperson and other 6 members.

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

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

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

2.3.4 Power Generation Entities[4]

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

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

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

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

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

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

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

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

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

2.3.5 Power Grid Company of Bangladesh (PGCB):

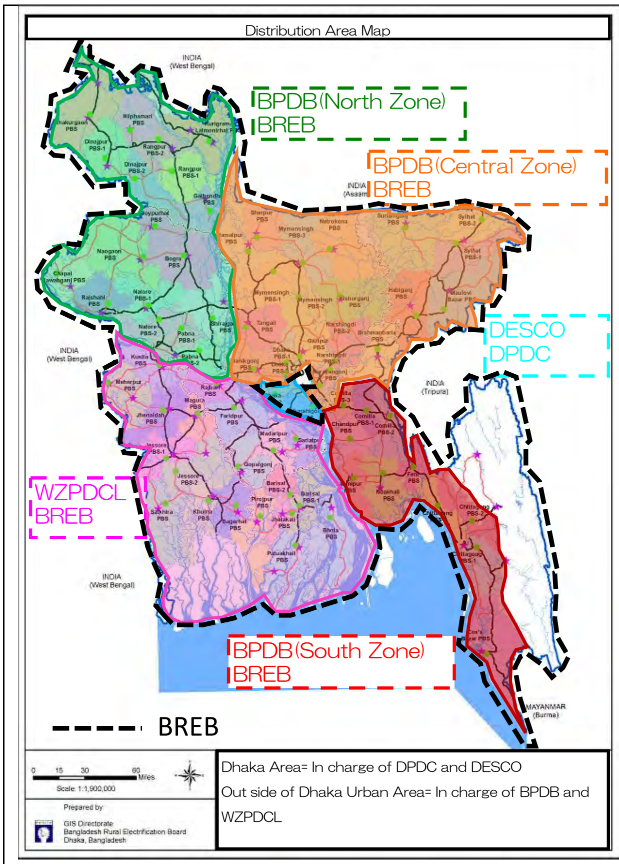
PGCB was established in 1995, as a result of unbundle of power sector, and the sole transmission company in Bangladesh. It has National Load Dispatch Center (NLDC) of its sub-division. As discussed in later Chapter 15, the independence of NLDC from PGCB will be an important institutional issue of network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

2.3.6 Distribution Entities and Rural Electrification

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

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

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



Source: JICA Survey Team

Figure 2-3 Distribution Companies and Areas

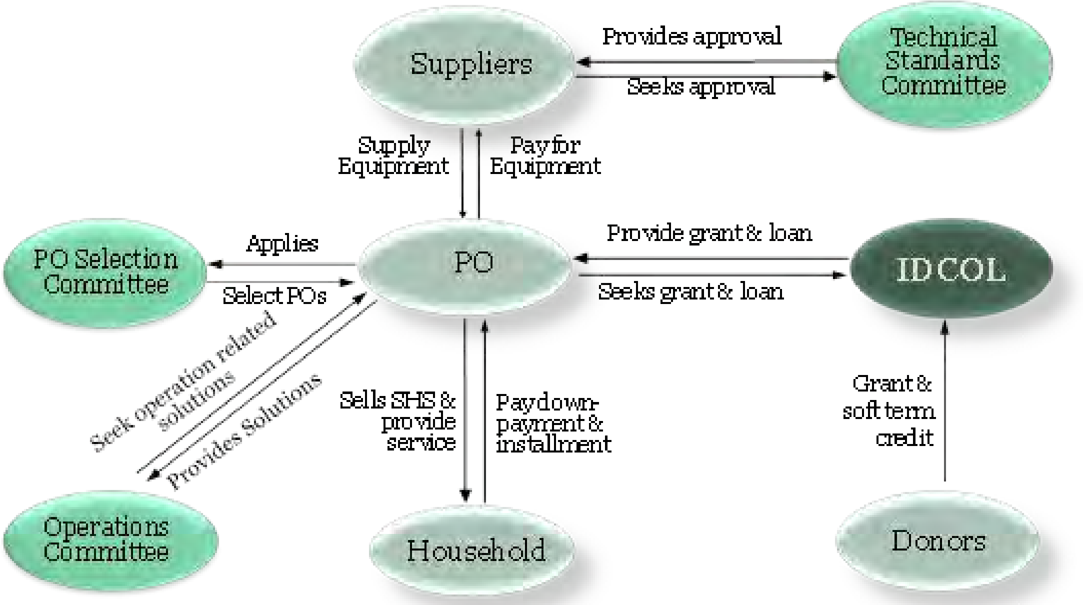
Source: BREB

Figure 2-4 PBS

2.3.7 Infrastructure Development Company Limited (IDCOL)

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

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



Source: IDCOL

Figure 2-5 Process Flow for Renewable Energy Project

Chapter 3 Energy and Power Policies

3.1 World Trend of Energy Policy ~ SDGs and COP21

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

3.1.1 Sustainable Development Goal[1]

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

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

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

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

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

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

The sustainable development can be defined as an approach of the development, in which the current generation's demand is met but the life support system of the globe, on which the current and future generation of mankind depends for the prosperity, is still protected[2]. This implies that the energy and power system development, which is indispensable for the modern socio-economic activities but having huge negative impacts on the global warming, cannot be separated from the international goals, and Bangladesh also should not be exempted.

3.1.2 Paris Agreement

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

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

3.2 Road to the Vision 2041

During 2008-2011, Bangladesh sustained real GDP growth at 6.2% on average mainly led by the growth of exporting sectors, predominantly garment sector (80% of export, employing 4 million people), although it is provisioned to slow down in FY2012 to 6.3%[3]. In order to realize its vision to become a middle income country by 2021 and developed country by 2041, however, Bangladesh needs to keep its economic growth pace at 7%, especially by diversifying and sophistication of industry sectors, and creating high income jobs in the formal sectors. Although economic growth itself is not the only necessary and sufficient condition for Bangladesh to achieve its vision, it is well recognized that removing infrastructure-related bottlenecks and improving doing-business environments are the critical pre-conditions for further growth of Bangladesh. Especially sufficient, stable and affordable electricity supply is the key for Bangladesh to unleash its growth potential.

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

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

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

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

Source: World Bank WDI Database

3.3 7th Five Year Plan (2016~2020)

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

- Installed Generation Capacity of electricity to be increased to 23,000 MW by 2020
- Ensure energy mix for energy security

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

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

Source: 7th Five Year Plan and JICA Survey Team

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

3.4 Energy Sector Policy

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

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

NEP2005 also prioritizes the following subjects:

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

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

3.5 Power Sector Policy

The Power Division of MoPEMR has a clear vision and mission statement that the universal access to quality electricity in a cost-effective and affordable manner, and ensuring reliable electricity for all by 2021 through integrated development of power generation, transmission and distribution system[4]. In order to seek a practical and short-term solution toward this vision, Power Division enacted "Power and Energy Fast Supply Enhancement (Special Provision) Act 2010", to expedite the introduction of highly expensive quick rental power plants[5].

Power Division also called for JICA for a holistic master plan development; that was the PSMP2010. However, as described in the Chapter 1, the coverage of PSMP2010 did not fully address the Bangladesh power sector development. In the PSMP2010, the planning policy was described as 3E; economy, energy security, and environment. However, two assumptions supporting the then 3E (availability of domestic coal and domestic natural gas) have been drastically changed in the last few years. In other words, the progress of these domestic resources development is much less than what had been assumed. Moreover, Bangladesh-unique issues such as the world-fastest deployment of off-grid renewable energy, hydro-origin power interconnector (power import from hydro-rich neighbors), and nuclear power development were not fully discussed in the previous PMSP2010. In Bangladesh context, these power generations should be treated as vital complements to the conventional thermal power plants. Therefore, in PMSP2016, these issues are well studied in this Survey.

Lastly, the quality of power supply, and the thermal power plant operation and maintenance (O&M) have never been addressed in the past Bangladesh power policy. However, these issues are quite critical for Bangladesh to achieve the Vision 2041. Especially for the better quality of industrial products hence for the further economic development industrial and sophistication, stable frequency is critical. For stable power supply at reasonable cost, fuel cost reduction by plant efficiency improvement through periodical maintenance is indispensable, especially when the most of the power plant fuel will be imported and the fuel cost is expected to substantially increase. These two issues are discussed in detail in Chapter 16 and Chapter 18 respectively.

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

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

Bangladesh is in fact the world-renowned photovoltaics (PV) system, and as of April 2016, 4 million sets of solar home systems (SHS) t have been installed. The initiative has been implemented by a government-owned financial institution IDCOL (Infrastructure Development Company Limited) and its active implementation partners (such as local NGOs[6]) and supported by concessional funds from development partners. Now Bangladesh is aiming to distribute another 2 million by 2017 to reach the poorest households. By then, the total installed capacity of SHS will be 220MW[7]. Also a small number of biogas-based power generations, a wind power plant in total contribute some 20 MW.

However, the number is still unsatisfactory to the Government target: the renewable energy 5 % of all generation, which means roughly 500MW equivalent. Even with the 230MW Kaptai hydro-power is counted, the total renewable-base generation in Bangladesh is merely 404MW.

In December 2012, the Sustainable Renewable Energy Development Authority (SREDA) Act was

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[4] http://powerdivision.portal.gov.bd/site/page/e224f7e6-6d8d-403e-b64b-5d7c958140b9/Vision-&-Mission

[5] Quick rental is mainly an oil-based, small capacity, privately owned short-term power generator. Because the construction period is short, and can be quickly developed, these power plants are called "quick rental".

[6] In the IDCOL initiative, such NOGs are called "Partner Organizations" (in abbreviation POs).

[7] http://idcol.org/home/solar

approved by the Parliament and SREDA was established. The purpose of this authority is to ensure the energy security, by promoting renewable energy and energy efficiency and conservation. The Act defines the roles of SREDA, and the capability of accepting loans (from GoB and international sources), as well as developing systems such as Energy Audit, Energy Auditor and Energy Manager.

In 2013, GoB announced "500MW Solar Program" to accelerate the renewable/PV solution deployment[8]
It is the high time for Bangladesh to deal the conventional on-grid and off-grid (such as PV) in one development plan, with an integrated manner.

3.7 Energy Efficiency and Conservation Policy

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

3.8 Role of PSMP2016 as Complemental Energy and Power Policies

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

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

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

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

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

Source: JICA Survey Team

Chapter 4 Environmental Policy

4.1 Current Position of Bangladeshi Government Concerning Greenhouse Gas Emission

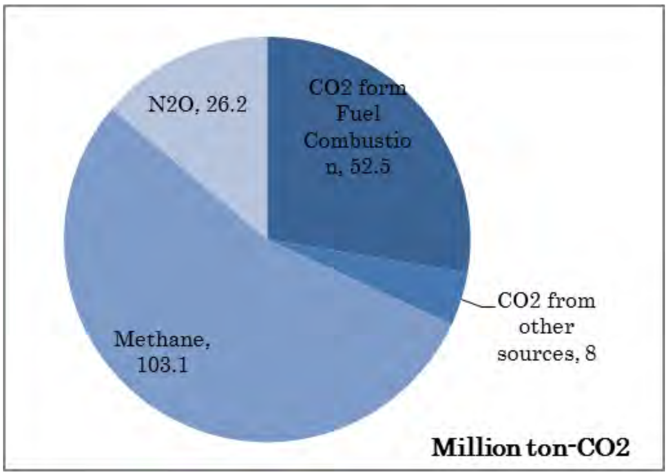
4.1.1 Status of GHG emission in Bangladesh

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

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

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

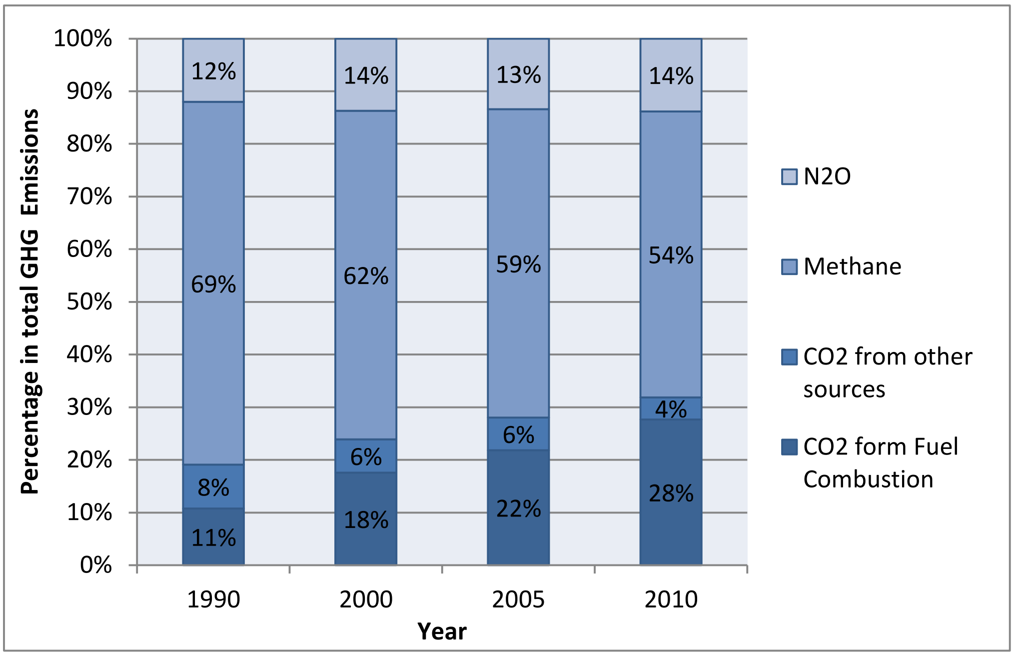
Source: IEA "CO2 Emissions from Fuel Combustion"



Source: IEA "CO2 Emissions from Fuel Combustion 2015"

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

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



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

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

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

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

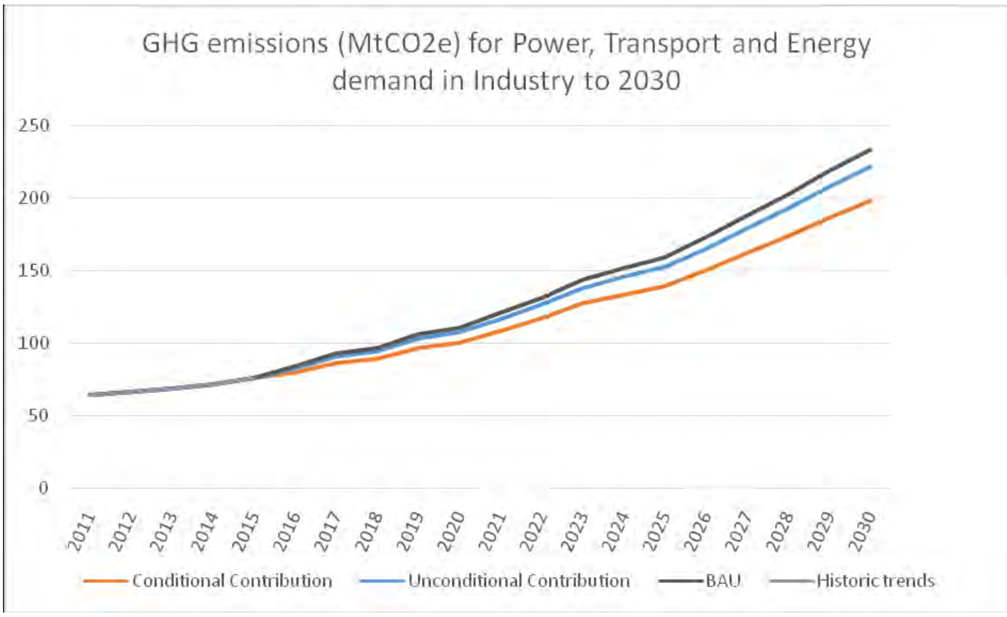
Table 4-2 Outline of INDC by GoB and Assumed Actions Related to Power Sectors

Mitigation contribution ■Unconditional contribution (Contribution assuming no additional international support) ・ Reduce GHG emissions in the power, transport, and industry sectors by 12 MtCO2e by 2030 or 5% below BAU emissions for those sectors ■Conditional contribution (Contribution assuming additional international support) ・ Reduce its GHG emissions in the power, transport, and industry sectors by 36 MtCO2e by 2030or 15% below BAU emissions for those sectors Measures assumed in Unconditional contribution ■Power ・ A target to deliver 5% of energy from renewable sources by 2015, and 10% by 2020 (2008Renewable Energy Policy) ・ Construction of Combined Cycle Power Plant (CCPP) by the Government of Bangladesh and utilities companies Measures assumed in Conditional contribution (with international support)

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

Source: JICA Survey Team

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



Source: JICA Survey Team

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

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

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

Source: JICA Survey Team

4.2 Recent Trend and Future Prospects of UNFCCC and IPCC

4.2.1 IPCC Fifth Assessment Report (AR5)

The Fifth Assessment Report (AR5) is the latest compilation of wide area of scientific views on climate change by the Intergovernmental Panel on Climate Change (IPCC). This report contains the mitigation scenarios of GHG emissions and the pathways developed in the latest scientific articles in its Chapter 6 of WG3 report.

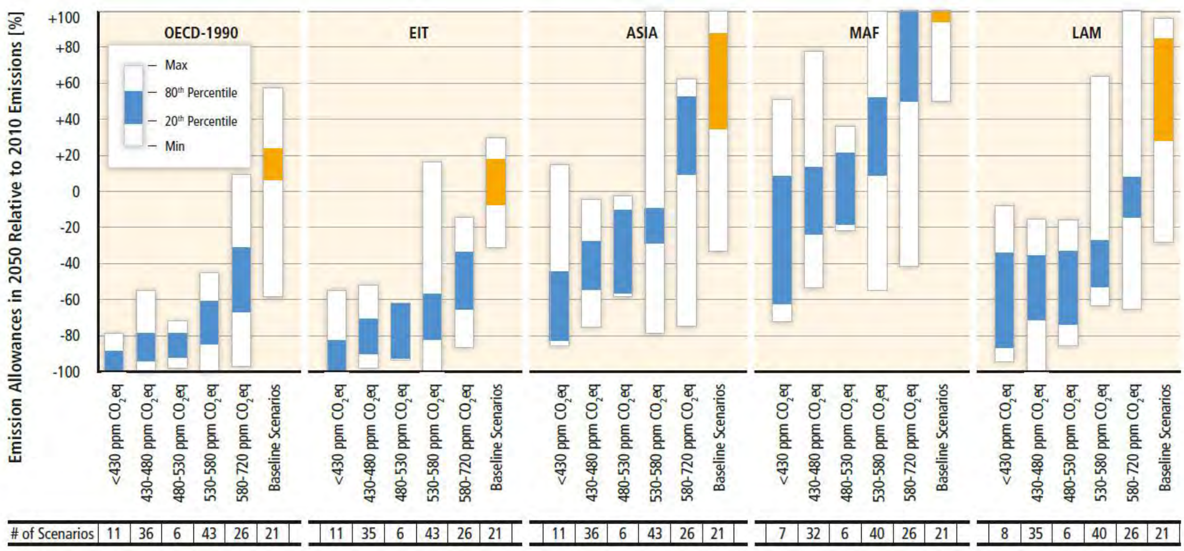
These scenarios are classified into seven categories of CO2-equivalent concentration levels, as shown in Table 4-4. Paris agreement refers to the GHG reduction goal with 2 degrees stabilization and balance between anthropogenic emissions and absorptions of GHG in 2100, which is approximately consistent with the scenarios classified into 430-480ppm category.

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

CO_2-equivalent concentration in 2100 (ppm CO_2eq) (based on full radiative forcing)[1]		Secondary categorization criteria[2]		Corresponding RCP[3]	No of scenarios extending through 2100	
CO_2eq concentration (ppm)	Radiative forcing (W/m²)	Kyoto gas only CO_2eq concentration in 2100 (ppm)	Cumulative total CO_2 emissions 2011–2100 ($GtCO_2$)		Total[4]	With Overshoot Greater than 0.4 W/m²
430–480	2.3–2.9	450–500	< 950	RCP 2.6	114 (114)	72 (72)
480–530	2.9–3.45	500–550	950–1500		251 (257)	77 (77)
530–580	3.45–3.9	550–600	1500–1950		198 (222)	22 (22)
580–650	3.9–4.5	600–670	1950–2600	RCP 4.5	102 (109)	8 (8)
650–720	4.5–5.1	670–750	2600–3250		27 (27)	0 (0)
720–1000	5.1–6.8	750–1030	3250–5250	RCP .6	111 (120)	0 (0)
> 1000	> 6.8	> 1030	> 5250	RCP 8.5	160 (166)	0 (0)

Source: IPCC AR5, WG3 report Chapter6

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



Source: IPCC AR5, WG3 report Chapter6

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

4.2.2 Outcomes of COP21

(1) Outline of the Paris Agreement

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

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

Article 2

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:
   (a)**Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels,** recognizing that this would significantly reduce the risks and impacts of climate change;

Article 4

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

(2) Global stocktake

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

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

Article 4

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

Article 14

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

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

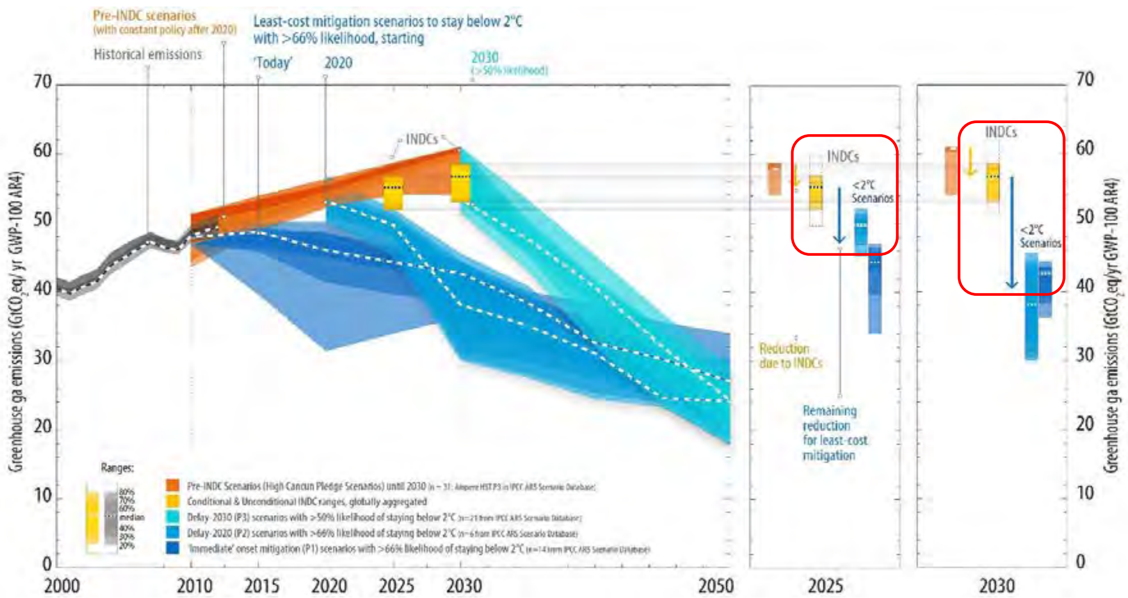
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2028	2030	2033
UNFCCC	Adoption of Paris agreement	open for signature				enter into force?			global stocktake			global stocktake		global stocktake
Individual countries	First INDC	signature and ratification				INDC update					INDC update		INDC update	

Source: JICA Survey Team

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

(3) Remaining GHG reduction for the long term target

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



Source: UNFCCC

Figure 4-6 Difference between 2 Degree Scenario and INDCs

4.2.3 Overview of INDCs submitted by other Asian Countries

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

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

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

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

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

Country&date	Emission reduction goal	Policies described	Technology context
	approximately 260,000 cook stoves between 2016 and 2031 ■Climate Change & Environment Achieve climate resilient, low-carbon, resource efficient and inclusive development, mainstream environment and climate change into the national policy development, strengthen the climate change related institutional and policy environment, promote, increase awareness of climate change, promote an economy based on green growth. monitor and take stock of the status of national environmental quality ■Forest Management Decrease the rate of deforestation, Preserve natural forest cover, Decrease the risk of floods and landslides, Increase the resilience of mangroves and coastal communities, Increase capacity Sustainable Forest management, Rural electrification through the use of at least 30% renewable sources. ■Energy Achieve the optimal level of renewable sources, increase the understanding of the potential of renewable power, realize a 20% electricity saving potential by 2030, ■Other Key Sectors Reduce the increasing rate of GHG emissions, ensure that increasing urbanization takes place in a sustainable manner, mitigate emissions, generate power and reduce pollution from non-recyclable waste, mitigate GHG emissions from the agriculture sector	National Forestry Master Plan(2001), National Biodiversity Strategy and Action-Plan(2011), forest plantations, agroforestry practice, community forestry, coastal zone management plan, ■Energy National Energy Policy (2014), Long Term Energy Master Plan(2016), National Energy Efficiency and Conservation Policy, Strategy and Roadmap for Myanmar(2015), National Electricity Master Plan, Myanmar National Rural Development and Poverty Alleviation Programme(includes a Rural Electrification Plan(2017)) ■Other Key Sectors National Transport Master Plan and National Implementation Plan on Environmental Improvement in the Transport Sector, National Urban and Regional Development Planning Law, a National Housing Policy, National Urban Policy, National Waste Management Strategy and Action Plans(2017).	
Philippines 1 Oct. 2015	Undertake GHG (CO2e) emissions reduction of about 70% by 2030 relative to its BAU scenario of 2000-2030.	INDC is consistent with the -Philippine Development plan, -the National Framework Strategy on Climate Change,	Technology transfers and innovations are needed to support adaptation and minimization of loss-and-damages as well as enhanced capacity for

Country&date	Emission reduction goal	Policies described	Technology context
	Conditioned on the extent of financial resources, including technology development & transfer, and capacity building, that will be made available. Assumptions Used For the Baseline scenario · historical GDP from 2010 – 2014 and an annual average of 6.5% for 2015 – 2030 · Average annual population growth of 1.85% · Loss-and-Damages from climate change and extreme events will not require substantial diversion of resources for rehabilitation and reconstruction thereby affecting development targets as well as mitigation commitments under this INDC. · Identified co-benefits for mitigation options such as environmental and socio-economic benefits are realized. · Climate projections were considered in the assessment of mitigation options	-the National Climate Change Action Plan -the National Disaster Risk Reduction and Management Plan. These plans and the INDC were developed through exhaustive, inclusive and participatory processes. The Philippines is already undertaking initiatives to mainstream and institutionalize climate change adaptation and mitigation into the plans and programs of the government as reflected in government expenditures. The Philippine government has installed a system for tagging its expenditure for climate change adaptation and mitigation and is envisioned to use this system for its annual budgeting process starting 2015.	mitigation. Technical inputs and assistance are critical for certain sectors such as -grid efficiency improvement, -standard development for energy and water efficiency, -cost-effective renewable energy, -alternative or high-efficiency technology for conventional power generation, among others.
Thailand 1 Oct. 2015	■Unconditional reduction reduce greenhouse gas emissions by 20 percent from the projected business-as-usual (BAU) level by 2030. (BAU2030: approx. 555 $MtCO_2e$) ■Conditional reduction increase up to 25 percent	- National Economic and Social Development Plans - Climate Change Master Plan B.E. 2558-2593 (2015-2050) - Power Development Plan B.E. 2558-2579 (2015-2036) - Thailand Smart Grid Development Master Plan B.E. 2558-2579 (2015-2036) - Energy Efficiency Plan B.E. 2558-2579 (2015-2036) - Alternative Energy Development Plan B.E. 2558-2579 (2015-2036) - Environmentally Sustainable Transport System Plan B.E.2556-2573 (2013-2030) - National Industrial Development Master Plan B.E. 2555-2574(2012-2031) - Waste Management Roadmap	Thailand's TNA report formulated in 2012 has identified three highly impacted sectors in urgent need of adaptation technologies. These are: (1) Agriculture in need of forecasting and early warning system technologies, crop improvement technologies, and precision farming technologies (2) Water Resource Management in need of networking (via pipes and canals) and management of infrastructures (including zoning), seasonal climate prediction, and sensor web using observation and/or modeling data (3) Modeling in need of an integrated national data center, national data transfer/management process and the advanced research, weather research and

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

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

Source: JICA Survey Team

4.2.4 Other environmental considerations

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

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

4.3 Implications for the PSMP

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

PART III   PRIMARY ENERGY BALANCE

Chapter 5 Prospects of Economic Development

5.1 History of Bangladesh Economy

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

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

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

Source: Bangladesh Bureau of Statistics (BBS) and Sixth Plan;
*Balance of last day of corresponding terminal year
**For the terminal year of Plan period
***Corresponding HES, HIES year's figure

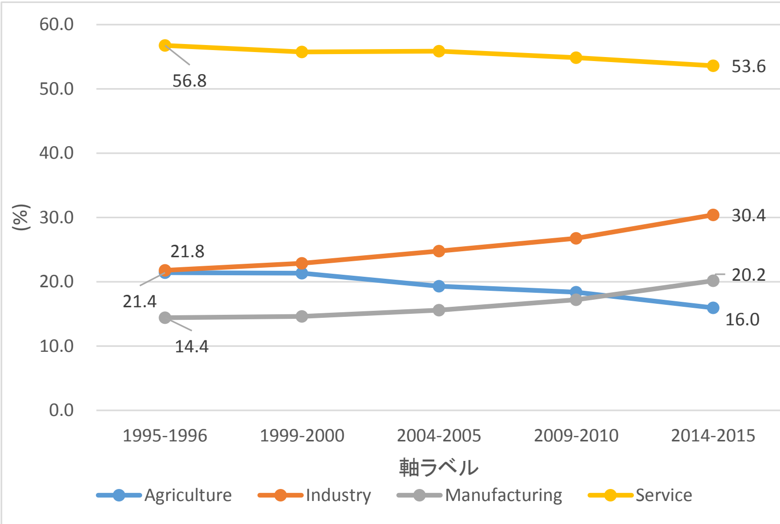
Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

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

Table 5-2 Sectorial Share of GDP Since 1995

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

Source: Prepared by the JICA Survey Team using the statistical data of Bangladesh National Account Stati stics (BBS)



Source: Prepared by the JICA Survey Team using the statistical data of Bangladesh National Account Statistics (BBS)

Figure 5-1 Sectorial Share of GDP Since 1995

With the rapid growth of national economy, the structure changes of national economy, i.e. industrialization, has started. Until early-1980s, jute and jute goods have been the main industries in and the major products for export. These industries, however, has lost competitiveness in the market with the diffusion of synthetic fiber.

Since mid-1980s, ready-made garment (RMG) has emerged as the major industry, and the export of RMG exceeded that of existing exporting industries by around 1990. The export of RMG continued increasing, and now it accounts for over 80% of the country's earnings from export.

Diversification of exporting goods, i.e. promoting other exporting industries besides RMG is becoming a new big challenge for Bangladesh. There is a potential of developing new industries that utilize domestically available resources and labor forces of the country as well as industries that already exist in Bangladesh and have a potential for further advancement. These prominent industries are footwear and leather products, light engineering products, pharmaceuticals and ceramics etc. Promoting these industries is expected to help Bangladesh economy to grow continuously beyond 2020.

5.2 Scenario Analysis of Economic Development

Bangladesh economy has taken on a track of rapid growth, and structural changes are expected to occur in the upcoming years. It needs to be noted that simply extending the past trend of a country's economic development linearly to the future may not be cogent enough for formulating long-term prospects of Bangladesh economy.

It is widely observed that a country's economic development can be triggered by a non-continuous structural change of the industries and hence the study will look at the possibility of non-continuous

changes of economic fundamentals of Bangladesh by formulating future scenarios considering the "likely to occur" structural changes of its economy.
The basic model as the preconditions of the analysis in this study can be described as follows.

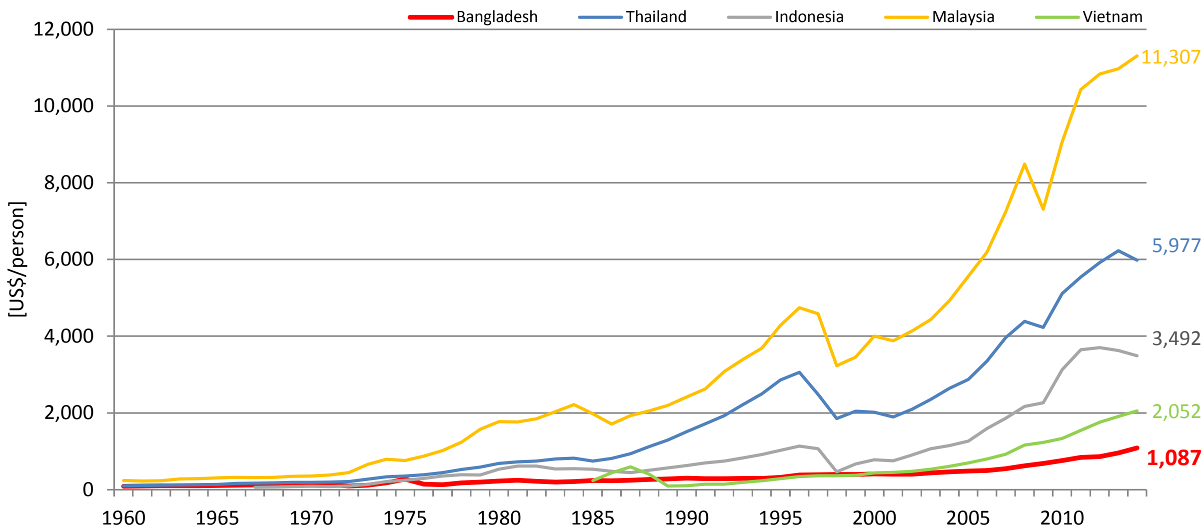
Technology spillover→Structural changes of industry→Economic development→Energy consumption

As well known, many countries in Southeast Asia, although the situation differs significantly among them, have achieved economic developing remarkably for the last decades. Therefore, studying on the history of industrial and economic development of those countries as the role model can be a useful reference in considering the future scenario of Bangladeshi economy.

5.3 Historical Trend of Economic Indices and Energy Demand in Southeast Asian Countries

5.3.1 Historical trend of economic indices in Southeast Asian countries

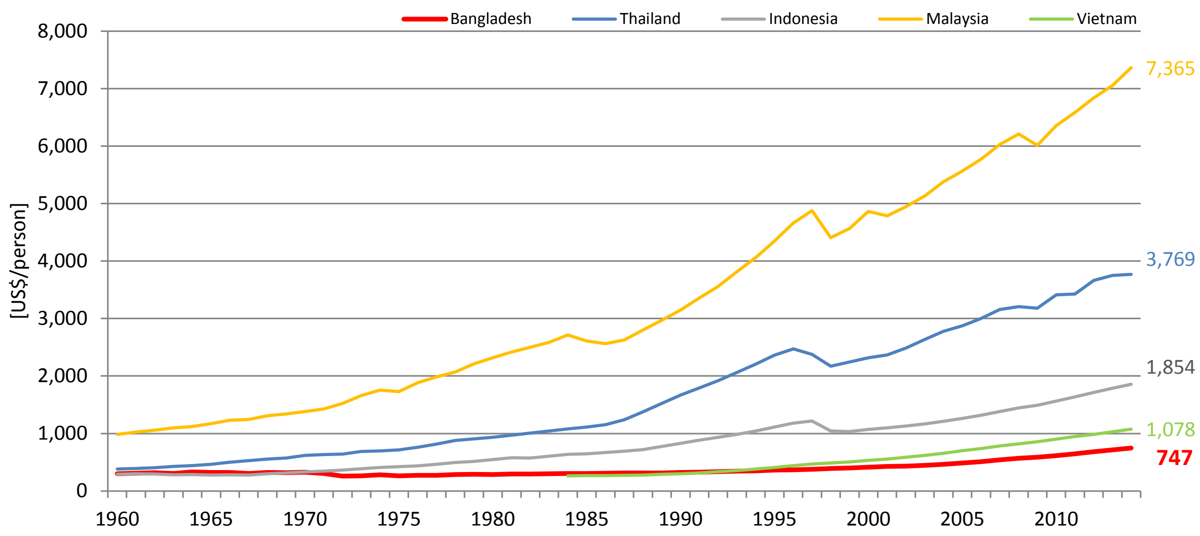
Historical trend of GDP per capita of Bangladesh in comparison with Malaysia, Thailand, Indonesia and Vietnam is shown in Figure 5-2. Malaysia, which has achieved advanced economic development among ASEAN countries along with Brunei and Singapore, has yielded higher number than the other three ASEAN countries in the figure. Thailand, Indonesia and Vietnam are positioned as second-tier countries to follow them and the experiences of these countries are expected to provide implications for studying the direction of economic development of Bangladesh towards 2041.
The GDP per capita (at current USD) of Bangladesh as of 2014 is 1,087 USD, which is only one-fifth of Thailand, one-third of Indonesia and one-half of Vietnam. Vietnam achieved this level of 1,087 USD in GDP per capita in 2008, Indonesia did in 2004, and Thailand in 1988 that is 26 years before.



Source: World Bank database

Figure 5-2 Trend of GDP per Capita (current USD) in Southeast Asian Countries and Bangladesh

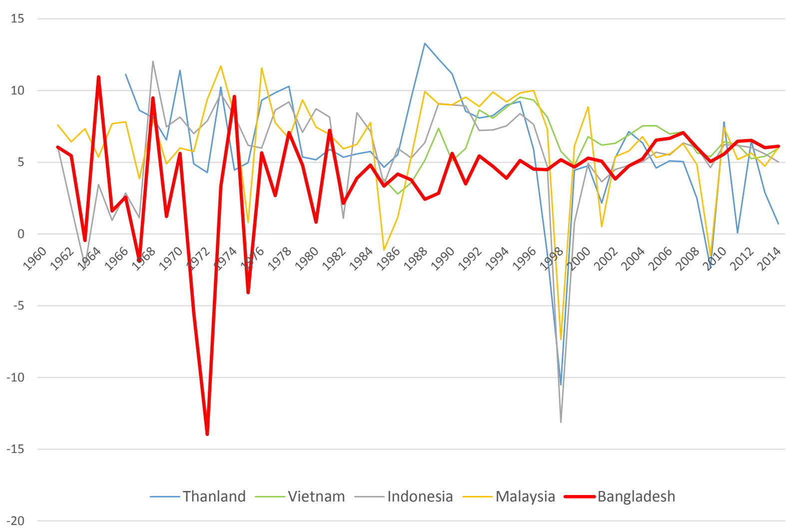
Figure 5-3 shows the same comparison in terms of GDP per capita at constant price of 2005 USD. In this figure GDP per capita of Bangladesh as of 2014 is 747 USD which is around one-fifth of Thailand like in Figure 5-2. In this case, Vietnam achieved this level of 747 USD in GDP per capita in 2008, Indonesia did in 1989 that is 25 years before, and Thailand in 1977 that is 37 years before.
Because this study aims to project the economic development of Bangladesh in 2041, which is after 26 years from now, the past experience of economic development of Thailand and Indonesia can be a good reference.



Source: World Bank database

Figure 5-3 Trend of GDP per Capita (constant 2005 USD) in Southeast Asian Countries and Bangladesh

Figure 5-4 shows the historical trend of GDP growth (constant 2005 USD basis) of the same five countries as in Figure 5-2 and Figure 5-3. Whereas Bangladesh has performed a stable growth, the other four countries occasionally experienced huge fluctuations of growth rate for the past thirty years. Considering that these fluctuations are largely the effect of external factors such as the incidents on global economy, these four countries also have achieved relatively constant economic development without these irregularities. If Bangladeshi economy continues to grow constantly for a long period with this relatively high growth rate, the country's industry is expected to reach a certain level of development towards 2041.

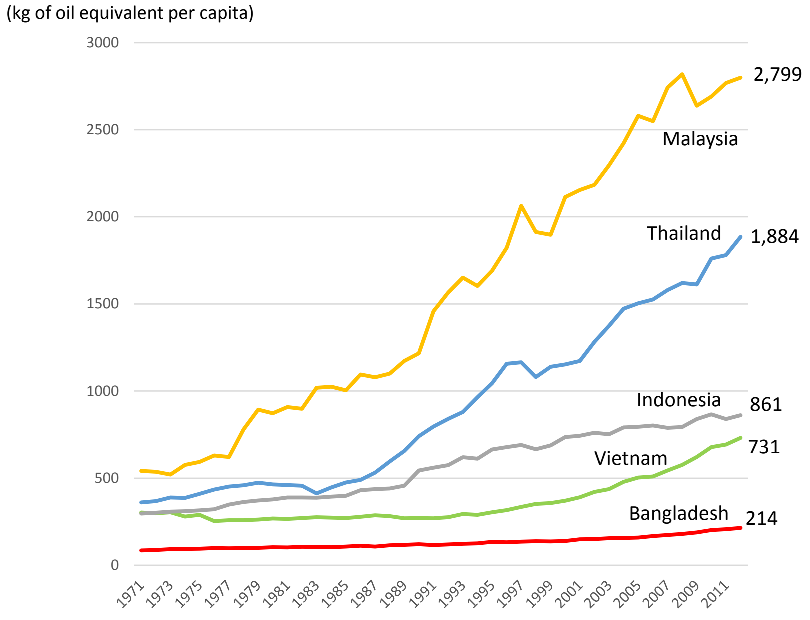


Source: World Bank database

Figure 5-4 Historical Trend of GDP Growth Rate in Southeast Asian Countries and Bangladesh

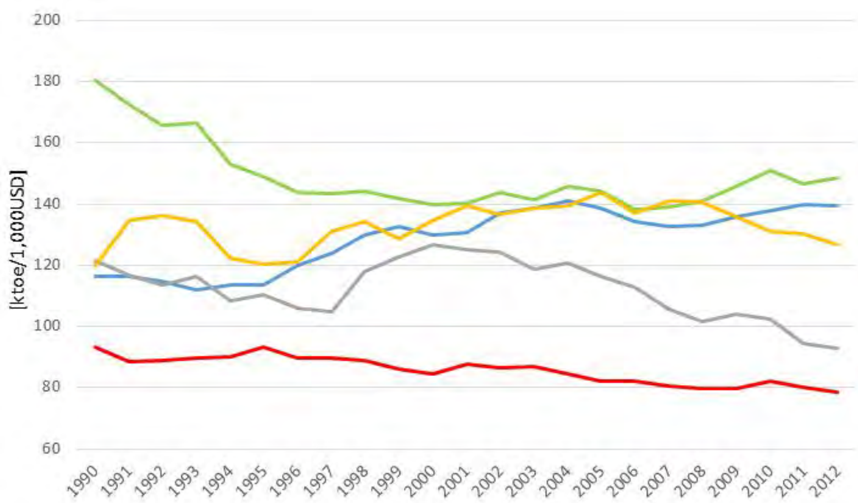
5.3.2 Historical trend of energy consumption

Figure 5-5 shows the historical trend of energy consumption per capita of the aforementioned five countries. The energy consumption per capita of Bangladesh as of 2012 is 214 kg of oil equivalent, which is one-ninth of Thailand, one-fourth of Indonesia and over one-third of Vietnam. That is, there is a wider gap among the performance of these countries than that for GDP per capita as seen in Figure 5-2. This means that Bangladesh has used less energy for producing the same economic value than the other four countries, and as shown in Figure 5-6, the energy intensity in Bangladesh has seen a declining trend. In other words, Bangladesh economy has been growing with relatively low energy input until now. It is highly possible, however, that energy consumption of Bangladesh will increase more rapidly than ever in the course of industrial structure modernization and the introduction of advanced industrial technologies that inevitably demand huge volume of energy consumption.



Source: IEA Statistics and World Bank database

Figure 5-5 Trend of Energy Use per Capita in Southeast Asian Countries



Source: World Bank database

Figure 5-6 Trend of GDP per Unit of Energy Use in Southeast Asian Countries

5.4 Study on the Economic Development Scenarios

5.4.1 Identification of the role model

(1) Thailand as the role model

Among the four ASEAN countries that are discussed in the previous sections, this study chooses Thailand as the role model for drawing future scenario of economic development of Bangladesh. The reasons for this are as follows.

- Thailand has achieved the industrialization and the modernization of the society with a relatively high growth rate of economic development for a long period;
- Thailand is now positioned as one of Upper Middle Income Countries (UMICs) by DAC (Development Assistance Committee), which can be an ambitious but realistic target for Bangladesh;
- As discussed in Figure 5-2 and Figure 5-3, Bangladesh is expected to reach the present economic level of Thailand by 2041 if the current economic growth rate continues;
- In the meantime, Thailand also has a plenty of agricultural resources and the agricultural products still accounts for around 10% of its merchandise exports even now, though it was also helped by the protective policy of agriculture;

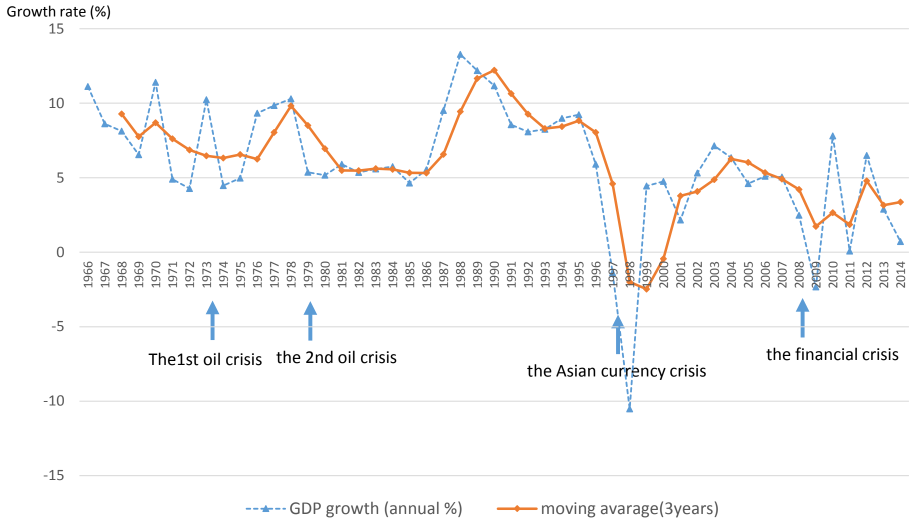
(2) Economic development of Thailand

1) Historical trend of GDP growth

Figure 5-7 shows the long term trend of annual GDP growth of Thailand at constant 2005 USD basis. In order to remove the noise of short term fluctuation, three-year moving average is also shown in addition to the annual growth rate.

Thai economy has kept a high growth rate of GDP for a long time though it was occasionally affected by the turbulence of global economy in the past, such as the Global Financial Crisis precipitated by the bankruptcy of Lehman Brothers in 2008, the Asian Financial Crisis in 1997 and the Oil Crises in 1973 and 1979. The economy especially kept a relatively high growth rate during the following periods.

- From 1976 to 1978: GDP growth rate around 10% p.a.;
- From 1988 to 1997: GDP growth rate around 10% p.a.;
- From 2001 to 2008: GDP growth rate around 5% p.a.;

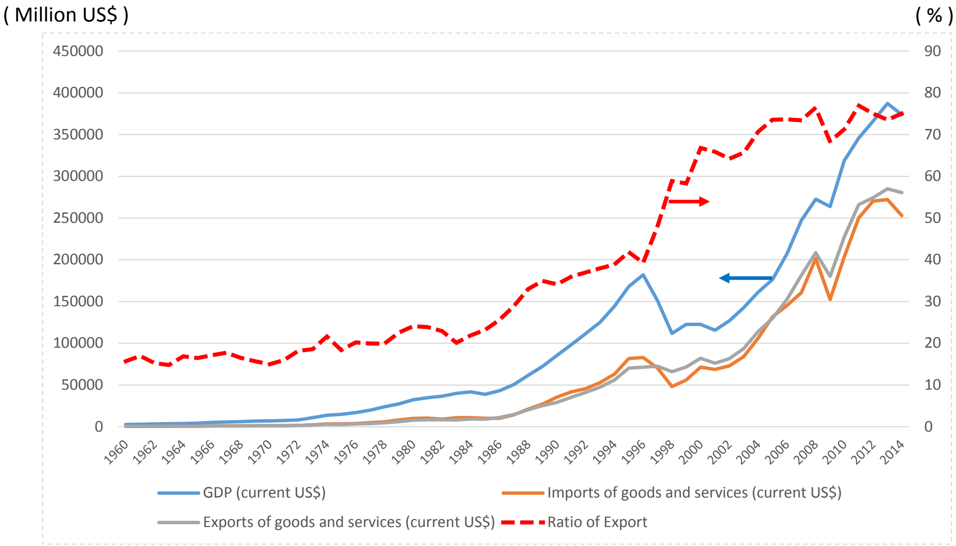


Source: World Bank database

Figure 5-7 Historical Trend of GDP Growth Rate of Thailand

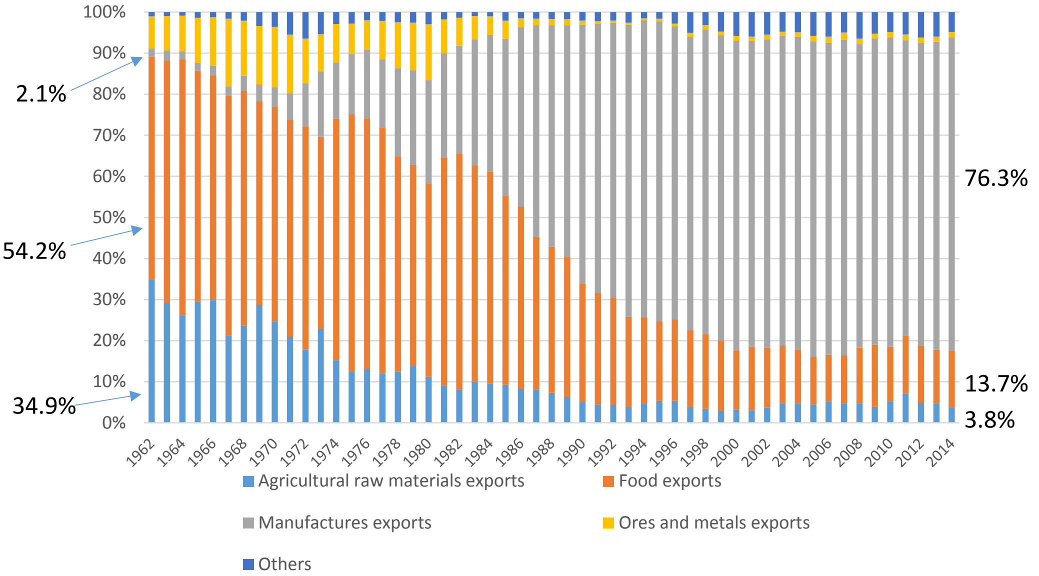
2) Historical trend of goods import and export

The solid lines in Figure 5-8 show the historical trend of goods import and export along with that of GDP. It is observed that both import and export took a similar trend of increase to that of GDP. There are two implications from this observation. One is that the economic growth of Thailand has been strongly driven by the growth of export. And another is that Thailand's economy has been supported by the processing trade so that the country imports raw material and exports a value-added product.
The red dotted line in the figure shows the ratio of export to GDP. Until mid-1980s this ratio was low around 20%, but afterwards, especially after 1996, it started increasing rapidly, and currently the ratio of export against GDP has reached around 75%. This clearly indicates that goods export has pushed up Thai economy.
Figure 5-9 shows each sector's share in the merchandise export every year. In 1962 the share of manufacturing was only 2.1%. Since then this ratio has been growing rapidly in line with the economy's dependence on export as aforementioned and recently it has become more than three quarters of merchandise export. Another thing to be noted in the figure is that the total share of agricultural product and foods in merchandise export, though it has been declining, still keeping nearly 20% for the past fifteen years. This means that Thailand's export is characterized not only by industrial products such as machines and machinery parts but also by agricultural products and value added foods.



Source: World Bank database

Figure 5-8 Historical Trend GDP, Import and Export of Thailand

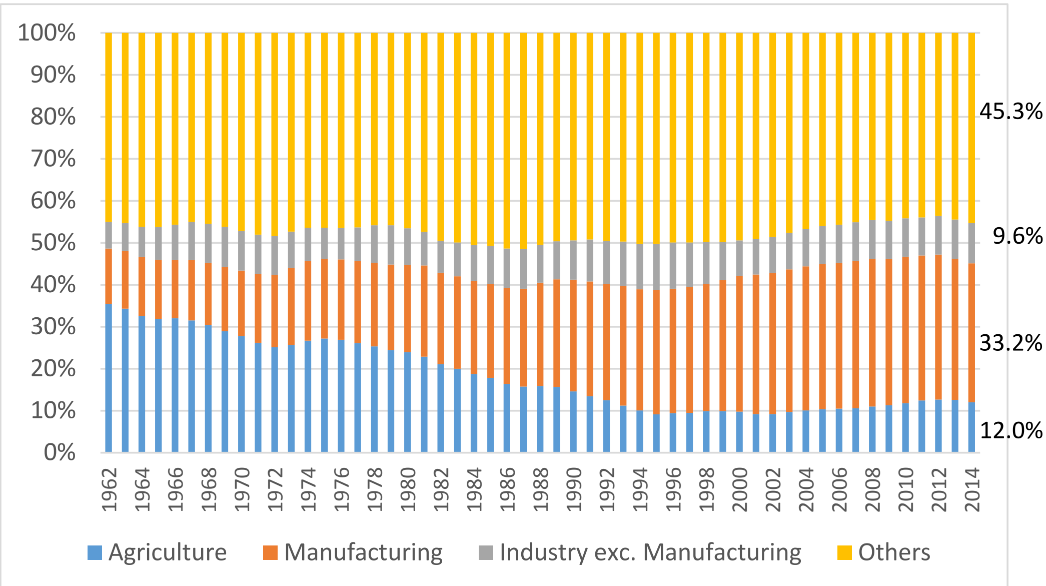


Source: World Bank database

Figure 5-9 Historical Trend of Sectorial Share in Merchandise Export

3) Historical trend of industrial structure

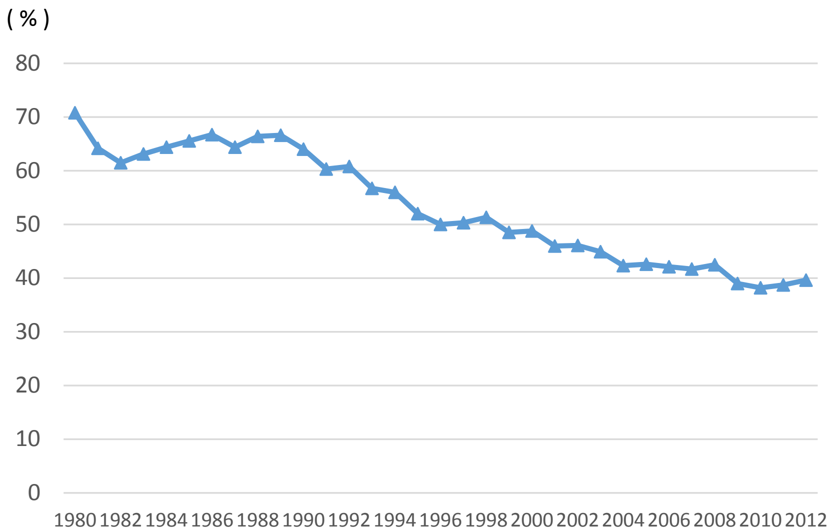
Figure 5-10 shows each sector's share in the GDP of Thailand. The long-term trend is that the share of agriculture has decreased while the share of manufacturing has been growing, but recently the share of agriculture stopped declining and has maintained about 10% share for the past fifteen years.



Source: World Bank database

Figure 5-10 Historical Trend of Sectorial Share in Merchandise Export in GDP

Figure 5-11 shows the ratio of employment in agricultural sector against total employment. Likewise the percentage sees a declining trend, but it still keeps relatively high level at 40%. Looking at the historical trend of industrial structure, along with that of import-export as aforementioned, it can be said that Thailand endeavors to maintain agriculture as one of main components of its economy even at present when the industrialization has reached certain level.



Source: World Bank database

Figure 5-11 Share of Agriculture in Total Employment

4) Industrial policy of Thailand

As seen in the previous section of this chapter, Thailand was traditionally an exporting country of agricultural products and the country has been taking policies to protect agriculture and to support the business of farmers. In these days when the competition of agricultural exports against Asian emerging countries such as China and Vietnam has become severer, Thailand has shifted its position to the exporter of more value-added products, such as fresh fruits, jasmine rice and processed foods so that the agriculture still remain and important part of Thai economy.

In the meantime, the role of manufacturing was minor until 1960s. In 1961, Thai Government launched the first National Economic and Social Development Plan for promoting investment and industrial development. Since then the government has been taking policies on industrial development continuously while changing its focal point in accordance with the economic development. Table 5-3 summarizes the outline of industrial policies stipulated in the National Economic and Social Development Plans from First to Eleventh.

Table 5-3 Outline of Industrial Development Policy Stipulated in National Economic and Social Development Plan (from 1st to 11th)

National Plan	Period	Key policies on industrial development
1st	1961-1966	● protection of domestic industry ● import substituting industrialization ● promote investment by private sector
2nd	1967-1971	
3rd	1972-1976	● promote exports ● export-driven industrialization ● selective foreign capital introduction policy
4th	1977-1981	● continue of promotion of export-driven industrialization ● development of petro-chemical industry
5th	1982-1986	
6th	1987-1991	● promote investment by private sector ● privatization of energy sector
7th	1992-1996	● promote high value added industry through technology transfer ● local dispersion of the industrial development ● improve of quality of life
8th	1997-2001	● people-centered development ● human resource development ● maintain international competitiveness ● promote small and medium enterprises (SMEs)

National Plan	Period	Key policies on industrial development
9th	2002-2006	● Sufficiency Economy philosophy ● sustainable development ● improve of quality of life
10th	2007-2011	● Human development ● community development and alleviation of poverty ● Reform the economic structure for balance and sustainability ● safeguard natural resources and the environment
11th	2012-2016	● empowerment of social capital ● strengthening of economic capital ● restoration of natural resource and environmental capital

Source: JICA Survey Team

The main point at the initial stage of industrialization was that the country adopted a policy to protect domestic industry to promote industrialization to substitute import. Afterwards, when the domestic industries had accumulated basic technologies and enough experiences, the government shifted to the policy for export-driven industrialization and for promoting export. In Thailand 1971 was the turning point. After turning to the policy for export-driven industrialization, the Thai government started adopting policies for promoting exports such lowering import tax on raw materials and machinery parts for manufacturing export products, incentives for promoting export with low-interest loan on exporters and establishment of export-promoting zone.

During the period of Thailand's import substituting policy in 1960s, Japanese manufacturing companies started to develop business in Thailand for domestic production in the fields of home appliances, motor cars etc. With the progress of technology transfer, the production increased gradually. According to an old Japanese study report, the share of local products in home appliance industry before 1990 was only 20-50%. In 1990s the share of local products increase as the manufacturing of cathode-ray tube (CRT) for color TV started in Thailand.

The Seventh National Economic and Social development Plan (1991-1996) chose six industries as prioritized one; food processing, textile, metal, electronics device, petrochemical and steel. Then the Eighth National Plan (1996-2001) nominated four industries as prioritize; car manufacturing, electric and electronics, machinery, and telecommunications.

5.4.2 Implications for the future scenarios of economic development in Bangladesh

Bangladesh has some advantages in its fundamentals for future economic development compared to other countries, such as:

- Bangladesh has a huge area of rich farmland that can yield a good plenty of agricultural products;
- Bangladesh has a huge population, which helps the country to provide a good amount of labor force with relatively low cost compared to neighboring countries;

In addition, Bangladesh has already started the process of industrialization and the economic development is already on a good track centering on the following industries:

- Bangladesh has already become a production base of production for garment industry globally:
- In the field of manufacturing home electric appliances such as lumps, fans, and refrigerators, some local companies are growing up and a part of them already started export to Europe;
- Beside electric appliances, there already exist some industries locally grown in Bangladesh, such as food, pharmaceutical, ship building, and they have unique position as Bangladeshi company.

In general the latecomer developing countries are said to have advantages of shortening the duration of economic development because of speed of technology transfer. Taking into consideration the current status of Bangladeshi economy and the lessons from the experience of Thailand's industrial and economic development, there is a high possibility that Bangladesh has a good potential to achieve the same level of economic development towards 2041 as that of the present Thailand. The challenges for bringing the country on the track of long-term economic development are summarized in Table 5-4.

Table 5-4 Challenges for Bangladesh to Achieve Long-term Economic Development

Industrial Sector	Future Scenario
Agriculture	● Productivity improvement ● Improvement of farmers' income
Food and beverage	● Improvement of quality ● Export of products
Garment	● Evolution from consignment manufacturing to manufacturing by original design and own brand
Other secondary industries	● Catch up of technologies for manufacturing ● Export of products ● Capacity development of human resources

Source: JICA Survey Team

5.5 Future Scenarios of Economic Development of Bangladesh

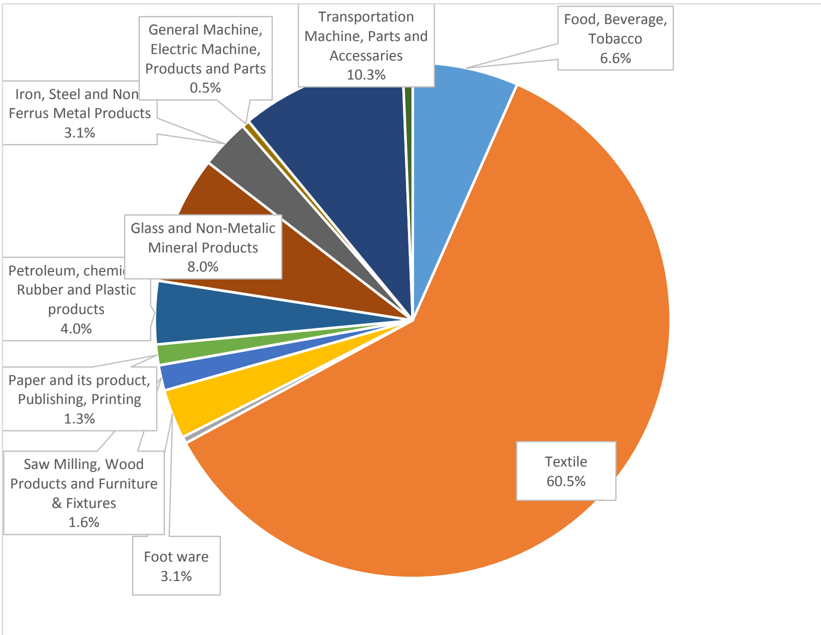
5.5.1 Manufacturing sector in Bangladesh

There are some statistics, though not many, which provide quantitative data on the manufacturing sector in Bangladesh. Table 5-5 and Figure 5-12 show the gross value added in large & medium-scale manufacturing sector broken down by industrial subsectors. Textile is the largest industry among manufacturing and is expanding from the share of 41.4% at 2008-09 to 60.5% at 2013-14. Those that follow textile industry are 'Transportation machine, parts and accessories' (10.3% in 2013-2014), 'Glass and non-metallic mineral products' (8.0%), 'Food, beverage, tobacco' (6.6%), 'Petroleum, chemical, rubber and plastic products' (4.0%), 'Foot ware' and 'Iron, steel and non-ferrous metal products' (3.1%) . Food industry is one of the prominent industries which would increase value added and gain foreign currency through export because Bangladesh is rich in agricultural and fishery resources. Furthermore, the fact that industrialization has already come to a certain level in some sectors such as machinery, plastic products, steel, non-ferrous metal products etc. implies that Bangladesh has a good possibility of further industrialization by placing appropriate policy measures to promote this trend.

Table 5-5 Gross Value Added in Large & Medium Scale Manufacturing Sector

	2008-09		2013-14(p)	
	Million Tk.	Share	Million Tk.	Share
Food, Beverage, Tobacco	84,268	9.0%	121,772	6.6%
Textile	386,477	41.4%	1,107,888	60.5%
Leather and its product	5,312	0.6%	7,753	0.4%
Foot ware	28,196	3.0%	56,789	3.1%
Saw Milling, Wood Products and Furniture & Fixtures	26,284	2.8%	28,990	1.6%
Paper and its product, Publishing, Printing	18,980	2.0%	23,859	1.3%
Petroleum, chemical, Rubber and Plastic products	71,734	7.7%	72,556	4.0%
Glass and Non-Metalic Mineral Products	107,320	11.5%	146,580	8.0%
Iron, Steel and Non-Ferrus Metal Products	48,982	5.2%	56,687	3.1%
General Machine, Electric Machine, Products and Parts	7,980	0.9%	8,694	0.5%
Transportation Machine, Parts and Accessaries	145,146	15.5%	189,588	10.3%
Others	2,902	0.3%	11,529	0.6%
Total	933,581	100.0%	1,832,685	100.0%

Note: (p) denotes provisional,
The data in the table are at Current Price,
Source: Prepared by the JICA Survey Team using Bangladesh National Account Statistics: Sources and Methods 2013-14 (BBS)



Note: (p) denotes provisional
The data in the table are based on Table 5-5 at 2013-2014(p).
Source: Prepared by the JICA Survey Team using Bangladesh National Account Statistics: Sources and Methods 2013-14 (BBS)

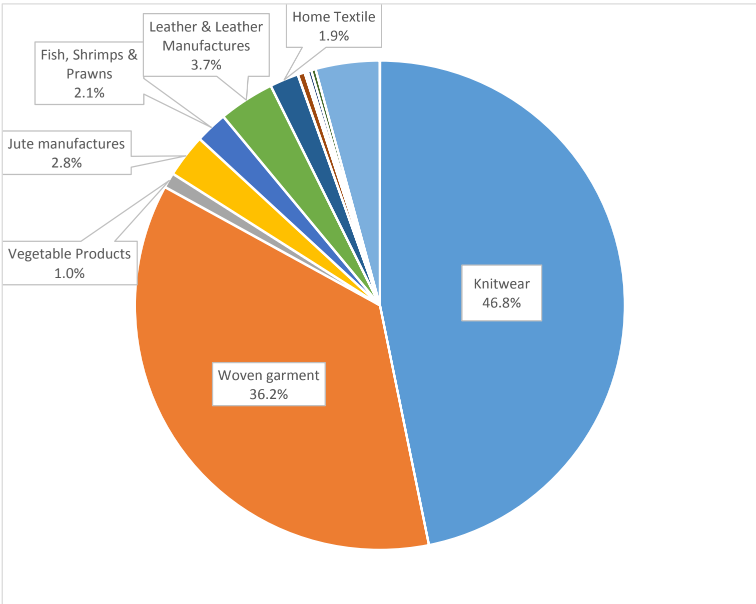
Figure 5-12 Gross Value Added in Large & Medium Scale Manufacturing Sector

Another useful statistic data which help understand the present status of manufacturing in Bangladesh is the export of each product as summarized in Table 5-6. The total amount of export increased from 153,225 Crore BDT at 2011-2012 to 187,971Crore BDT at 2014-2015 (see the sub-total in the data, which is the total value of export excluding SEZ). The average growth of total export was 7.1% per year. Knitwear and woven garment account for 46.8% and 36.2% respectively among total earnings from export and are representing the growth of total export. The exports of “vegetable products”, “leather & leather manufactures” and “pharmaceuticals” are increasing likewise. In the meanwhile, the export of “raw jute”, “terry towel”, and “petroleum & petroleum products” has been decreasing. At present, the country’s earnings from export are heavily dependent on textile industries including RMG, home textiles etc. and leather related industries including foot ware. For further economic development of Bangladesh, the new industries such as food processing, pharmaceuticals and light industries are expected to gain more shares in the export.

Table 5-6 Trends of Exports in Bangladesh

		2011-2012		2012-2013		2013-2014		2014-2015	
		crore Taka	% of	crore Taka	% of	crore Taka	% of	crore Taka	% of
RMG	Knitwear	70,910	46.3%	72,706	45.7%	82,425	46.2%	87,941	46.8%
	Woven garment	49,238	32.1%	55,563	34.9%	64,201	36.0%	68,104	36.2%
Vegetable Products		844	0.6%	1,030	0.6%	1,424	0.8%	1,894	1.0%
Jute manufactures		5,200	3.4%	5,988	3.8%	5,317	3.0%	5,351	2.8%
Fish, Shrimps & Prawns		4,758	3.1%	3,580	2.3%	4,097	2.3%	3,989	2.1%
Leather & Leather Manufactures		4,265	2.8%	5,399	3.4%	6,864	3.8%	6,890	3.7%
Home Textile		3,608	2.4%	3,316	2.1%	3,862	2.2%	3,589	1.9%
Raw Jute		1,866	1.2%	1,681	1.1%	948	0.5%	856	0.5%
Petroleum & Petroleum Products		972	0.6%	825	0.5%	535	0.3%	295	0.2%
Terry Towel		929	0.6%	193	0.1%	106	0.1%	123	0.1%
Bicycle		407	0.3%	462	0.3%	377	0.2%	443	0.2%
Pharmaeutical Products		391	0.3%	466	0.3%	508	0.3%	537	0.3%
Others		9,837	6.4%	7,902	5.0%	7,891	4.4%	7,959	4.2%
Sub-Total		153,225	100.0%	159,111	100.0%	178,555	100.0%	187,971	100.0%
Export of SEZ		27,086	-	30,549	-	34,820	-	38,515	-
Ground Total		180,310	-	189,660	-	213,375	-	226,486	-

Source: Prepared by the JICA Survey Team using the web site,
https://www.bb.org.bd/econdata/export/exp_rcpt_comodity.php, https://www.bb.org.bd/openpdf.php



Source: Prepared by the JICA Survey Team using the information from BBS Websites
(https://www.bb.org.bd/econdata/export/exp_rcpt_comodity.php, https://www.bb.org.bd/openpdf.php)

Figure 5-13 Composition of the Share of Each Products (2014-2015)

5.5.2 Roles and directions of manufacturing sector in Bangladesh

The study team conducted interviews with the officers of Ministry of Industries (MOI) and the policy adviser to MOI dispatched by JICA, and also reviewed the government plans such as Vision 2021 and the Seventh Five-Year Plan. The expected roles and directions of manufacturing that can be observed from aforementioned can be summarized as follows.

- Manufacturing is and will remain the driver of industrial growth.
- The main driver of manufacturing growth will be the export market.
- Until 1981, Jute and Jute goods dominated the export sector making up 70%, and then RMG export overtook the traditional export which rose to around 80%.
- The export concentration in RMG makes the economy extremely vulnerable to external changes and export diversification is very much important for the sustainable growth of Bangladesh.

According to the Perspective Plan of Bangladesh 2010-2021 (April 2012), the following industries are indicated as growth generator.

<Likely to be the main growth generator>

- Food processing, Leather and footwear, Pharmaceutical, Ship building, Toys, Ceramics , Furniture

<Likely to be the emergence of new products>

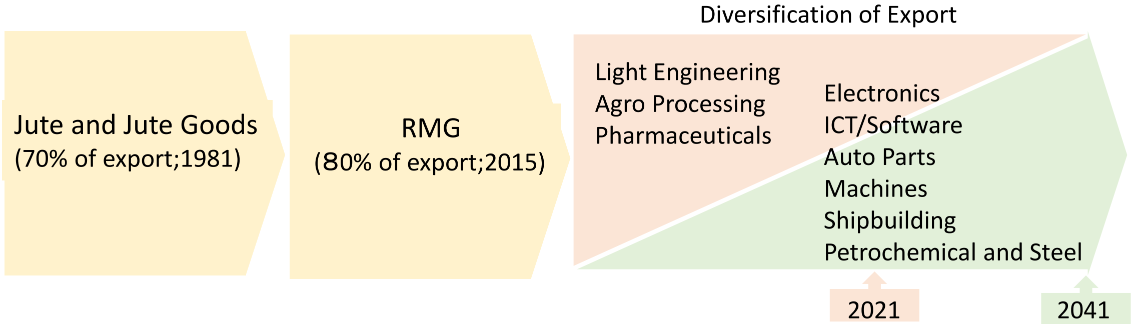
- Auto parts, Electronics, Light engineering

In addition, the Seventh Five-Year Plan FY2016-2020 (Final Draft, 11 November 2015) lists the industries as the growth generator.

<Likely to grow at a much faster rate>

- Footwear and Leather products, light engineering products (bicycle and electronics), pharmaceuticals, jute goods, ocean-going ship

To summarize the aforementioned, this study summarizes the future image of industrial development toward 2041 as illustrated in Figure 5-14.
Up to early-2020s, whereas Bangladesh economy still depends high on conventional industries such as RMG, jute and leather, new industries are expected to grow gradually. The export products are expected to be more diversified, such as light engineering, agro processing products and pharmaceuticals. Afterwards, i.e. towards 2041, the diversification will be further progressed to cover new industries and products with more value added, such as electronics, ICT/software, auto parts, machines and shipbuilding.

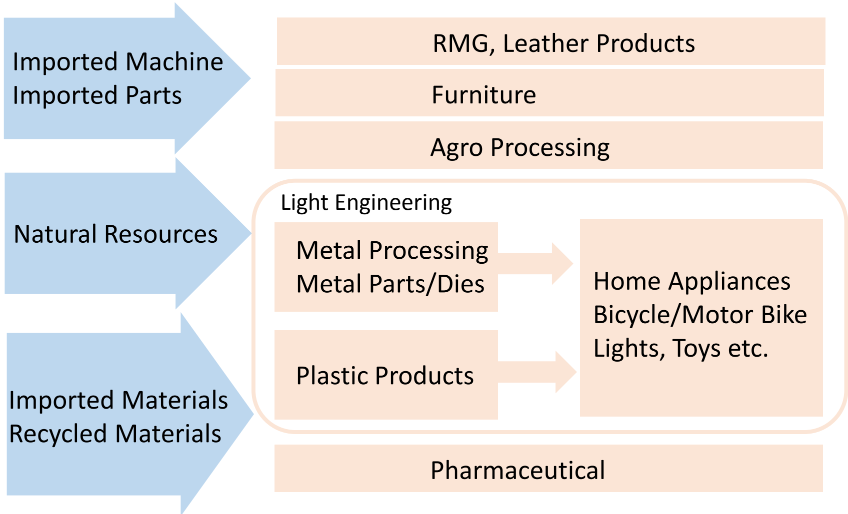


Source: JICA Survey Team

Figure 5-14 Future Image of Industrial Development in Bangladesh Towards 2041

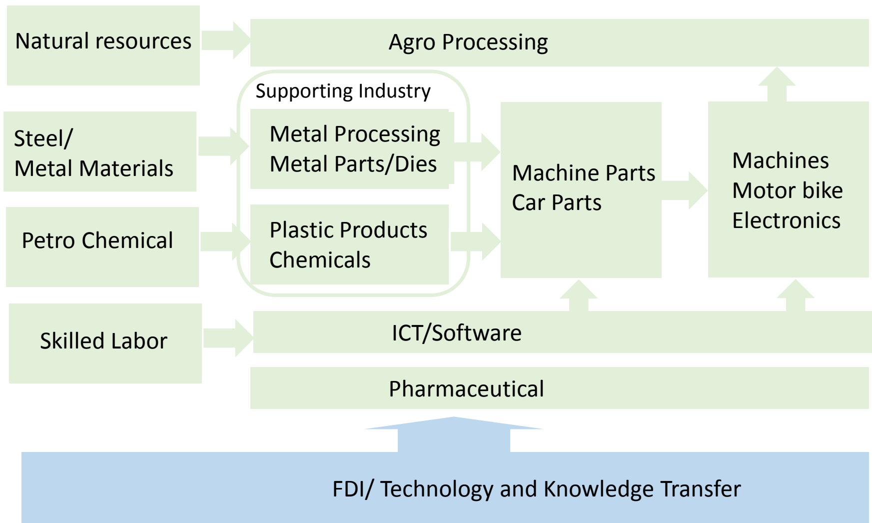
Future image of industrial structure in Bangladesh in early-2020s and 2041 is shown in Figure 5-15 and 16.
Up to early-2020s, Bangladesh industry will continue using imported materials and imported parts & machines as well as the direct use of domestically available natural resources. This means that the value chain of manufacturing from material to product is relatively simple. Here, SMEs (small and medium enterprises) are expected to play an important role. To develop SMEs and to support them to entry into the export market, various support policies should be undertaken.
Towards 2041, Bangladesh industry is expected to provide more multi-layered value chain for itself from raw material to machinery and then to final products, so that it will produce higher value added.

Introducing FDIs and taking advanced technologies and knowledges is indispensable to achieve this. Here, heavy industries like petrochemical and steel making will be integrated into industrial value chain in Bangladesh as well as SMEs. This study also emphasizes that agro processing industry will still remain as an important industry because it utilizes Bangladesh's own natural resources. Agro industry is expected to continue playing an important role because it is appropriate for Bangladesh to sustain huge labor force and secure food supply. Agro industry can be a highly value-added industry through the advancement of value-added processing, as seen in the experience of Thailand.



Source: JICA Survey Team

Figure 5-15 Image of Industrial Structure in Early-2020s



Source: JICA Survey Team

Figure 5-16 Image of Industrial Structure in 2041

5.5.3 Positioning of Bangladesh in the process of industrialization and measures to be taken

According to some academic researches on economic development in Asian developing countries, it is generally observed that there are three phases of industrialization in these countries as follows.

Phase 1: Import Substitution Industrialization by labor intensive and light industries under infant industry protection policies.

Phase 2: Export Oriented Industrialization by labor intensive industries like textile and footwear industry under export industry development policies.

Phase 3: Export Oriented Industrialization by technology and capital intensive industries like metal processing and machine industry.

The study team considers that this process can also be applicable in Bangladesh. According to the Seventh Five-Year Plan, Bangladesh after independence embraced a predominantly import-substituting trade regime. Around 1990, Bangladesh economy reached a point that protective policy for promoting import-substitution has become an obstacle for further growth and policy change is needed. It means that Bangladesh economy proceeded from Phase 1 to Phase 2 around 1990 and currently Phase 2 is in progress.

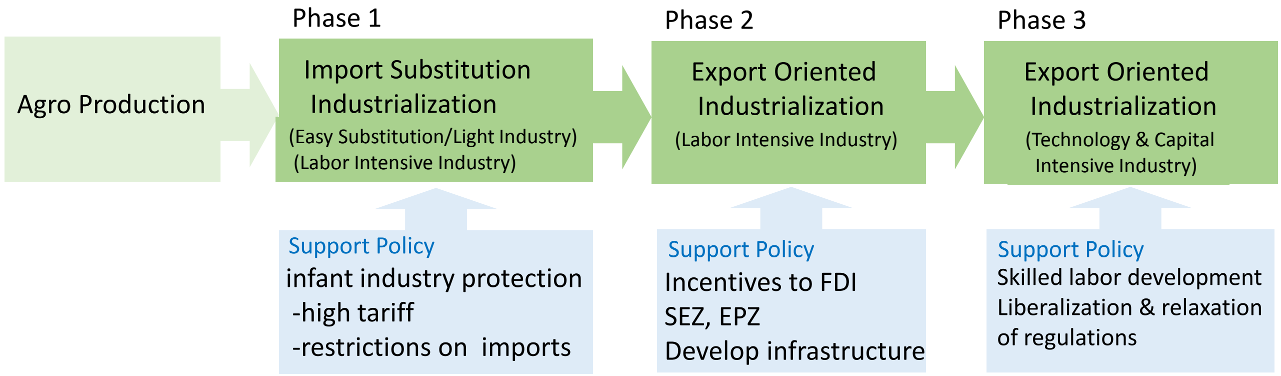
According to past studies, Thailand adopted import substitution industrialization policy during 1960s and changed the policy to export oriented industrialization in 1971. As a result, the ratio of trade amount in GDP increased from less than 30% in 1970 to 50% in 1981 and 65% in 1990. Industrialization in Thailand entered into Phase 3 in the middle of 1980s.

Considering the policies taken in Thailand over the period of industrialization, various policies need to be taken in each process of industrialization in the future in Bangladesh as follows

Phase 1: Import Substitution Industrialization
Policies for infant industry protection should be implemented (ex. High tariff, restriction on imports).

Phase 2: Export Oriented Industrialization (Labor Intensive Industry)
Policies on provision of incentives to FDI, construction of Industrial zone such as SEZ for foreign enterprises and development of various infrastructures like port, road, railway, and power supply must be needed.

Phase 3: Export Oriented Industrialization (Technology and Capital Intensive Industry)
In the stage of Phase 3, in addition to the above mentioned policies in Phase 2, skilled labor development and liberalization & relaxation of regulations are needed for realizing the industrialization among international competition.



Source: JICA Survey Team

Figure 5-17 Stages of Industrialization and Necessary Policy Measures

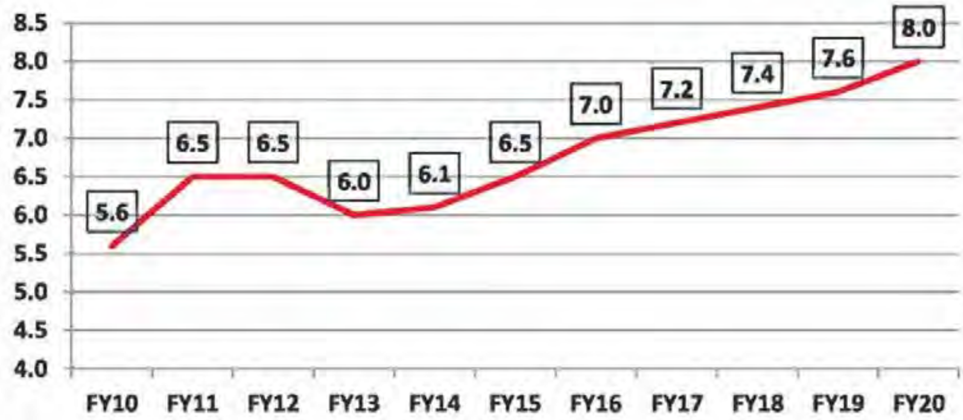
5.6 Projections of GDP in Bangladesh up to 2041

Based on the assumptions discussed in the precious sections, this study projected the GDP growth of Bangladesh up to 2041.

5.6.1 Bangladesh Government's GDP growth target

For the first five years up to 2020, this study refers to the GDP growth target set out in the Seventh Five-Year Plan. The Government of Bangladesh sets the country's growth to be 7.4% p.a. (per annum) during the five-year period (FY2016-FY2020), as shown in Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015
Figure 5-18. The growth rate is expected to increase steadily from 6.5% in FY2015 to 8.0% in FY2020.

The Government sees that the upward trend of GDP growth rate since FY2013 is expected to continue.



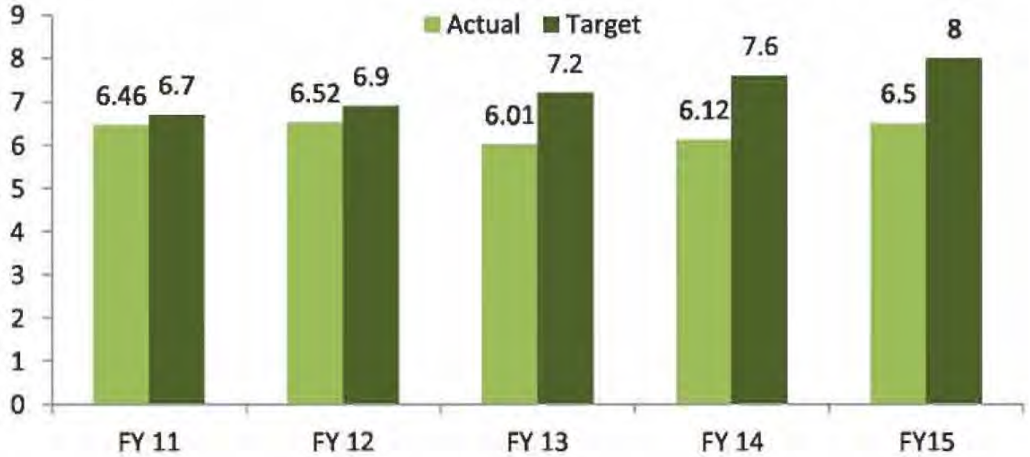
Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015

Figure 5-18 Projection of GDP Growth Rate in the Seventh Five-Year Plan

According to the announcement of the Government, the provisional result of GDP growth rate in FY2015-2016 was 7.05%, which attained the first year's target of the Seventh Five-Year Plan that was 7.0%. Considering the improved productivity of national economy and the strengthened international competitiveness, the country's economy is capable of keeping at least higher than 6% growth rate for the upcoming 5 years. However, it appears that achieving 7.4% growth target is not easy.

It has to be noted that in general the "target" is apt to be ambitious. As seen in Table 5-1, the actual growth rate during the period of past five-year plans (from first to sixth) has been underperforming the government plan, though the acceleratedly increasing trend of GDP, up from 3.8% p.a. in 1985-1990 to 6.3% p.a. in 2011-2015, proves that Bangladesh economy took on a track of rapid growth.

For the past five years during the period of Sixth Five-Year Plan (from FY2011 to FY2015), the actual growth rate has been constantly underperforming the target, as shown in Figure 5-19. According to the GOB's review on the achievements of the Sixth Five-Year Plan, which is described in the Seventh Five-Year Plan, the main factors of this gap are the "constrained growth of the service sector," "shortfall in the investment rate, both public and private" and "inability to achieve the projected growth rate in agriculture." They imply, in short, that the delay of economic reforms for inducing further economic growth. The country may not be able to fully reap the opportunity of economic development and the growth rate may continue underperforming the government's expectation unless the economic policies to support the development are not in place as planned.



Source: Bangladesh Planning Commission "Seventh Five Year Plan FY2016-FY2020", December 2015
Note: the actual performance of growth rate in FY2014-2015 was later amended from 6.5% to 6.6%

Figure 5-19 Comparison between the Government's Projection and Actual Performance during the Period of Sixth Five-Year Plan

5.6.2 Projections of international agencies

Table 5-7 shows the projection of GDP growth rate in Bangladesh with comparison of International Organizations, such as International Monetary Fund (IMF), World Bank and Asian Development Bank (ADB).
These international organization expects Bangladesh's GDP to grow at 6.7%-7.0% in 2016 and afterwards. These projections reflect the recent performance of Bangladesh's economy growth and are considered to be very positive. However, compared to them, GOB's GDP growth target is still more ambitious.

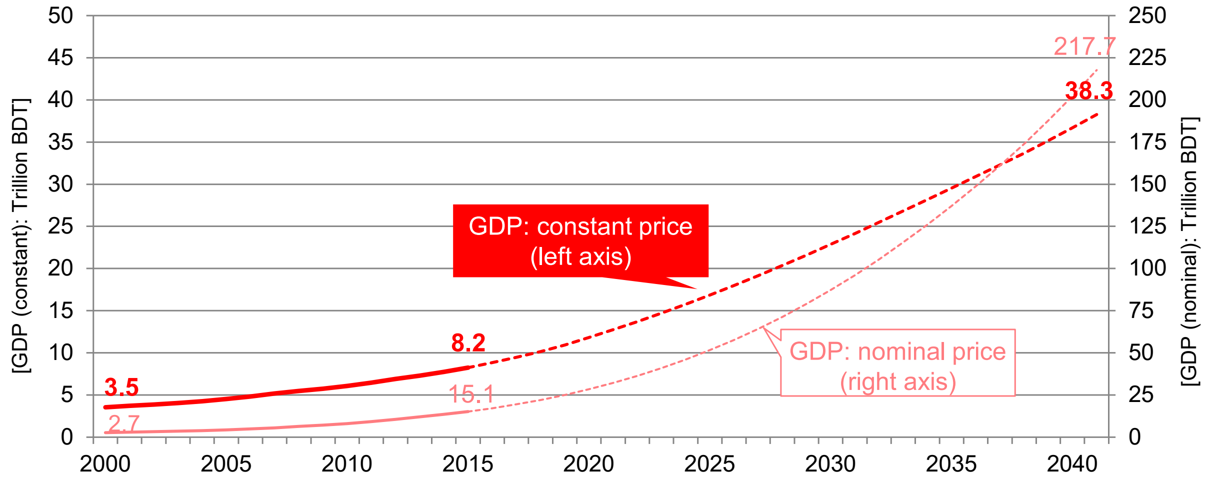
Table 5-7 Projection of GDP Growth Rate in Bangladesh:Comparison with International Organizations (real GDP)

	2015	2016	2017	2018	2019	2020
IMF "World Economic Outlook" (October 2015)	6.5%	6.8%	7.0%	7.0%	7.0%	6.7%
World Bank "Global Economic Prospects" (January 2016)	6.5%	6.7%	6.8%	6.8%	-	-
ADB "Asian Development Outlook 2015" (update: September 2015)	6.5%	6.7%	-	-	-	-
GoB "Seventh Five-Year Plan" (December 2015)	6.5%	7.0%	7.2%	7.4%	7.6%	8.0%

Source: Publications from International Monetary Fund, World Bank and Asian Development Bank

5.6.3 Projection in PSMP2016

The study team initially analyzed that the 7.4% p.a. growth from 2016 to 2020 might be overstretching and that the growth rate between 6.5 and 7.0%, as projected by international organizations, appears to be more realistic. Even if the fundamentals of Bangladesh economy continue to perform well, the recent slowdown of global economy, as typically seen in China, may also affect the economic growth of Bangladesh, considering that the country has been shifting to export-driven economy.
However, considering the consistency with the economic development plan officially made public by the GOB, this study follows the GOB's economic growth target, i.e. 7.4% p.a. from 2016 to 2020, assuming that policy measures to promote the economic growth, as discussed in the previous sections, will be optimally in place.
To follow this, Bangladesh economy in the next five years in early 2020s is expected to grow as high as during the period of Seventh Five-Year Plan and is expected to reach the criteria of upper-middle income countries. Afterwards, the growth rate may become slightly moderate as the economy comes to a certain level of maturity, but GDP will continue to grow steadily.
Figure 5-20 shows the study team's projection of GDP, both in constant and nominal price, up to 2041. Real GDP (constant at 2005 price) as of 2041 is estimated to reach 38 trillion BDT, about 4.6 times of the current level (8.2 trillion BDT). Nominal GDP (current price) is estimated to become about 220 trillion BDT in 2041. The average growth rate from 2016 to 2041 is 6.1% p.a. in real price and 10.8% in nominal price.
Methodologies of the GDP projection are discussed more in detail in the next section.



Source: JICA Survey Team

Figure 5-20 GDP Projection Up to 2041

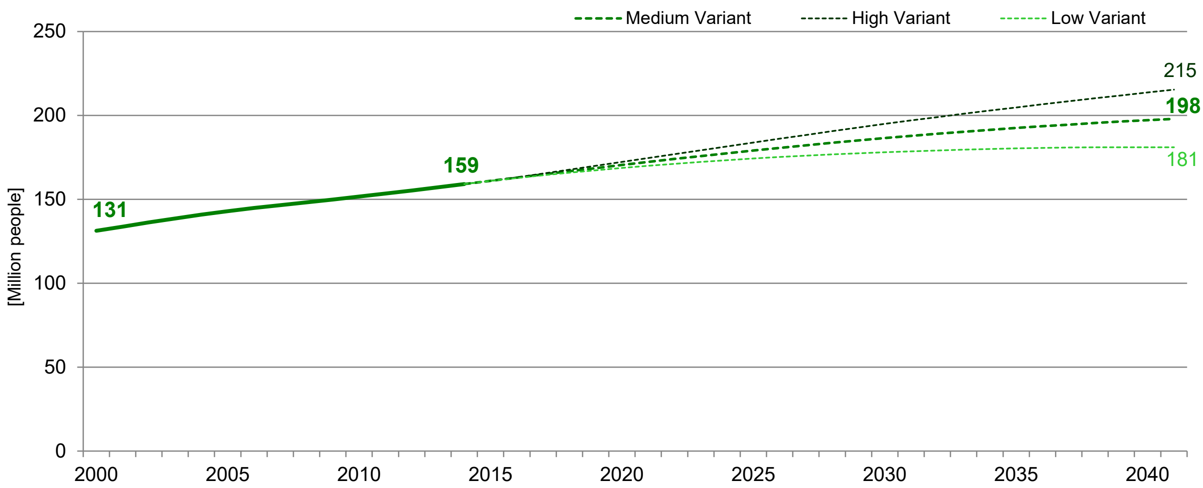
5.7 Methodologies of GDP Projection in this Study

5.7.1 Population

Population projection refers to United Nations' "World Population Prospects 2015" (WPP) as shown in Figure 5-21. WPP provides three scenarios of population growth, "High Variant," "Medium Variant," and "Low Variant" scenarios. In the "Medium Variant" scenario, which was adopted for this GDP projection, the population as of 2041 is expected to reach 198 million.

In Bangladesh, where the population density is high, population is still growing but the growth is getting moderate recently. The growth rate was about 2% around 2000, but it declined to 1.2% in 2014. In the "Medium Variant" scenario, this declining trend is expected to continue and the growth rate in 2041 will be 0.4% in 2041. The average growth rate for the entire period from 2015 to 2041 is 0.8% p.a. Table 5-8 summarizes the population projection and five-year (or six-year) average in each period.

In the "High Variant" scenario, the population growth is rather constant though the growth rate starts declining slightly from 2020s, whereas in the "Low Variant" scenario, the growth rate drops much faster and the total population starts decreasing (i.e. growth rate becomes negative) from 2039.



Source: United Nations "World Population Prospects 2015"

Figure 5-21 Population Projection Up to 2041

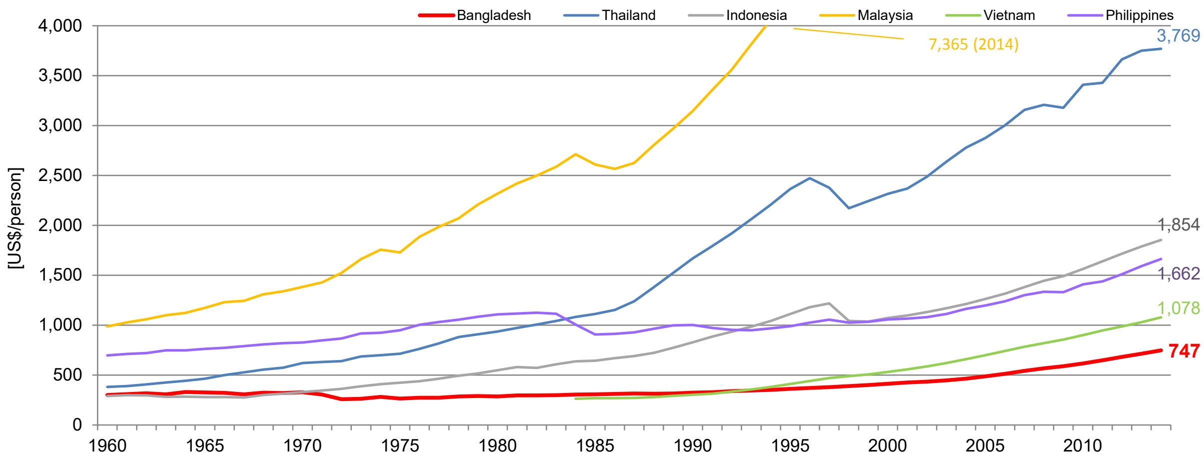
Table 5-8 Population Projection Up to 2041 (Medium Variant Scenario)

	2010	2015	2020	2025	2030	2035	2041
Population (1,000 people)	151,617	153,406	155,257	157,157	159,078	160,996	162,911
Average growth rate (p.a.)	1.2%	1.2%	1.1%	1.0%	0.8%	0.6%	0.5%

Source: United Nations "World Population Prospects 2015"
Note) Average growth rate is the five-year average except in the column of year 2041 that is six-year average.

5.7.2 Economic development scenario

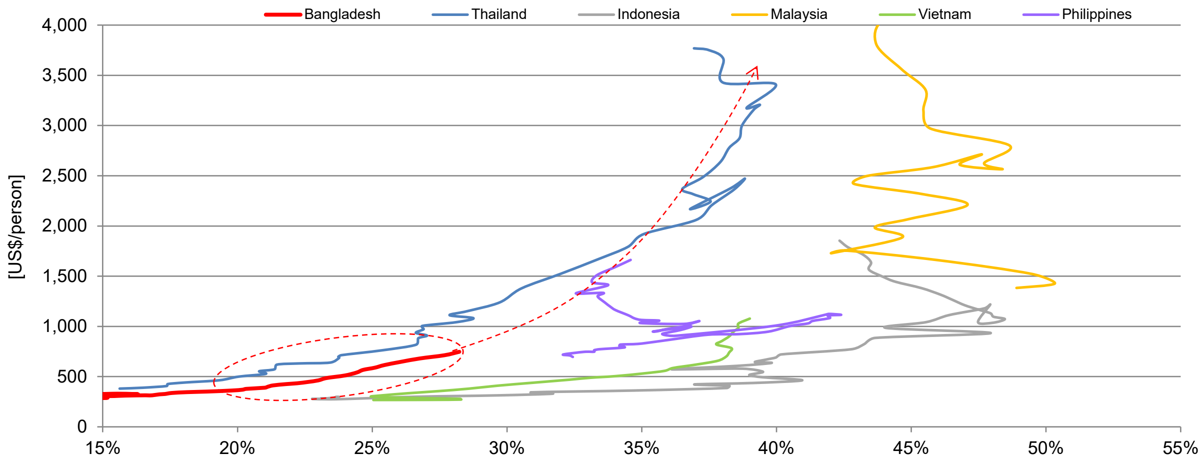
Figure 5-22, likeFigure 5-3, compares the historical trend of GDP per Capita of Bangladesh with that of ASEAN countries, as also discussed in Section 5-3. Bangladesh's real GDP per capita (constant at 2005 price) in 2014 was 48,664 BDT, which is equivalent to 747 USD in 2005 price.
Considering that in ASEAN countries GDP per capita saw a rapid growth after it reached 1,000 USD, Bangladesh, which will reach this threshold soon, is also supposed to have a good potential of accelerated economic growth to follow this trend.



Source: World Bank database

Figure 5-22 Historical Trend of GDP per Capita (real GDP) of Bangladesh and ASEAN Countries

Figure 5-23 plots the relation between the share of industrial sector in GDP (horizontal axis) and the GDP per capita (vertical axis) of Bangladesh and ASEAN countries since 1960. As a general trend, GDP per capita increases along with the growth of the industrial sector's share in GDP up to a certain level, which is supposed to be the stage of initial industrialization, and then GDP continues to grow while the share of industrial sector in GDP become relatively stable, which is considered the economic growth after the country's industrialization comes to a certain level of maturity.
Bangladesh's GDP capita started increasing rapidly when the industrial sector's share exceeded 20%. And this trend curve has been taking a similar track to what Thailand experienced before. Hence this study assumes that Thailand's history of economic development can be a good reference for projecting a future scenario of Bangladesh's economic development.



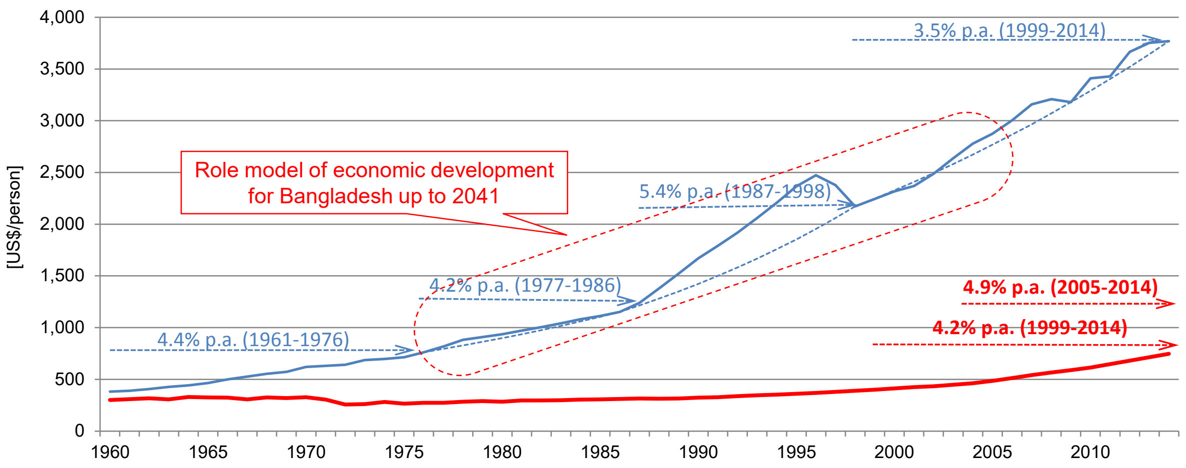
Source: Prepared by the JICA Survey Team using World Bank database

Figure 5-23 Industrial Sector's Share in GDP and GDP per Capita (real GDP) of Bangladesh and ASEAN Countries (1960-2014)

As already discussed above, Bangladesh's GDP per capita (real GDP in 2005 price) as of 2014 was 747 USD, which is almost equivalent to that of Thailand around 1976. Figure 5-24 shows the historical trend of GDP per capita of Thailand as a role model of economic development for Bangladesh. The current status of economic development of Bangladesh can be compared with that of Thailand also from the view point that Bangladesh saw a 4.2% p.a. growth of GDP per capita from 1999 to 2014 (16 years), which is similar to Thailand's growth rate from 1961 to 1976 (16 years) that was 4.4% p.a., and the growth rate from 1977 to 1986 (10 years) that was 4.2% p.a.

Thailand saw a rapider growth of economy afterwards, i.e. from mid-1980s to late-1990. Thought the country suffered an economic slump in late-1990s caused by the Asian Financial Crisis, the average growth rate of GDP per capita from 1986 to1998 was 5.4%, even higher than beforehand and afterwards. From late-1990s up to now, GDP per capita in Thailand has been keeping a 3.5% p.a. growth in average, though there's a fluctuation from year to year.

Assuming that Bangladesh follows the track of Thailand's economic growth in the past, the high growth is expected to continue, especially during the period when the country's GDP per capita reaches around 2,000 USD. Considering the recent rapid growth of Bangladesh economy and the follower's advantage for Bangladesh, this study assumes that the GDP per capita of Bangladesh for 27 years from 2014 to 2041 grows a little faster than that of Thailand for 27 years for 1976 to 2003.



Source: Prepared by the JICA Survey Team using World Bank database

Figure 5-24 Historical Trend of GDP per Capita (real GDP) of Bangladesh (red) and Thailand (blue)

Based on the aforementioned observations, this study assumes the growth rate of GDP per capita up to 2041 as follows.

- From 2016 to 2020:
  Average growth rate 6.2% p.a., which coincides with the government's target of GDP growth rate (7.4% p.a.), will be achieved.
- During 2020s:
  High growth rate continues like the past experience of Thailand achieved a rapid growth in 1980s and 1990s when GDP per capita increased from 1,000 USD to 2,000 USD.
- During 2030s and afterwards:
  Growth rate starts getting slightly moderate as the country's economic development comes to a certain level of maturity.

The result of the study team's projection of GDP per capita is summarized in Table 5-9. GDP per capita as of 2041 is expected to reach about 3,000 USD, about 3.8 times of that in 2015.

Table 5-9 Projection of GDP per Capita Up to 2041 (Real Basis at 2005 Price)

	2010	2015	2020	2025	2030	2035	2041
GDP per capita (USD)	615	787	1,063	1,444	1,883	2,357	2,970
GDP precipitate (BDT)	40,042	51,215	69,245	94,035	122,611	153,446	193,361
Exchange rate (BDT/USD)	65.1						
Growth rate (p.a.)	4.8%	5.0%	6.2%	6.3%	5.5%	4.6%	3.9%

Source: JICA Survey Team
Note: Average growth rate is five-year average except in the column of year 2041 that is six-year average.

The projection of GDP per capita at current price (nominal GDP) is shown in Table 5-10. At current price, GDP capita is expected to reach around 1.1 million BDT, or around 11,000 USD. GDP deflator in Bangladesh, which is currently around 7%, is expected to decline gradually to about 3%. Considering the inflation in Bangladesh, BDT is expected to depreciate against USD and the exchange rate in 2041 will be about 100 BDT/USD.

Table 5-10 Projection of GDP per Capita Up to 2041 (Nominal Basis)

		2010	2015	2020	2025	2030	2035	2041
GDP per capita (USD)		760	1,207	1,998	3,270	5,060	7,396	10,993
GDP per capita (BDT)		52,602	94,015	166,131	287,938	467,860	712,373	1,100,271
Exchange rate (BDT/USD)		69.2	77.9	83.2	88.0	92.5	96.3	100.1
GDP deflator (p.a.)		6.8%	6.9%	5.5%	5.0%	4.5%	4.0%	3.4%
Growth rate (p.a.)	USD	9.4%	9.7%	10.6%	10.4%	9.1%	7.9%	6.8%
	BDT	12.0%	12.3%	12.1%	11.6%	10.2%	8.8%	7.5%

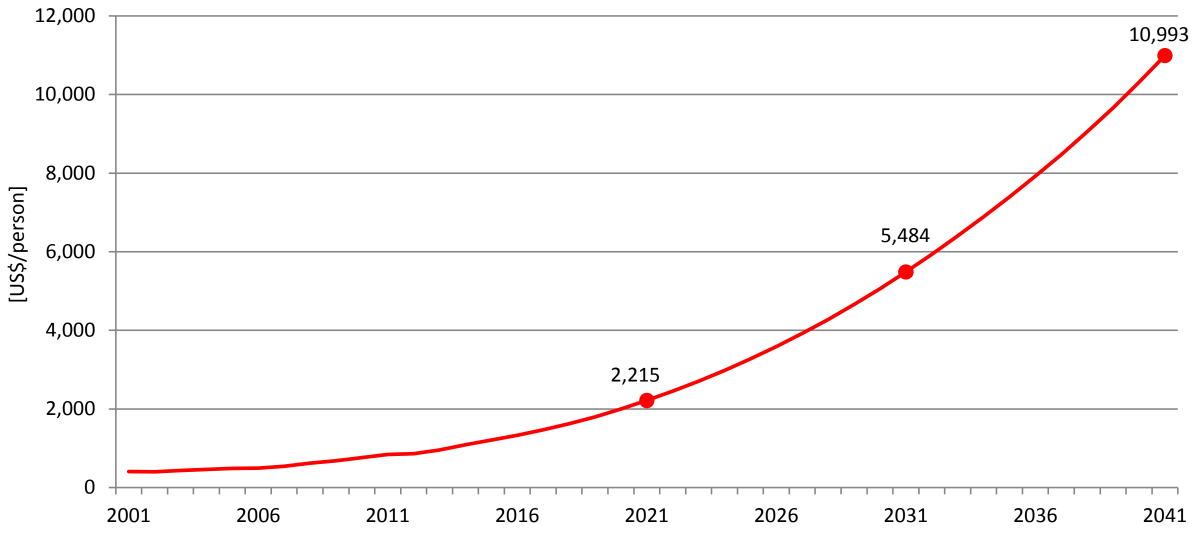
Source: JICA Survey Team

Note: GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

According to the World Bank's country classification (updated: February 2015), low-income, middle income, and high-income economies are defined as follows.

- Low-income economies: Countries with GNI (Gross National Income) per capita of 1,045 USD or less.
- Middle-income economies: Countries with GNI per capita of more than 1,045 USD but less than 12,736 USD.
  (Lower-middle-income and upper-middle-income economies are separated at a GNI per capita of 4,125 USD)
- High-income economies: Countries with GNI per capita of 12,736 USD or more.

This study expects that the GDP per capita of Bangladesh in 2041, about 11,000 USD (see alsoFigure 5-25), almost reaches the definition of "High-income economies", considering that GDP and GNI are not much different. That is, GOB's target to turn Bangladesh into a developed country by 2041 may not be too much unrealistic, though achieving this target may require some optimistic assumptions of economic growth. The criterion of upper-middle economies, i.e. GNI per capita of 4,125 USD, is supposed to be reached in 2020s.



Source: JICA Survey Team

Figure 5-25 Historical Trend and Projection of GDP per Capita (Nominal Base)

5.7.3 GDP projection up to 2041

Multiplying the GDP per capita and the population, the GDP of Bangladesh up to 2041 was forecasted, as already shown in Figure 5-20.
Table 5-11 and Table 5-12 are the summary table of forecasted GDP on real basis (constant at 2005 price) and nominal basis (current price) respectively. Real GDP is expected to continue growing higher than 7% until mid-2020s, then the growth rate will become slightly moderate as the economic development comes to a certain level of maturity.

Table 5-11 Real GDP Projection (constant at 2005 price)

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	93,236	126,630	181,282	258,598	351,109	453,642	587,665
GDP (billion BDT)	6,071	8,245	11,804	16,838	22,862	29,538	38,265
Exchange rate (BDT/USD)	65.1						
Growth rate (p.a.)	6.1%	6.3%	7.4%	7.4%	6.3%	5.3%	4.4%

Source: JICA Survey Team
Note) Growth rate is five-year average except in the column of year 2041 that is six-year average.

Table 5-12 Nominal GDP Projection (current price)

		2010	2015	2020	2025	2030	2035	2041
GDP (million USD)		115,279	194,300	340,576	585,615	943,451	1,423,643	2,175,520
GDP (billion BDT)		7,975	15,136	28,320	51,559	87,237	137,132	217,738
Exchange rate (BDT/USD)		69.2	77.9	83.2	88.0	92.5	96.3	100.1
GDP deflator (p.a.)		6.8%	6.9%	5.5%	5.0%	4.5%	4.0%	3.4%
Growth rate (p.a.)	USD	10.7%	11.0%	11.9%	11.4%	10.0%	8.6%	7.3%
	BDT	13.3%	13.7%	13.3%	12.7%	11.1%	9.5%	8.0%

Source: JICA Survey Team
Note) GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

Table 5-13 and Table 5-14 are the GDP projection expressed in PPP (power purchasing parity). World Bank's database was referred to in setting the conversion factor. In terms of PPP, GDP capita at current price is expected to reach about 32,000 USD in 2041.

Table 5-13 GDP Projection (PPP, constant at 2011 price)

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	371,659	504,770	722,625	1,030,822	1,399,588	1,808,308	2,342,549
GDP per capita	2,451	3,135	4,239	5,757	7,506	9,394	11,837
Conversion factor (BDT/USD)	13.5						

Source: JICA Survey Team

Table 5-14 GDP Projection (PPP, current price)

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	364,141	558,287	978,583	1,682,660	2,710,837	4,090,581	6,250,966
GDP per capita	2,402	3,468	5,741	9,397	14,538	21,250	31,587
Conversion factor (BDT/USD)	21.9	27.1	28.9	30.6	32.2	33.5	34.8

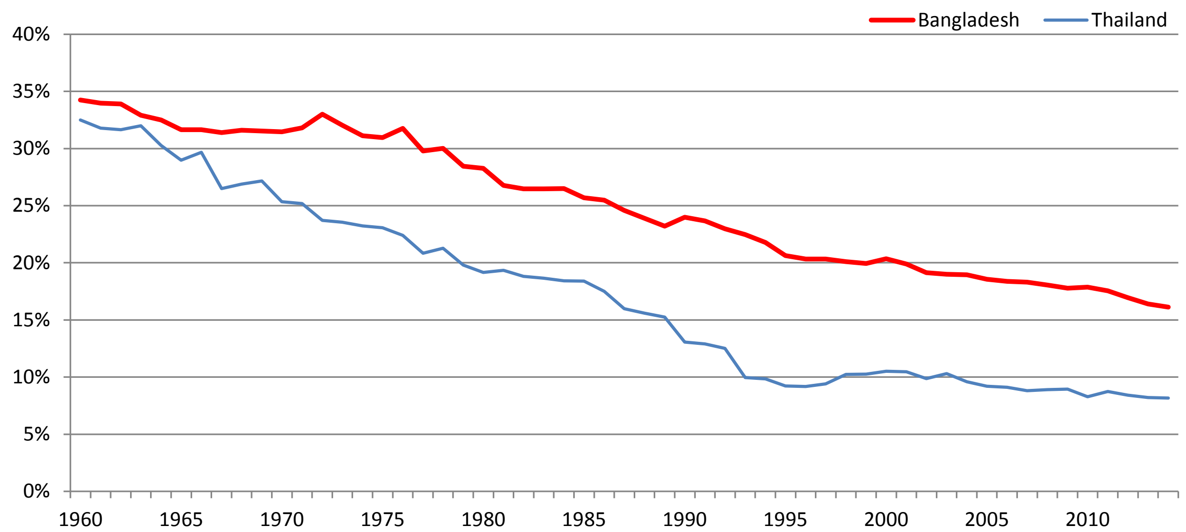
Source: JICA Survey Team

5.7.4 Sectorial breakdown of GDP

This study then estimated the share of GDP broken down by sectorial value added, such as agriculture, industrial and commercial & public services.

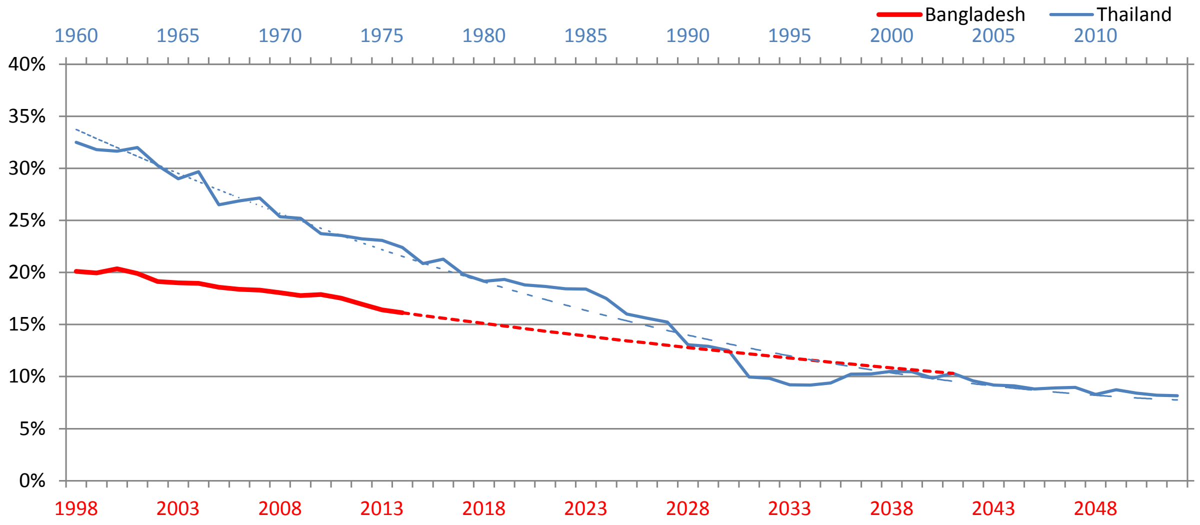
(1) Agriculture

Figure 5-26 compares the historical trend of agricultural sector's share in total GDP between Bangladesh and Thailand. Both in Bangladesh and Thailand, the share of agricultural sector's value added has been declining constantly.
Thailand saw a rapider decrease of agricultural share in the national economy until mid-1990s, but since then it has been keeping a relatively constant share around 8-10%. The trend that agricultural sector still retains certain share in Thailand's total GDP supports the argument that agriculture has been modernized to shift from self-sufficiency to more value-added products and gained competitiveness for export.
Bangladesh has been following the trend of Thailand, though the pace of decline is slower. Hence this study expects that the share of agriculture in GDP will continue to decline but will retain about 10% even as of 2041, as shown in Figure 5-27.



Source: World Bank database

Figure 5-26 Share of Agriculture in GDP: Bangladesh (red) and Thailand (blue)



Source: JICA Survey Team

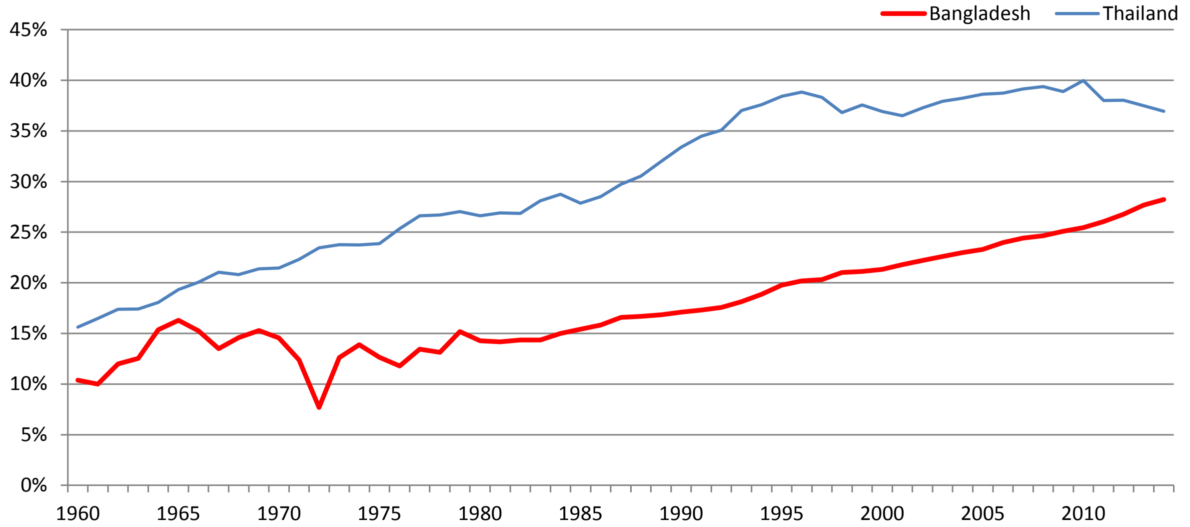
Figure 5-27 Share of Agriculture in GDP: Bangladesh (red) and Thailand (blue)

(2) Industry

Figure 5-28 compares the historical trend of industrial sector's share in total GDP between Bangladesh and Thailand. In Bangladesh, the share of industrial sector's value added started increasing from early-1980. Since then the country has been on a track of industrialization.

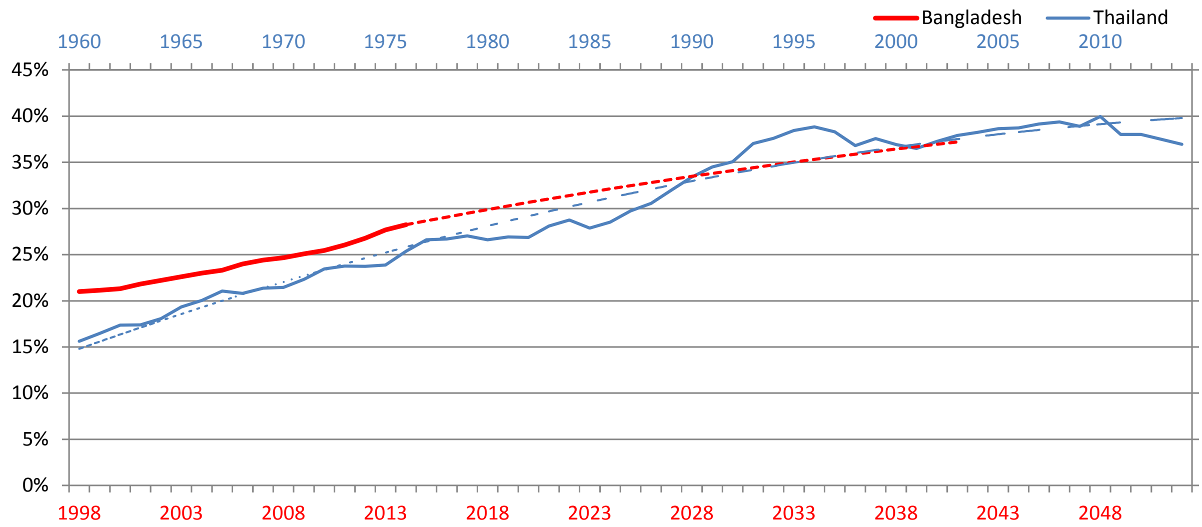
In Thailand, the share of industrial sector in GDP also saw a continuous increase until mid-1990, and since then it has been relatively constant between 35% and 40%. This is considered that the country's industrialization came to a certain level of maturity.

This study assumes that Bangladesh follows the past trend of Thailand and that the industrial sector's share in GDP is expected to increase up to 37% in 2041 as shown in Figure 5-29.



Source: World Bank database

Figure 5-28 Share of Industrial Sector in GDP: Bangladesh (red) and Thailand (blue)

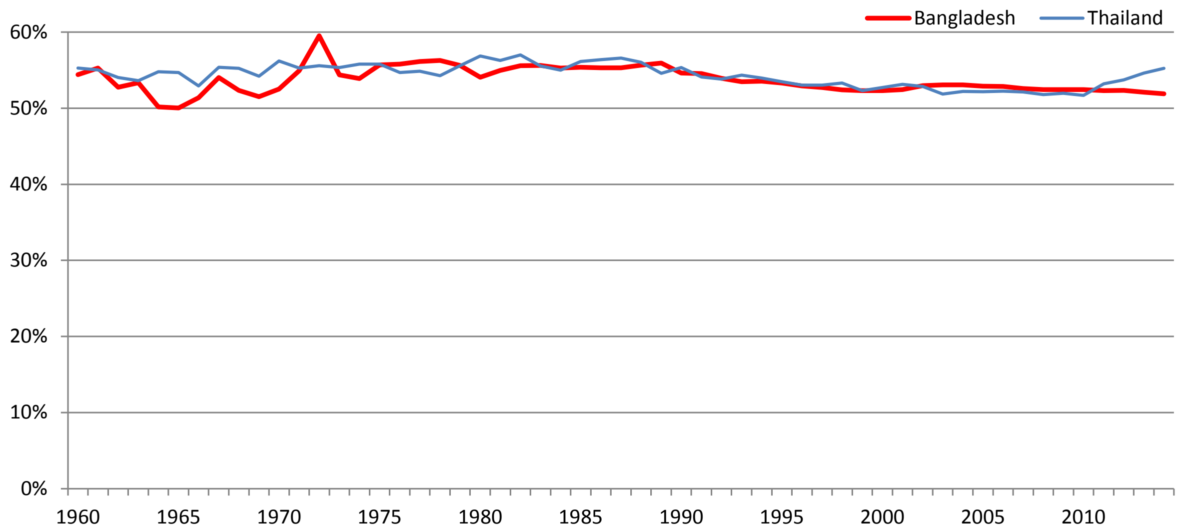


Source: JICA Survey Team

Figure 5-29 Share of Industrial Sector in GDP: Bangladesh (red) and Thailand (blue)

(3) Commercial & public services

Figure 5-30 compares the historical trend of commercial & public services' share in total GDP between Bangladesh and Thailand. Both countries saw a relatively stable share between 50% and 60% and a slightly declining trend has been observed in Bangladesh. This study assumes that this trend is expected to continue.

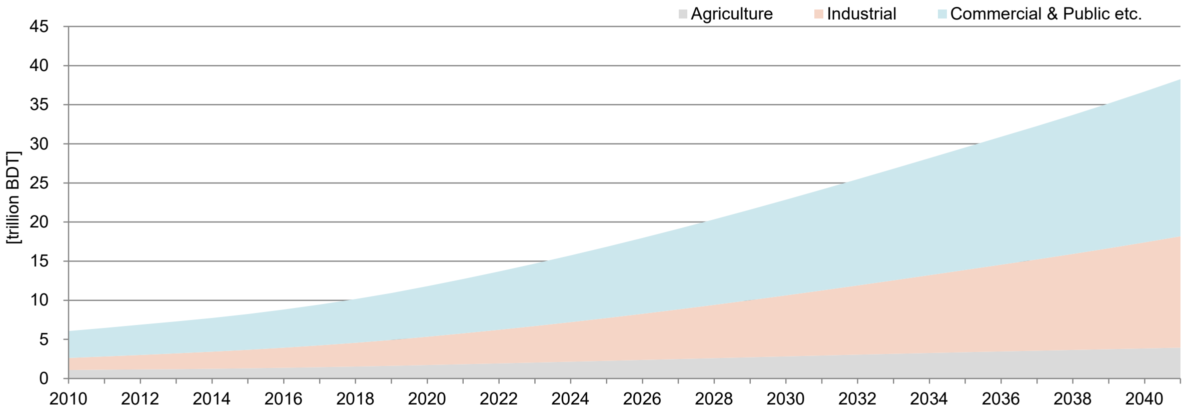


Source: World Bank database

Figure 5-30 Share of Commercial & Public Services in GDP: Bangladesh (red) and Thailand (blue)

(4) Summary

Figure 5-31 shows the study team's projection of sectorial breakdown of GDP (constant at 2005 price) up to 2041. As of 2041, agriculture, industry, and commercial & public services are expected to grow to 3.9 trillion BDT, 14.2 trillion BDT, and 20.1 trillion BDT, respectively.



Source: JICA Survey Team

Figure 5-31 Sectorial Breakdown of GDP Projection (Real GDP, constant at 2005 price)

5.7.5 Projection of "High-growth Scenario" and "Low-growth Scenario"

Besides the projection of GDP growth in section 5.7.3 as the "Base Scenario", this strudy also projected a "High-growth Scenario" and "Low-growth Scenario".

This study assumed that, in all of these scenarios, Bangladesh economy will continue growing in accordance with the economic scenario discussed in section, but this study considered that the trend of long-term economic development may vary depending on the strength of economic reform policies etc. To be specific, all these scenarios assumed that the GDP growth target up to 2020 that is stipulated in the Seventh Five-Year Plan will be achieved, but after 2020s when the growth rate becomes gradually moderate in the course of maturity of economic development, the pace of declining growth rate is relatively slow in the "High-growth Scenario" whereas in the "Low-growth Scenario" the pace of declining growth rate is relatively rapid.

As a result, whereas the "Base Scenario" assumed that the average growth rate of GDP (real price) from 2036 to 2041 becomes 4.4% p.a., the "High-growth scenario" assumed 5.0% p.a. and the "Low-growth Scnerio" assumed 4.0% p.a. GDP projection in the "High-growth Scenrio" are shown in (real price) and (nominal price), and that in the "Low-growth Scenario" are shown in (real price) and (nominal price) respectively.

Table 5-15 Real GDP Projection (constant at 2005 price) – High-growth Scenario

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	93,236	126,630	181,282	259,889	357,613	472,273	633,087
GDP (billion BDT)	6,071	8,245	11,804	16,922	23,286	30,751	41,223
Growth rate (p.a.)	6.1%	6.3%	7.4%	7.5%	6.6%	5.7%	5.0%

Source: JICA Survey Team
Note: Growth rate is five-year average except in the column of year 2041 that is six-year average.

Table 5-16 Nominal GDP Projection (current price) – High-growth Scenario

		2010	2015	2020	2025	2030	2035	2041
GDP (million USD)		115,279	194,300	340,576	588,540	960,930	1,482,112	2,343,672
GDP (billion BDT)		7,975	15,136	28,320	51,817	88,853	142,764	234,568
Growth rate (p.a.)	USD	10.7%	11.0%	11.9%	11.6%	10.3%	9.1%	7.9%
	BDT	13.3%	13.7%	13.3%	12.8%	11.4%	9.9%	8.6%

Source: JICA Survey Team
Note: GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

Table 5-17 Real GDP Projection (constant at 2005 price) – Low-growth Scenario

	2010	2015	2020	2025	2030	2035	2041
GDP (million USD)	93,236	126,630	181,282	257,740	346,830	441,597	559,104
GDP (billion BDT)	6,071	8,245	11,804	16,782	22,583	28,754	36,405
Growth rate (p.a.)	6.1%	6.3%	7.4%	7.3%	6.1%	4.9%	4.0%

Source: JICA Survey Team
Note: Growth rate is five-year average except in the column of year 2041 that is six-year average.

Table 5-18 Nominal GDP Projection (current price) – Low-growth Scenario

		2010	2015	2020	2025	2030	2035	2041
GDP (million USD)		115,279	194,300	340,576	583,671	931,953	1,385,843	2,069,790
GDP (billion BDT)		7,975	15,136	28,320	51,388	86,174	133,491	207,156
Growth rate (p.a.)	USD	10.7%	11.0%	11.9%	11.4%	9.8%	8.3%	6.9%
	BDT	13.3%	13.7%	13.3%	12.7%	10.9%	9.1%	7.6%

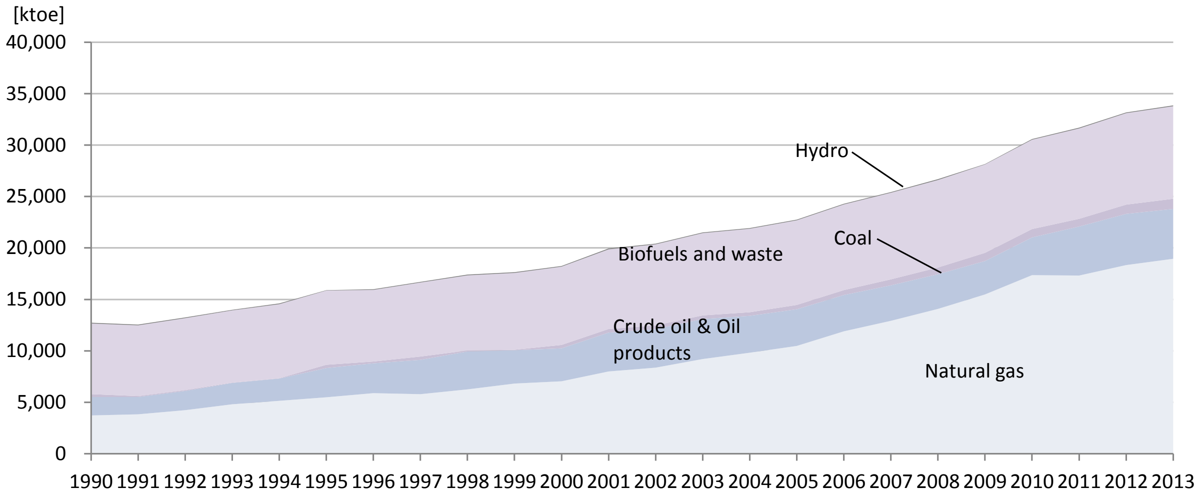
Source: JICA Survey Team
Note: GDP deflator and growth rate are five-year average except in the column of year 2041 that is six-year average.

Chapter 6 Prospects of Energy Supply and Demand

6.1 Overview of Energy Supply and Demand Balances of Bangladesh

6.1.1 Historical trend of primary energy supply

A main issue regarding the energy supply and demand in Bangladesh is that, whereas the energy demand has been growing and is expected to continue growing rapidly, domestic production of natural gas that accounts for more than half of the country's energy demand is coming to saturation hence the country will be faced with the necessity of structural changes of energy supply and demand.
Figure 6-1 illustrates the trend of primary energy supply in Bangladesh. The ratio of natural gas in the total supply of primary energy increased from 29% in 1990 to 57% in 2010, which means that the increase of energy demand during that period was mainly met by the increase of natural gas supply. However, from 2011 the domestic production of natural gas did not increase much and the gap from the increasing demand was mainly covered by crude oil & oil products.

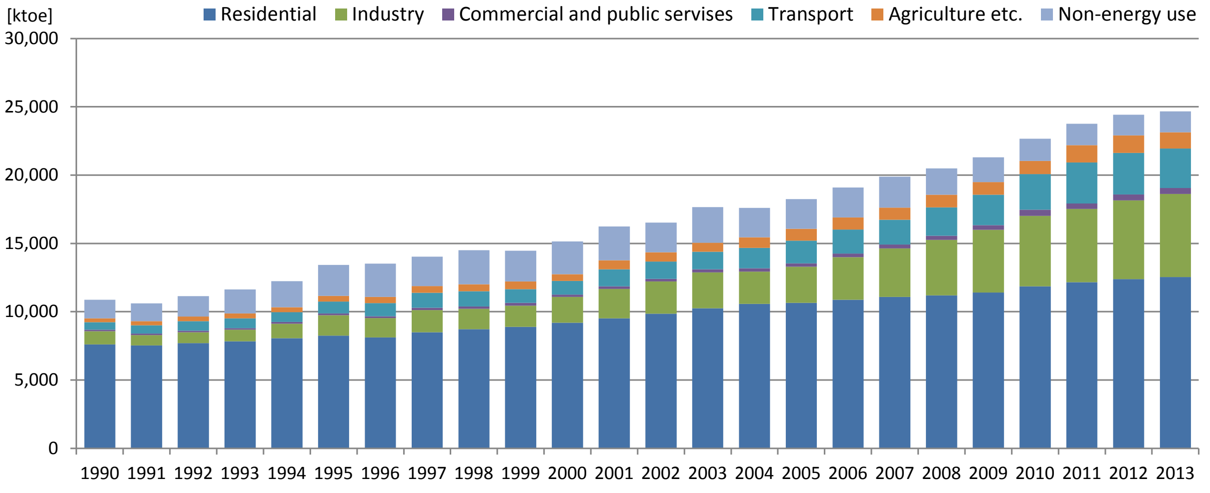


Source: IEA statistics

Figure 6-1 Historical Trend of Total Primary Energy Supply in Bangladesh (1990-2013)

6.1.2 Historical trend of final energy consumption and sectorial breakdown

Figure 6-2 shows the historical trend of final energy consumption and its sectorial breakdown. The total final energy consumption increased by 2.2 times (3.6% p.a.) from 1990 to 2013. The growth became moderate from 2012 to 2013, but this is considered a temporary effect caused by natural disaster like cyclone and so on, and the increasing trend is expected to continue.
Looking at the sectorial breakdown of the final energy consumption, the residential sector has been taken more than half and is still growing gradually. However, the increase of this sector during the same period was 1.6 times (2.1% p.a.), which is lower than that of the total and its share has been decreasing. In the meanwhile, the industrial sector, the commercial & public services sector, and the transport sector increased by 6.3 times (8.3% p.a.), 3.8 times (6.0% p.a.), and 5.3 times (7.5% p.a.) respectively during the same period, and they all outperformed the total energy consumption. Above all, the industrial sector and the transport sector saw a high growth in the past.



Source: IEA statistics

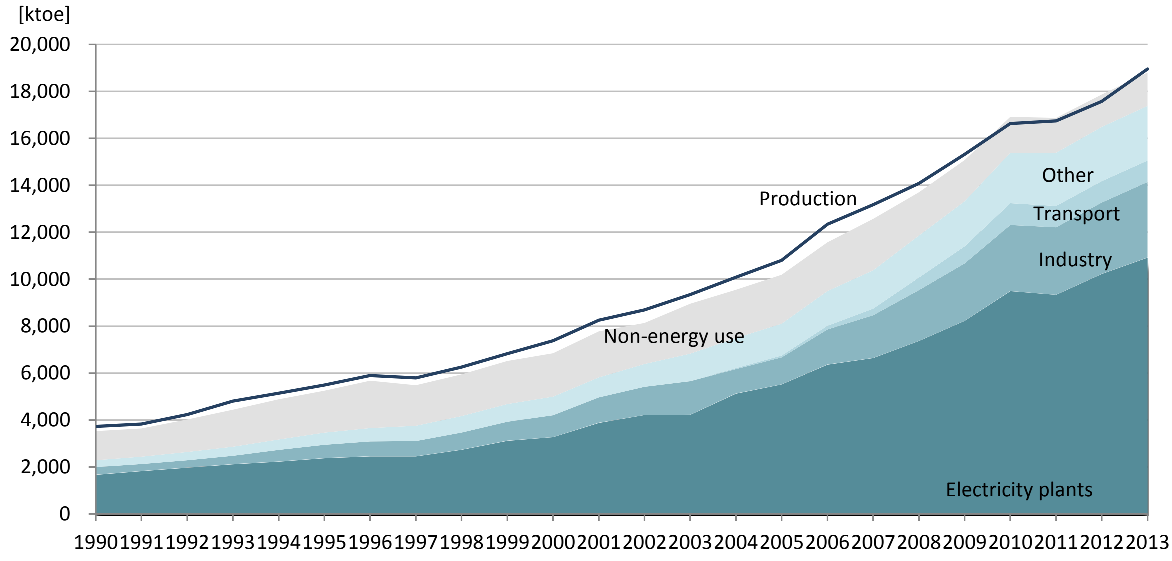
Figure 6-2 Historical Trend of Total Final Energy Consumption in Bangladesh (1990-2013)

6.1.3 Historical trend of supply and demand for each fuel type

The historical trend of energy supply and demand in Bangladesh is analyzed for each type of fossil fuel such as natural gas, coal and oil (crude oil and oil products).

Figure 6-3 shows the historical trend of domestic production of natural gas and the consumption broken down by main sectors. The line chart in the figure indicates the domestic production of each year. In the stacked area chart, "Electricity Plants" indicates the volume of fuel input for power generation. From here the thermal loss from thermal power generation, in-house consumption of power plants, and transmission and distribution losses are deducted before being delivered to final consumption. The electrical energy used for final consumption is less than half of the energy input.

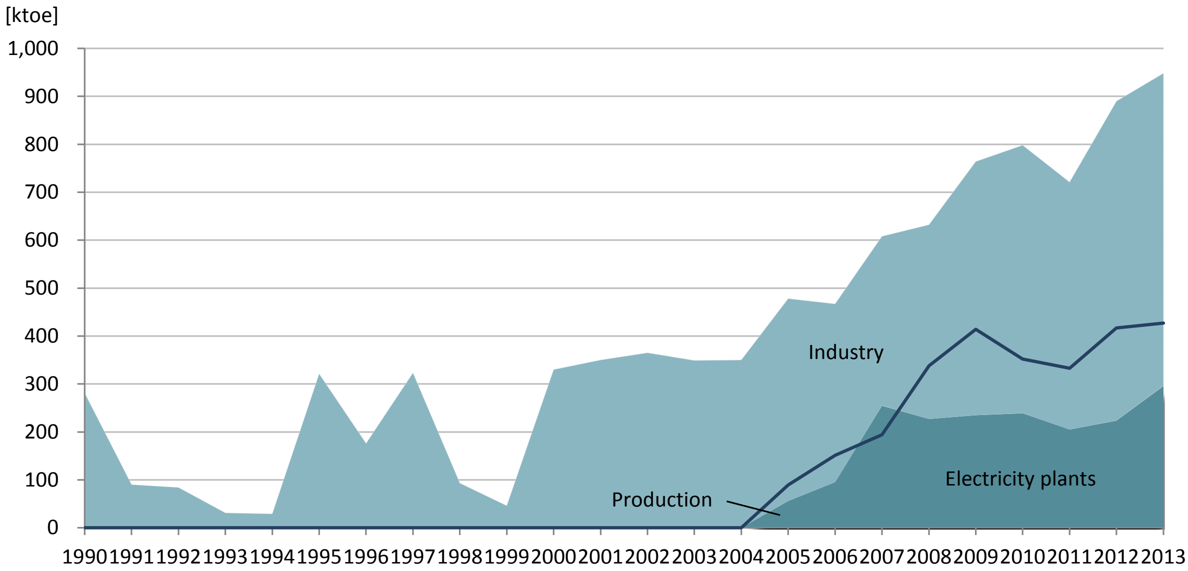
In Bangladesh, the demand of natural gas is almost 100% supplied from domestic production, and this is why the amount of production and consumption has been almost balanced. The share of power generation has been constantly about 50% of total consumption of natural gas in recent years. In the meanwhile, the share of industrial and transport sectors has been increasing, whereas the share of non-energy use (such as raw material of chemical fertilizer) has been decreasing.



Source: IEA statistics

Figure 6-3 Historical Trend of Natural Gas Supply and Demand (1990-2013)

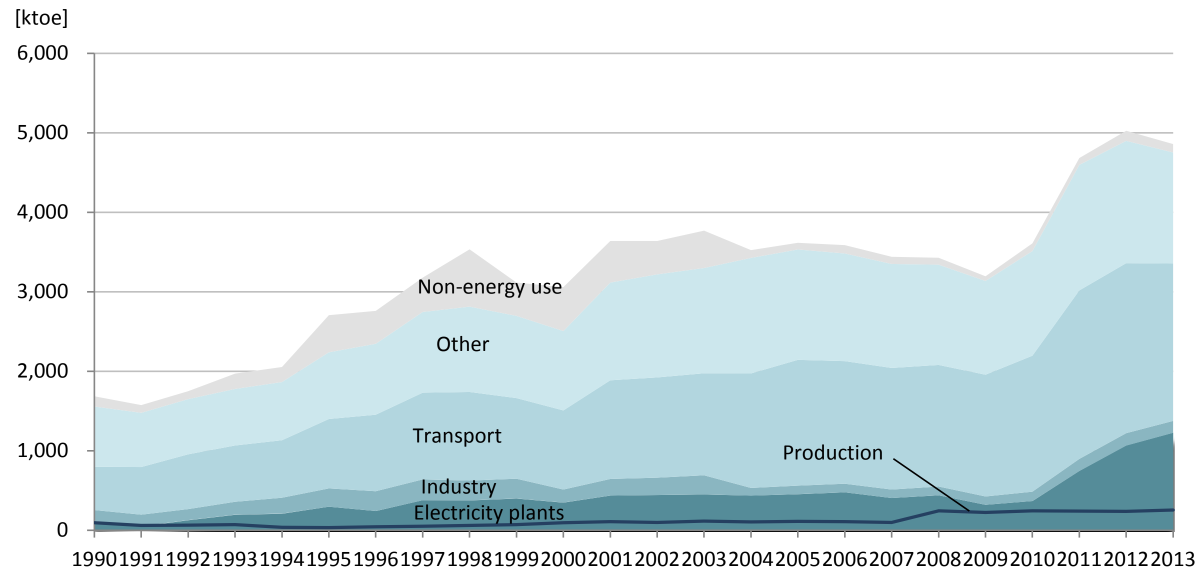
In the same way, Figure 6-4 shows the domestic production of coal and the consumption broken down by main sectors. In the statics, domestic production of coal in Bangladesh first appears in 2005, and since then the trend of consumption for power generation has been taking a similar trend as that of production. This means that the use of imported coal and domestic coal has been roughly segregated, i.e. imported coal for industrial use and domestic coal for power generation.
In the future, as the domestic production of natural gas is coming to saturation, the consumption of coal including import is expected to increase not only in volume but also in types of use. Expanding the utilization of imported coal as the energy source for power generation, as represented by “Matarbari Ultra Super Critical Coal-Fired Power Project” sponsored by JICA, is supposed to gain importance.



Source: IEA statistics

Figure 6-4 Historical Trend of Coal Supply and Demand (1990-2013)

Figure 6-5 shows the historical trend of domestic production of petroleum (crude oil and oil products) and the consumption broken down by main sectors. In Bangladesh, domestic production of petroleum is far less than that of natural gas, and the country’s demand mostly depends on imports. This graph shows that the consumption of petroleum for power generation has been increasing rapidly since 2011, but that the amount of domestic production has not increased during that period, which implies that the dependence of power generation on imported petroleum has been progressed.
However, because procuring imported oil for power generation is costly not only compared to domestic production of natural gas but also compared to procuring coal (both domestic production and import) in general, it is recommended that the increased dependence of power generation on imported oil should be confined to a temporary expedient so that the insufficiency of natural gas for power generation should be covered by other primary energy sources such as coal.



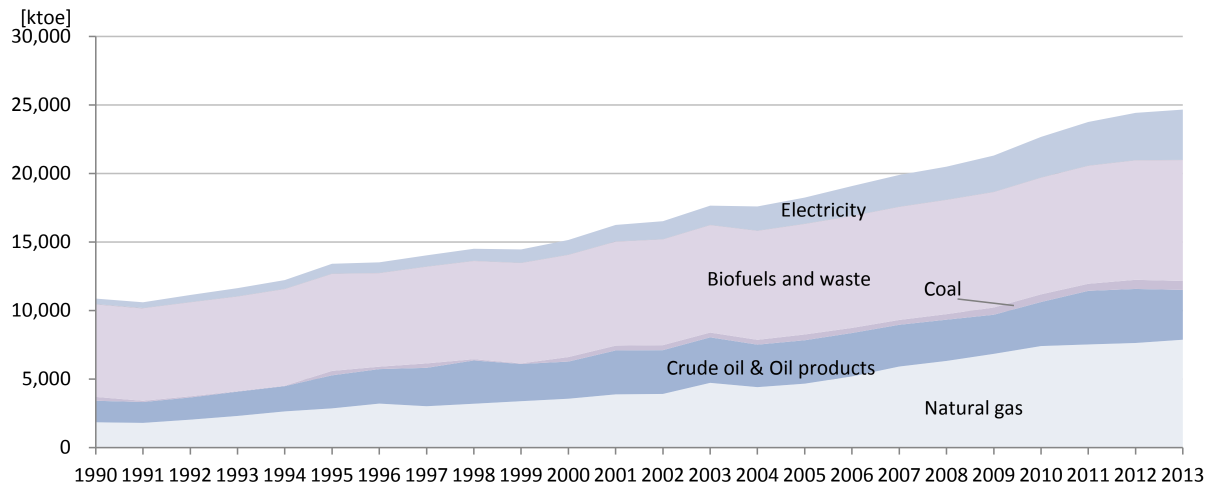
Source: IEA statistics

Figure 6-5 Historical Trend of Oil (Crude Oil & Oil Products) Supply and Demand (1990-2013)

6.1.4 Historical trend of final energy consumption for each sector

The historical trend of final energy consumption for each sector and its breakdown by the modes of energy supply are analyzed. First, Figure 6-6 illustrates the trend of total final energy consumption in Bangladesh broken down by the modes of supply.

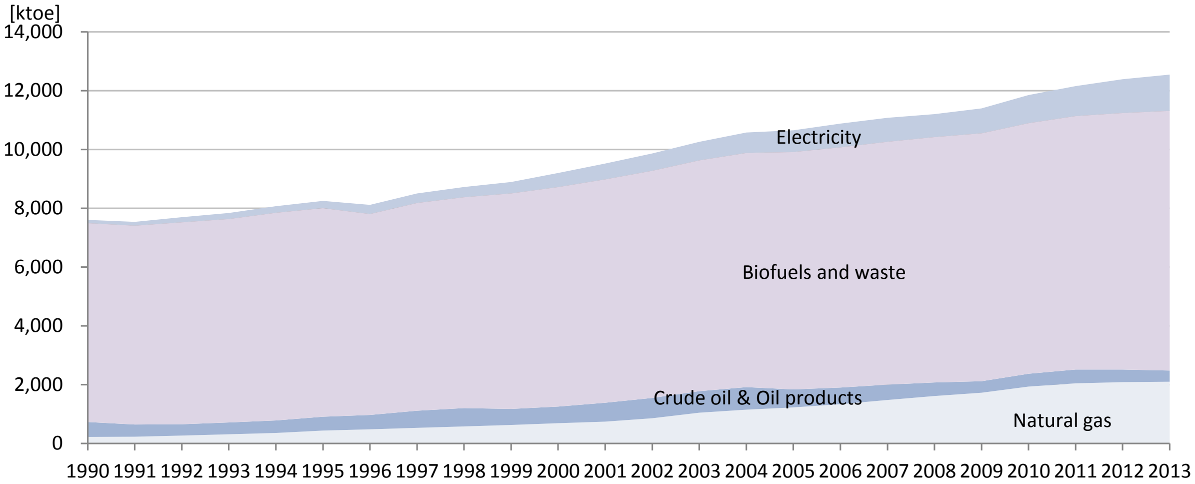
“Biofuels and waste”, which is consumed almost exclusively by the residential sector accounts for the largest share, but its share has been gradually declining due to the modernization of energy supply to the residential sector (shift to electricity and gas). The increase of oil consumption has become moderate since 2000s, which is mainly due to the electricification of residential sector and the shift of transport sector energy demand from oil to CNG. On the other hand, the share of electricity and natural gas in total energy demand has been increasing and especially the share of electricity, though it still accounts for only about 15% of total final energy consumption, has seen a rapid increase.



Source: IEA statistics

Figure 6-6 Total Final Energy Consumption Broken Down by Modes of Supply (1990-2013)

Then the breakdown of the final energy consumption by the modes of energy supply is analyzed for each sector. The breakdown of residential sector energy consumption by modes is shown in Figure 6-7. "Biofuels and waste" takes an overwhelmingly large share, and this is due to the fact that considerable number of unelectrified villages and households still exist mainly in rural area. Driven by the progress of household electrification, the share of electricity has been increasing, but the limited share of electricity and natural gas in the total energy consumption implies that even the electrified households more or less rely on conventional energy sources such as firewood.

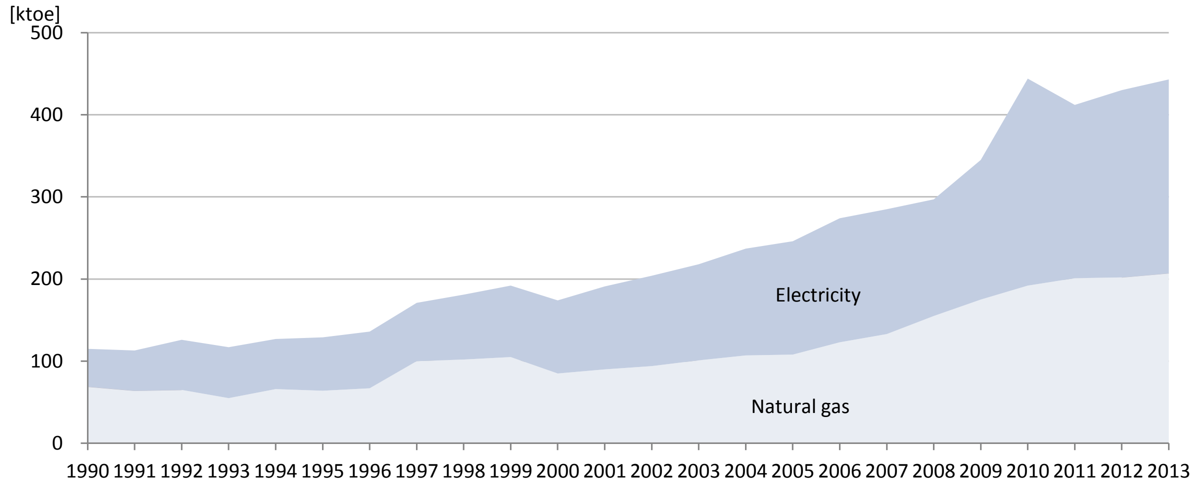


Source: IEA statistics

Figure 6-7 Historical Trend of Residential Sector Energy Consumption (1990-2013)

Figure 6-8 shows the breakdown of final energy consumption of commercial and public services sector by the modes of energy supply. According to the statistics, the share of this sector in total final energy consumption is small, i.e. less than one-twentieth of that of the residential sector and less than one-tenth of that of the industrial sector. The main reason is supposed to be that large commercial facilities and office buildings are still underdeveloped in Bangladesh but there is also a possibility that the statistical categorization of energy consumption is not accurate thus it may not reflect the actual status of energy consumption.

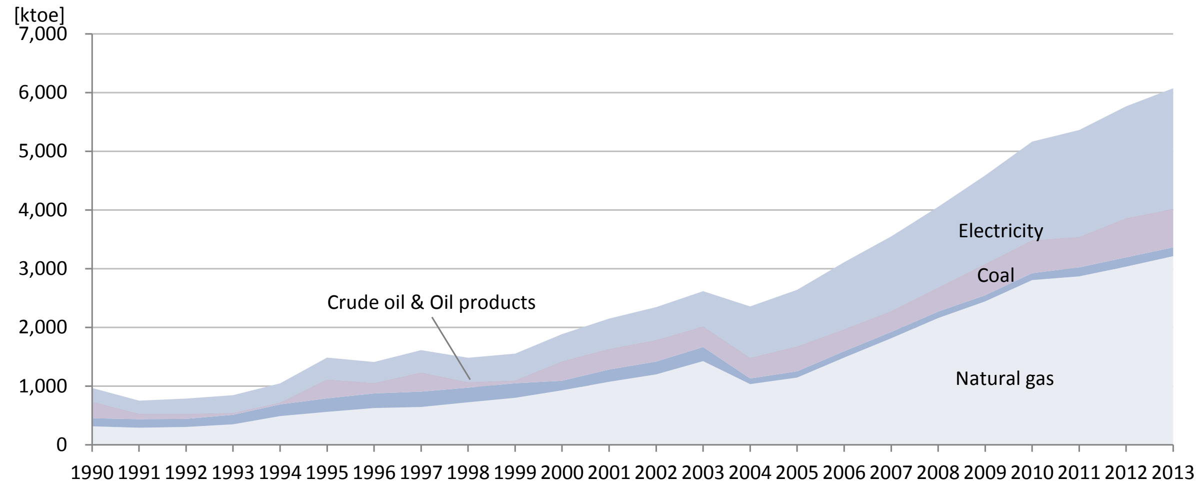
The share of electricity and gas in this sector has been nearly 50:50 since 2000, but recently the increase of electricity supply outstrips that of gas supply.



Source: IEA statistics

Figure 6-8 Historical Trend of Commercial/Public Services Sector Energy Consumption (1990-2013)

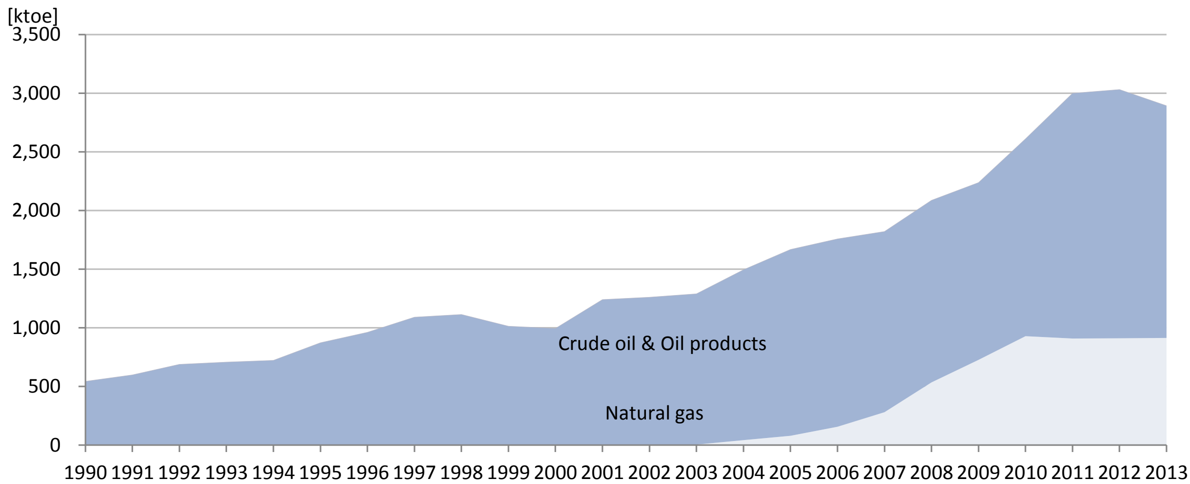
Figure 6-9 shows the breakdown of final energy consumption of commercial and public services sector by the modes of energy supply. The gas consumption takes up more than half of the energy consumption but recently electricity supply also sees a rapid increase.



Source: IEA statistics

Figure 6-9 Historical Trend of Industrial Sector Energy Consumption (1990-2013)

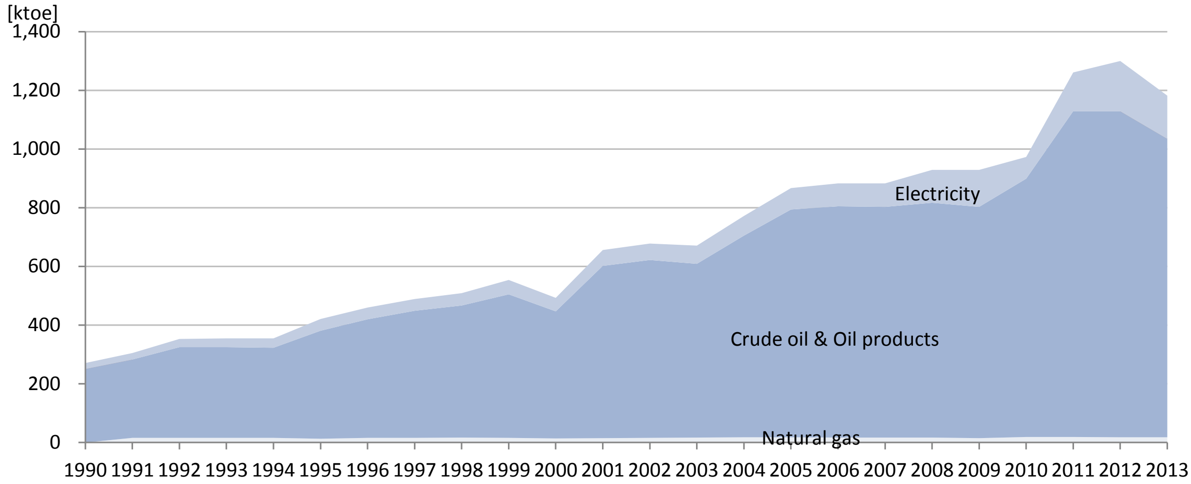
Figure 6-10 shows the breakdown of final energy consumption of transport sector by the modes of energy supply. It is observed that, reflecting the policy of Bangladesh government to promote the diffusion of CNG vehicles, the increase of energy demand of this sector is mainly covered by natural gas. However another trend can also be seen from 2011 when the increase of natural gas consumption became moderate and instead the consumption of oil products increased.



Source: IEA statistics

Figure 6-10 Historical Trend of Transport Sector Energy Consumption (1990-2013)

Figure 6-11 shows the breakdown of final energy consumption of other sectors such as agriculture by the modes of energy supply. Oil products account for an overwhelmingly large share. The share of electricity in the total final energy consumption is still only about 10% of the total final energy consumption but this share is gradually gaining.



Source: IEA statistics

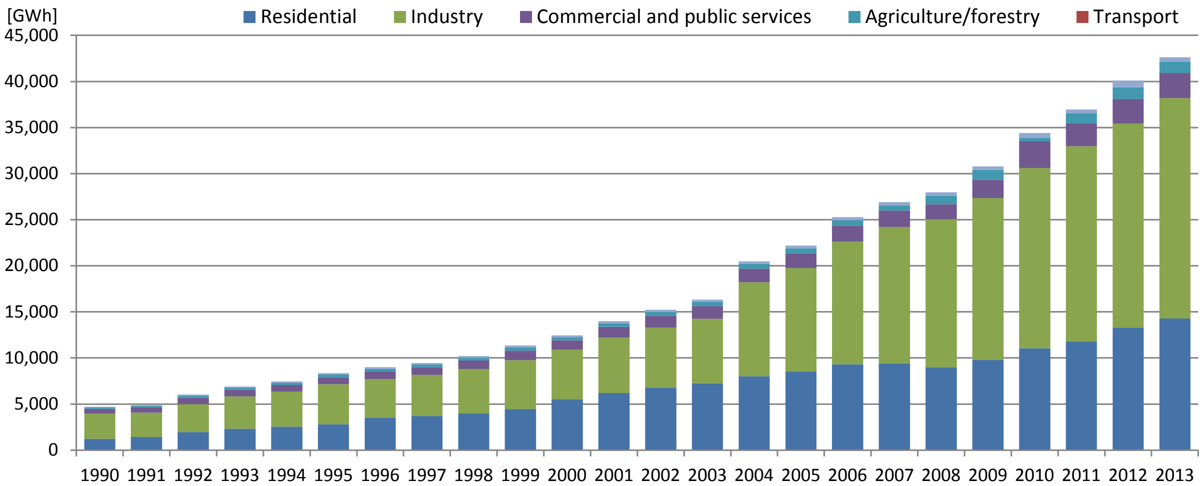
Figure 6-11 Historical Trend of Other Sectors (e.g. Agriculture) Energy Consumption (1990-2013)

6.1.5 Historical trend of electricity consumption and sectorial breakdown

The historical trend of electricity consumption in Bangladesh broken down by sectors, which is available from IEA statistics, is shown in Figure 6-12. From 1990 to 2013, the total electricity consumption increased by 9.1 times (10.1% p.a.), which is far higher than that of the total final energy consumption (see Figure 6-2: 2.2 times, 3.6% p.a.)

Looking at each sector, the industrial sector, which accounts for more than half of the total, increased by 8.8 times (9.9% p.a.) during that period, and the residential sector by 11.7 times (11.3% p.a.). These two sectors' growth rate is much higher than these sectors' growth rate in total final energy consumption, which means that the electrification of energy consumption i.e. shift to electricity supply from other modes of energy supply, is in progress.

On the other hand, the electricity consumption of commercial/public services sector increased by 5.1% (7.3% p.a.) during that period, which is lower than that of other sectors. In addition to that, the gap between the growth rate of this sector's electricity consumption and that of the sector's total energy consumption (3.8 times, 6.0% p.a.) is relatively small compared to other sectors, which means that this sector's shift to electricity supply is relatively dull. This is probably because most of the energy supply to the commercial/public services sector was established from scratch in the form of modern energy supply system consisting of electricity and gas.



Source: IEA statistics

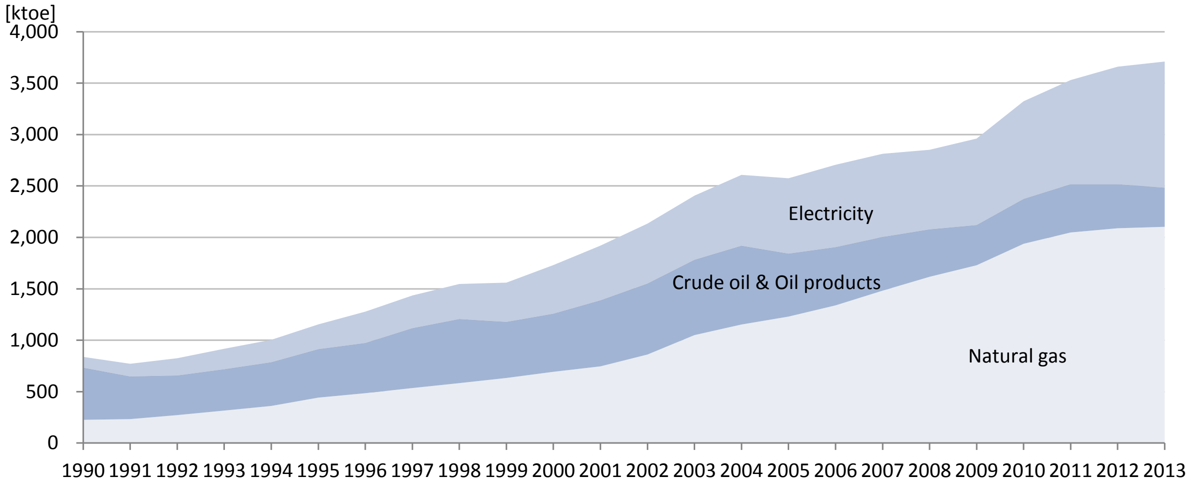
Figure 6-12 Historical Trend of Electricity Consumption in Bangladesh (1990-2013)

6.2 Civilian Sector (Residential and Commercial/Public Services)

6.2.1 Current status of energy demand

(1) Residential Sector

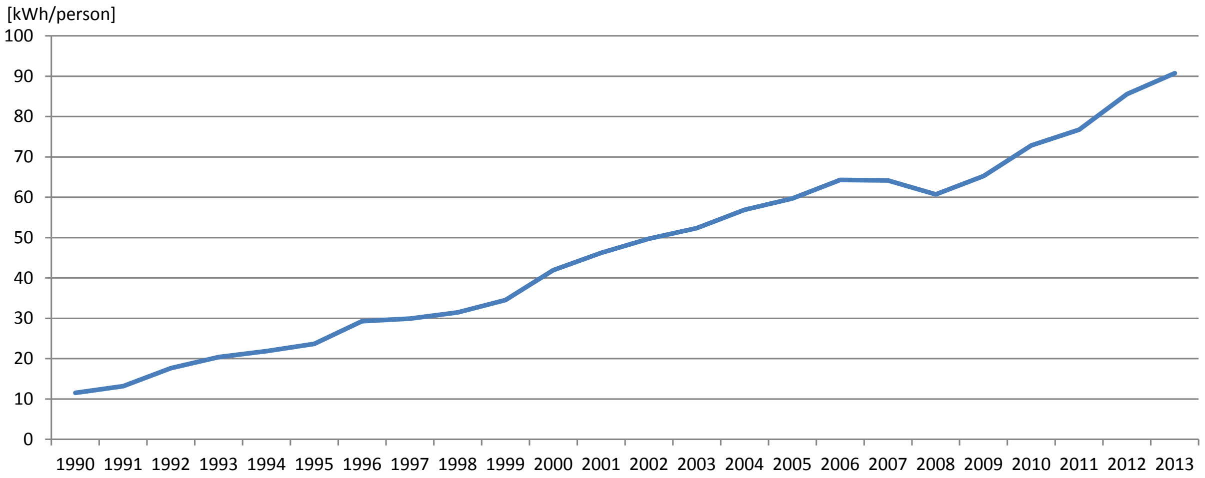
As observed in Figure 6-7, "Biofuels and waste", which is supposed to be mainly non-commercial energy source, accounts for a large share in the energy consumption of the residential sector. The historical trend of other modes of energy supply to end-consumption, i.e. electricity, gas, and oil products is shown in Figure 6-13. Among these three sources, oil products (e.g. kerosene) accounted for more than half as of early 1990s but as the supply of electricity and gas is getting diffused, consumption of these energy sources increased rapidly whereas the consumption of oil products started to decline. From 2011 to 2012 the growth of natural gas consumption became moderate and electricity consumption increased considerably.



Source: IEA statistics

Figure 6-13 Trend of Residential Sector Energy Consumption (excluding Biofuels and waste)

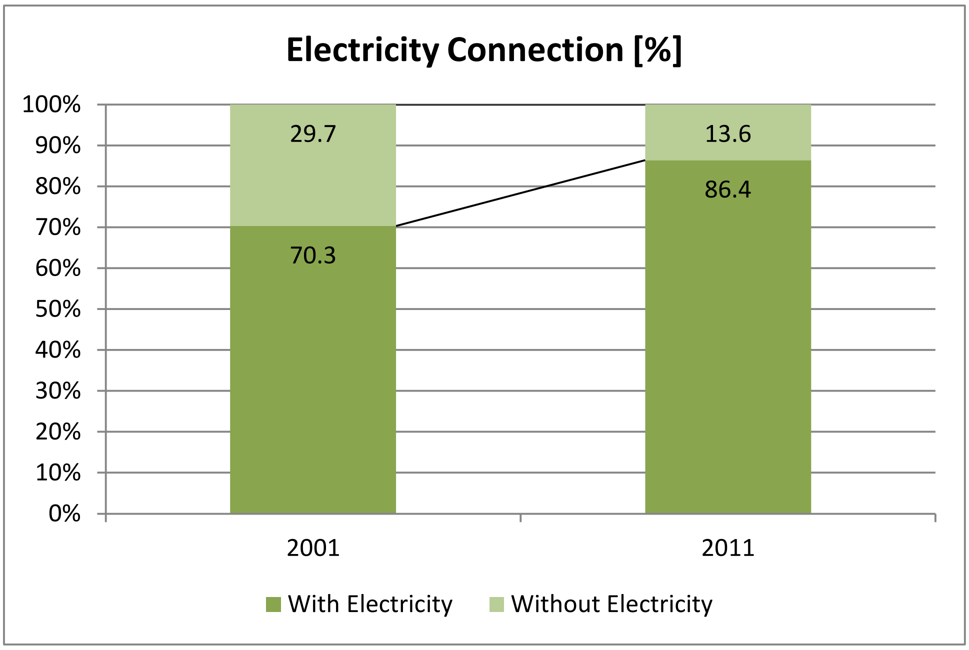
Figure 6-14 shows the historical trend of electricity consumption of residential sector divided by population. The electricity consumption per capital increase by about eight times in twenty-three years from 11.5 kWh/person in 1990 to 90.8 kWh/person in 2013, though this number decreased from 2012 to 2013. This implies not only the progress of electrifying the unelectrified villages and households but also the increase of energy consumption of the already electrified households as well as the shift of energy consumption from other sources to electricity as the background of this rapid increase.



Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

Figure 6-14 Historical Trend of Residential Sector Electricity Consumption per Capita

One of the statistical data that deals with household electrification is the "Population & Housing Census" conducted by the Bangladesh Bureau of Statistics (BBS). According to this survey, household electrification saw an improvement from 70.3% in 2001 to 86.4% in 2011. However, judging from the objective of this census, the "Electricity connection" appears to include not only the grid-connected electricity supply but also the electrification with stand-alone solar home system (SHS). Therefore this 86.4% household electrification may be overestimated if we define "electrification" to be the status of a household where electricity is accessible without quantitative limitations.



Source: Population & Housing Census-2011, Bangladesh Bureau of Statistics

Figure 6-15 Household Electrification Rate (2001 and 2011)

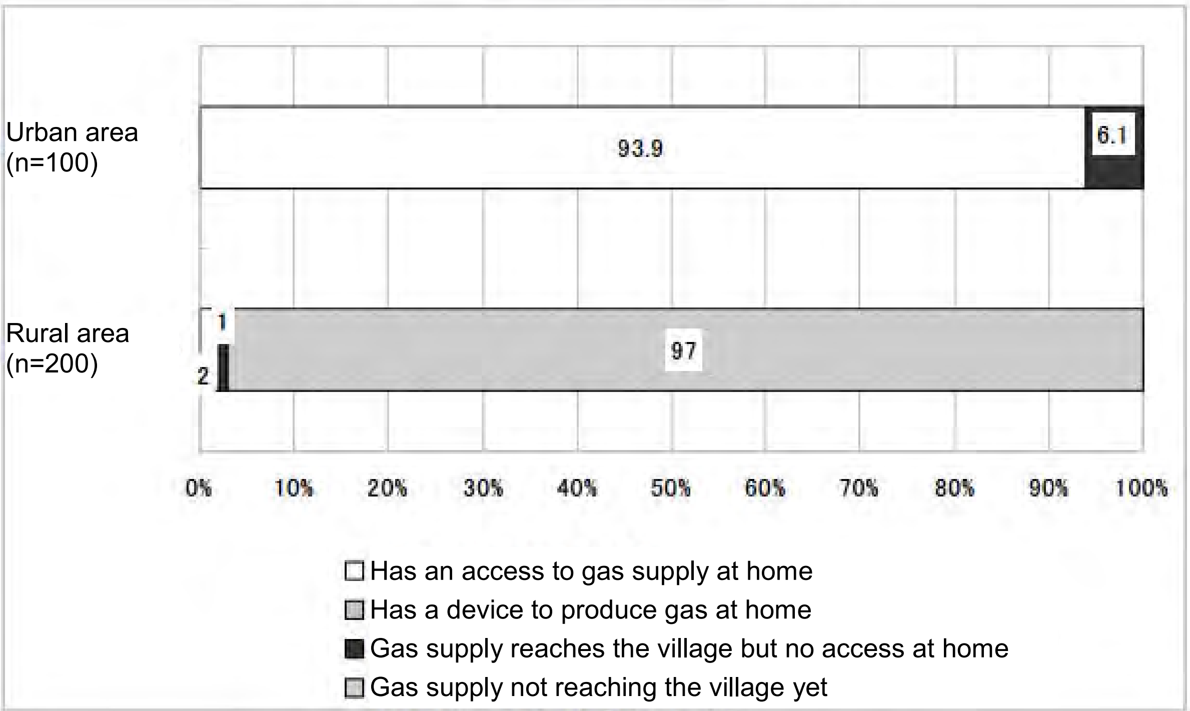
Another statistical survey published by BBS, which is called "Household Income & Expenditure Survey (HIES)", presents that the nation-wide household electrification rate as of 2010 was about 55%. This result significantly deviates from "86% in 2011" as seen in the census data, and there is a possibility that the definition of electrification may be different between them, such as whether to include SHS electrification or not. This survey classifies the status of household electrification not only into administrative divisions but also into rural/urban categorization. Whereas the household electrification in urban area has already reached 90%, the electrification rate in rural area is still only 42%, which implies a huge gap in energy supply infrastructure between urban and rural areas.

Table 6-1 Household Electrification Rate for Each Administrative District

	National	Barisal Div.	Chittagong Div.	Dhaka Div.	Khulna Div.	Rajshahi (Former) Div.	Rajshahi Div.	Rangpur Div.	Sylhet Div.
National	55.26	40.12	60.34	67.34	54.13	41.73	51.88	30.07	47.22
Rural	42.49	31.62	48.84	47.36	45.55	36.17	46.94	24.44	39.09
Urban	90.10	82.33	92.31	96.15	83.83	72.85	75.53	68.68	88.94

Source: Household Income & Expenditure Survey (HIES) 2010, Bangladesh Bureau of Statistics

There is also a survey on the status of household's access to gas supply. According to the study report that summarizes the results of inquiry survey that was conducted on 300 households in Bangladesh between 6th December 2010 and 14th January 2011, 93.9% of households in urban area had an access to gas supply while only 2% of households in rural area had an access, and here again a huge gap in energy supply infrastructure between urban and rural areas can be observed.



Source: JETRO (Japan External Trade Organization) "Study Report on the Potential Needs of BOP Business in Bangladesh: Energy Sector", March 2011

Figure 6-16 Status of Access to Gas Supply in Urban and Rural Areas

According to the results of inquiry survey on the energy consumption in rural area of Bangladesh that was conducted by the World Ban Group in 2004, biomass energy was mainly for cooking and firewood was the most consumed energy source and accounted for 41% of biomass energy for cooking in terms of weight. As for the lighting, grid electricity and kerosene were widely used, and only grid electricity served for cooling.

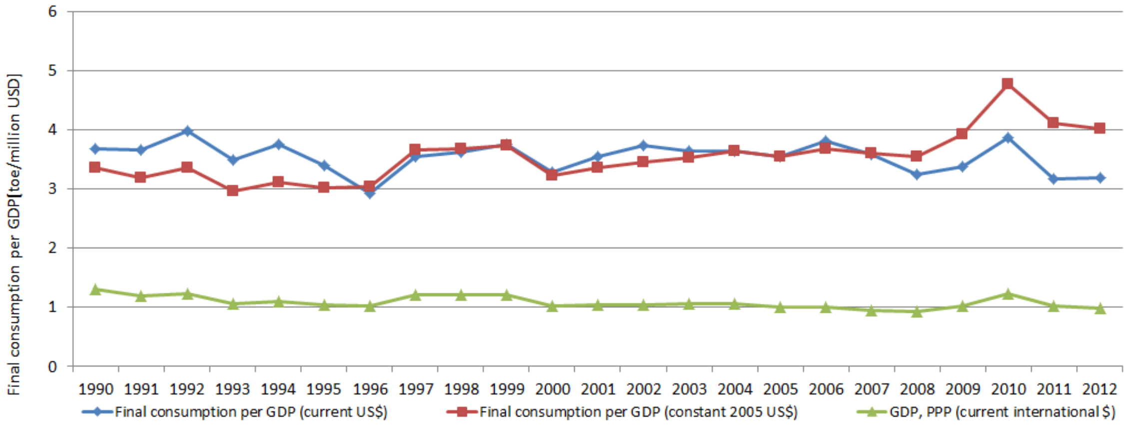
Table 6-2 Annual Energy Consumption per Capita in Rural Area (surveyed in 2004)

Energy Sourcce		Heating			Cooling	Lighting	Amusement	All Uses
		Cooking	Parboiling	Others				
Biomass								
Fuelwood	kg	1064.84	28.60	92.77	-	-	-	1,186.21
Tree leave	kg	470.67	29.99	0.85	-	-	-	501.51
Crop residue	kg	538.86	164.41	2.72	-	-	-	708.18
Dump cake/stick	kg	503.68	16.07	4.16	-	-	-	523.90
Non-Biomass								
Kerosene	liter	1.76	-	0.07	-	27.16	-	28.98
Grid electricity	kWh	0.25	-	4.00	49.50	80.74	9.34	143.83
Dry-cell batter	piece	-	-	-	-	-	-	15.01
Candle	piece	-	-	-	-	15.86	-	15.86
LPG/LNG	liter	0.05	-	-	-	-	-	0.05
Natural gas	Tk	9.59	-	-	-	-	-	9.59
Storrage cell	kWh	-	-	-	-	0.14	0.41	0.55

Source: M. Asaduzzaman et al. (2010) "Restoring Balance; Bangladesh's Rural Energy Realities", World Bank Working Paper No.181.

(2) Commercial/Public Services Sector

The final energy consumption of the commercial/public services sector has also been increasing by 3.8 times (6.0% p.a.) from 1990 to 2013. Looking at the energy consumption per GDP, the ratio against PPP-based GDP sees an almost flat line, implying a possibility of strong correlation.



Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

Figure 6-17 Final Energy Consumption per GDP in Commercial Sector

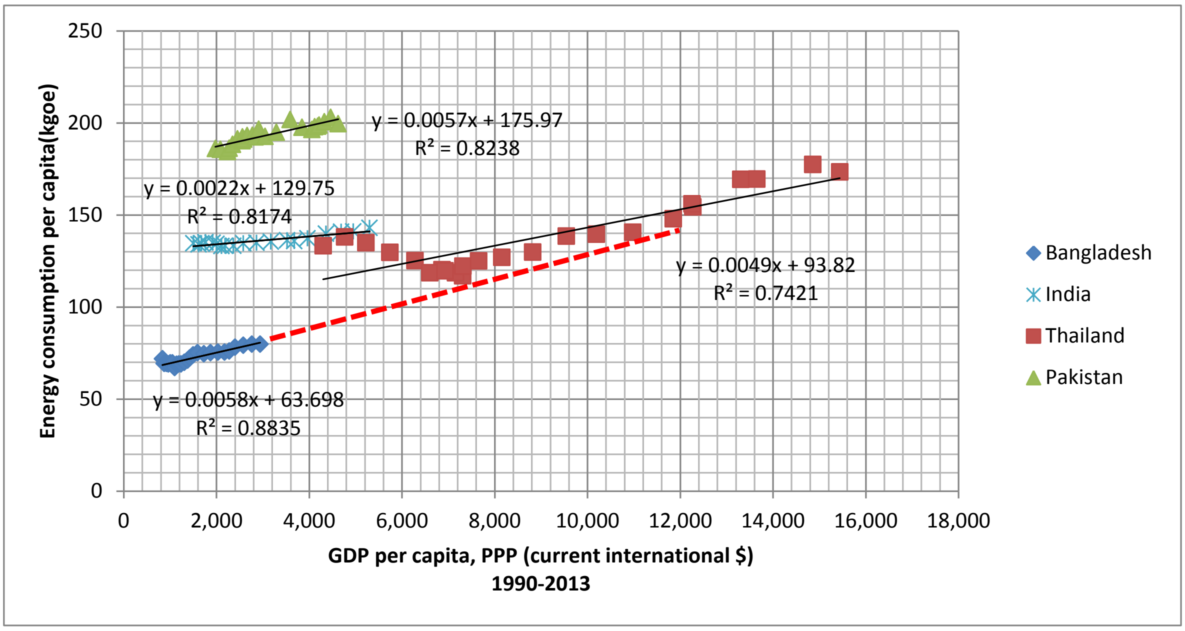
6.2.2 Key factors that affect future prospects of energy demand

There are three key factors that affect future prospect of energy demand in the residential sector. The first factor is population growth. The population is expected to grow steadily, reaching to nearly 200 million people with half of the population residing in the urban area and the other half in the rural area by 2041. Currently there is a significant difference in energy demand between urban and rural households. However such difference will be diminished by 2041, when households in the whole country will enjoy a good standard of living. The second factor is the market penetration rates of electric appliances such as refrigerators, washing machines, ACs and microwave ovens. Presuming that 100% electrification will be achieved by 2021, those appliances will be acceleratedly introduced. At the same time, it is noted that policies will be in place to promote energy efficient home appliances such as ACs, refrigerators, fans and LEDs. The third and last factor is availability of gas supply. It is pointed out that newly built households will have limited access to gas supply, therefore LPG filling the gap of demand and supply.

In the commercial sector, the key factors are growth of the tertiary industry and expansion of office buildings.

6.2.3 Projection of energy consumption

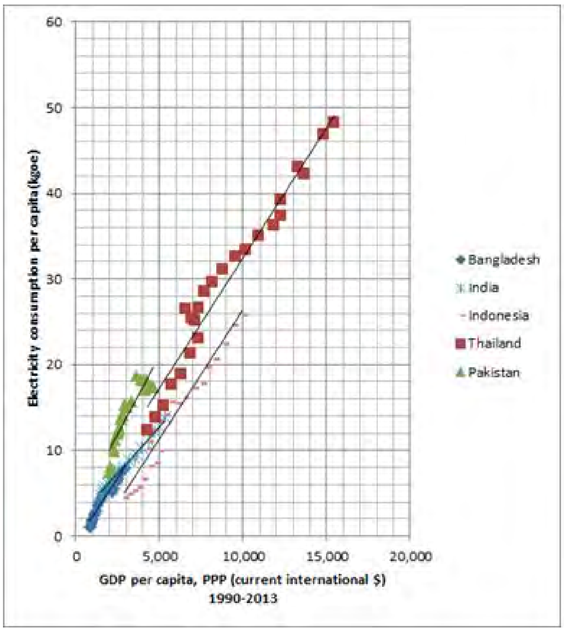
Projection of energy demand in the residential sector is made in the following manner. Firstly, overall energy demand is estimated to grow according to the historical annual growth rate (1990-2013), i.e. 2.2%. As shown in the figure below, there is a rough correlation between energy consumption per capita and GDP per capita. Therefore, energy demand in the Bangladeshi residential sector is expected to grow constantly.

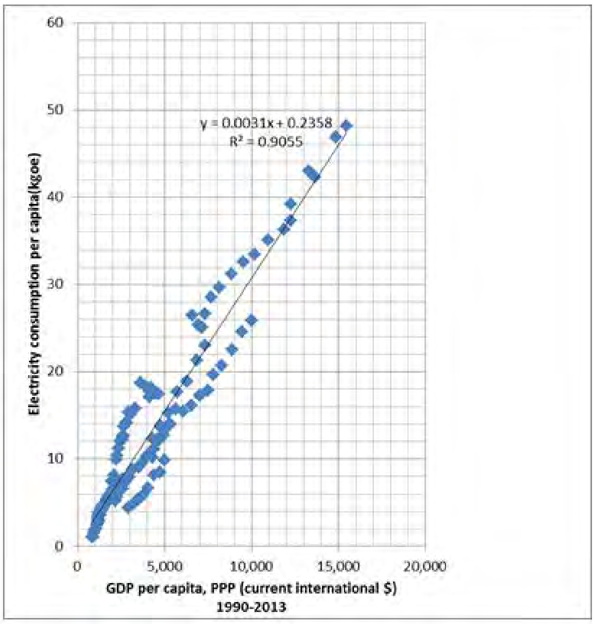


Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

Figure 6-18 Energy Consumption and GDP in Residential Sector

Secondly, demand for electricity is estimated drawing upon other countries' experiences. As shown in the figure below, it is widely discussed that electricity consumption per capita has a strong correlation with GDP per capita. Therefore approximation formula (y = 0.0031x + 0.2358) is applied to GDP growth of Bangladesh to project electricity demand.





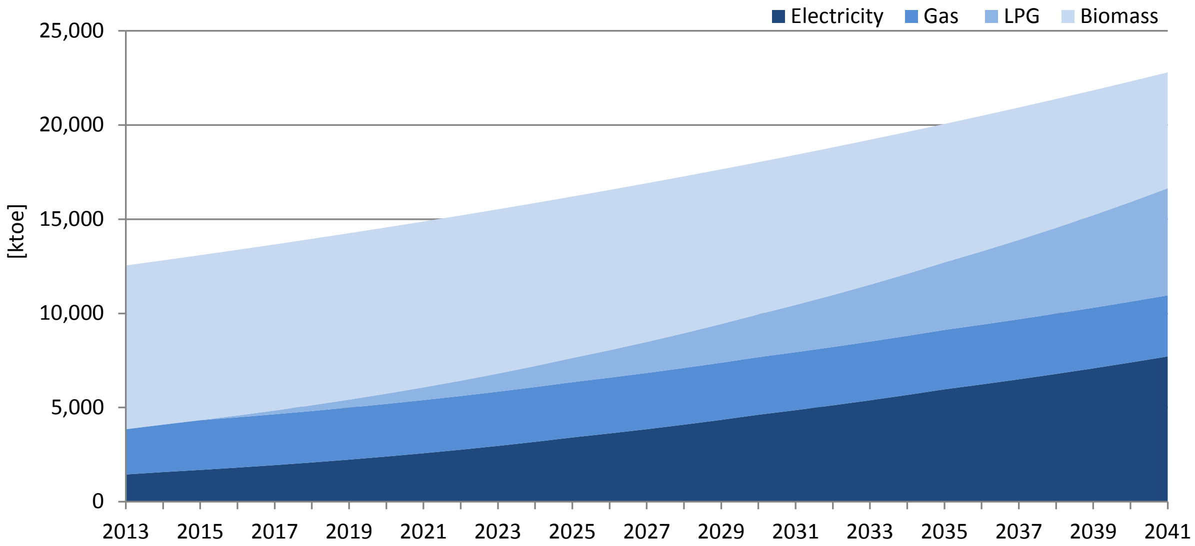
Source: Prepared by JICA Survey Team based on IEA statistics and World Bank database

Figure 6-19 Electricity Consumption and GDP in Residential Sector

Thirdly, gas demand is estimated. Unlike case of electricity, other countries' experiences show that there is little correlation between gas consumption and GDP growth. As the existing prospects of gas consumption in Bangladesh, Petrobangla's "Five Year Gas Supply Strategy (2015-2019)" estimates that gas demand in the residential sector will grow at 4.8% annually. However, such growing demand is unlikely to be met due to shortage of gas supply. It is thought to be rational to estimate that gas supply only grows in proportion to population growth, which means that gas consumption per capita remains constant from 2015 on. It is assumed that LPG will fill the gap of gas demand and supply.

Fourthly and lastly, the remaining portion, derived from "Overall energy demand in the residential sector – Electricity – Natural Gas – LPG," is categorized as "others" of which main source is biomass (both solid and gas).

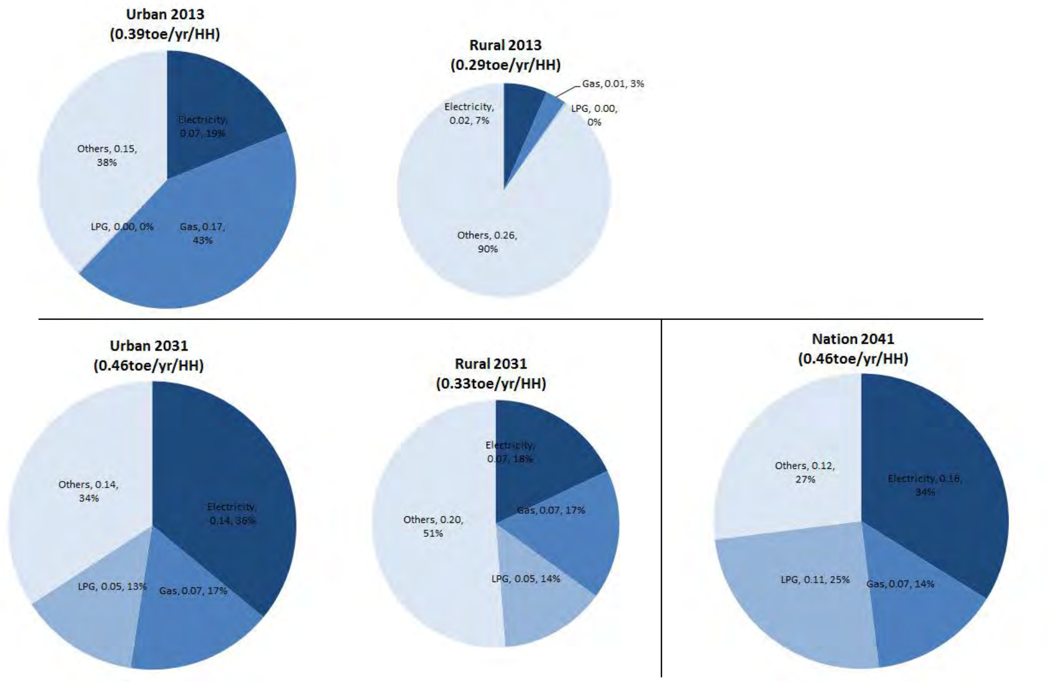
Figure 6-20 shows the projection of energy demand in the residential sector.



Source: JICA Survey Team

Figure 6-20 Energy Demand Projection in Residential Sector

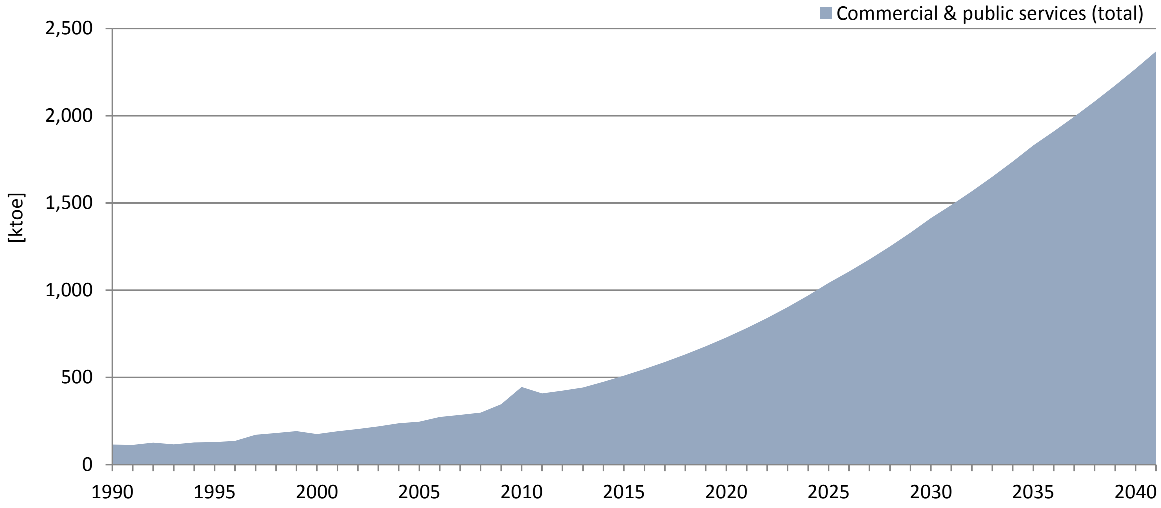
Differences of energy consumption patterns in urban and rural households are shown in some snapshots of year 2013, 2031 and 2041. With the improvement of living standard in rural area, the difference of energy consumption between urban and rural areas is expected to be diminished by 2041.



Source: JICA Survey Team

Figure 6-21 Energy Consumption Pattern of Urban and Rural Households

In the commercial sector, its activities are expected to grow continuously. Energy demand is expected to increase in line with GDP growth. It is noted that various Energy Efficiency and Conservation (EEC) policies and programs will be implemented in buildings, resulting in 25% energy reduction compared to Business as Usual.



Source: JICA Survey Team

Figure 6-22 Energy Demand Projection in Commercial & Public Services Sector

6.3 Industrial Sector

6.3.1 Current status of energy demand

(1) Positions of Industrial Sector in Bangladesh

The industrial sector roughly consists of manufacturing and mining. This study mainly focuses on manufacturing in discussing energy demand of the industrial sector. As seen in Figure 6-23 and Table 6-3, which is the sectorial breakdown of GDP of Bangladesh in 2014 (provisional, real base), whereas manufacturing accounts for 19.45% of the country's total GDP, the share of mining is only 1.64% and is less than one-tenth of that of manufacturing. Though the statistical data to provide breakdown of energy consumption between manufacturing and mining is not available, the share of mining in the energy consumption is supposed to be much less than that in GDP because the energy supply for producing crude oil and natural gas, which represents the mining industry in Bangladesh, is mainly self-contained.

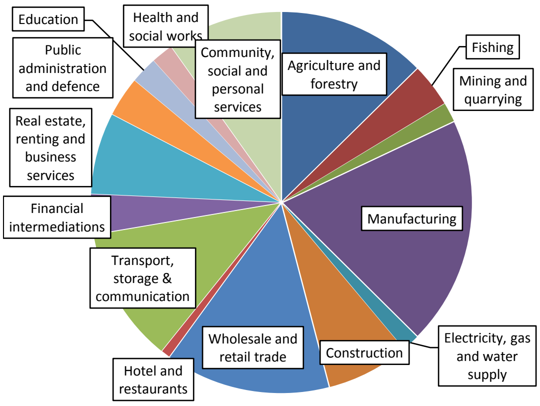


Figure 6-23 Sectorial Composition of GDP in 2014

Table 6-3 Sectorial Composition of GDP in 2014

Industries	GDP (million Tk)	Percentage
Agriculture and forestry	939,115	12.64
Fishing	274,537	3.69
Mining and quarrying	121,880	1.64
Manufacturing	1,445,438	19.45
Electricity, gas and water supply	108,746	1.46
Construction	524,380	7.06
Wholesale and retail trade	1,046,268	14.08
Hotel and restaurants	55,701	0.75
Transport, storage & communication	857,244	11.54
Financial intermediations	252,168	3.39
Real estate, renting and business services	516,092	6.95
Public administration and defence	252,030	3.39
Education	169,309	2.28
Health and social works	137,964	1.86
Community, social and personal services	729,554	9.82
Total	7,430,426	100.00

Source: Bureau of Statistics, "GDP of Bangladesh at 2013-2014(p)"

The growth rate of manufacturing sector for the past five years has outperformed that of total GDP, which indicates that manufacturing in Bangladesh has been growing rapidly.

Table 6-4 Growth Rate of Manufacturing and Total GDP (real base)

	2010	2011	2012	2013	2014
Manufacturing	6.65%	10.01%	9.96%	10.31%	8.68%
Total GDP	5.57%	6.46%	6.52%	6.01%	6.12%

Source: Bureau of Statistics, "GDP of Bangladesh at 2013-2014(p)"

Figure 6-24 and Table 6-5 show the sectorial breakdown of the employment in Bangladesh as of 2010.

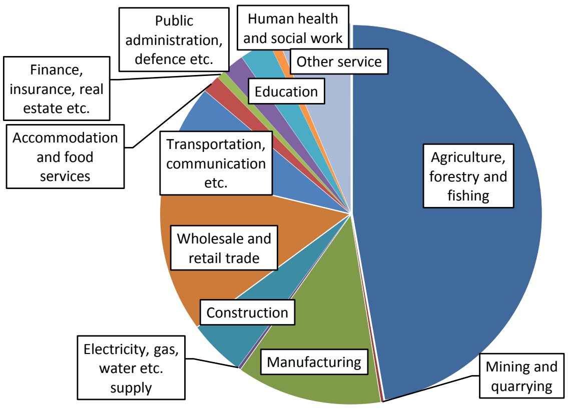


Figure 6-24 Sectorial Share of Employment (2010)

Table 6-5 Sectorial Share of Employment (2010)

Industries	Employees (000)	Percentage
Agriculture, forestry and fishing	25,727	47.57
Mining and quarrying	109	0.20
Manufacturing	6,737	12.46
Electricity, gas, water etc. supply	123	0.23
Construction	2,617	4.84
Wholesale and retail trade	7,557	13.97
Transportation, communication etc.	4,038	7.47
Accommodation and food services	832	1.54
Finance, insurance, real estate etc.	399	0.74
Public administration, defence etc.	1,030	1.90
Education	1,402	2.59
Human health and social work	430	0.80
Other service	3,431	6.34
Total	54,084	100.00

Source: Bangladesh Bureau of Statistics "Labor Force Survey 2010"

Whereas the share of manufacturing in the total employment is 12.4% the share in GDP is 19.45% (or 17.20% in 2010, when is the Labor Force Survey was conducted), which means that the manufacturing's value added per capita outperforms that of the average of all sectors. Assuming that there is no constraint on the liquidity of population migration, the trend of population influx from rural area to urban area to provide human resources to the manufacturing is expected to continue.

(2) Status of Energy Demand for Each Industrial Subsector

It needs to be noted that, even within the manufacturing sector, characteristics of energy demand may vary among subsectors, but at present no relevant statistic data exist in Bangladesh concerning the status of each subsector's energy consumption. Therefore, there's a limitation with quantitative analysis of each subsector's energy consumption using the data that are publicized by the government of Bangladesh.
This study therefore referred to past literature on the status of energy consumption of manufacturing in Bangladesh, such as the study report for grasping the status of each subsector's energy consumption. Literatures that were mainly referred to are the study report of JICA's "Bangladesh Energy Saving Master Plan Formulation Project" (2015) as the reference for energy supply to each subsector, and ADB's "Bangladesh: Industrial Energy Efficiency Finance Program" (Project Number: 45916, May 2014) as the reference for the current status of each industrial subsector. In addition, the information on the status of installing captive power generators in Bangladesh, which is publicized by Bangladesh Bureau of Statistics (BBS), is also referred to for supplementing the aforementioned.

1) Textile and Garment

In the textile and garment industry, both electricity and thermal energy are used in the process of manufacturing. General characteristics of electricity supply are as follows.

1. State Electricity Grid/State Utility: Almost every factory is connected to the grid of distribution companies. Voltage level of electricity supply varies among 33 kV, 11 kV, and 0.4 kV.
2. Captive Power Generation Utilizing Natural Gas: It is generally observed that electricity generation from on-site generators is utilized for sustaining factory production.
   According to existing literature, 80% of factories have their own captive power plant. The textile sector alone has a captive generation capacity of 1,100 MW, while the country as a whole has a total generation capacity of about 8,525 MW as of December 2012.
3. Diesel Generators: As a source of back up supply.
4. Thermal energy: Used for steam generation and hot water.

Since the most common steam generators are gas powered, there is frequent interruption in the production of steam whenever gas pressure reduces. Currently, new gas connections to industrial facilities have been halted due to the demand-supply gap. New facilities are therefore utilizing diesel-fired boilers, furnace oil boilers, compressed natural gas (CNG) boilers, etc. Some factories have started to use exhaust gas boilers (EGB) to get steam from generator, boiler and furnace exhaust; based on the ADB report, however, utilization of such technologies is less than 50%.

It needs to be noted that there's a commonly observed practice in many factories that the electricity demand mainly rely on captive generation from natural gas whereas the power supply from grid is used as back-up. This is due to the fact that the tariff of gas supply for captive power is set lower than electricity tariff, i.e. electricity supplied by distribution companies to factories is at the rate of 6.95 BDT/kWh while the cost of electricity generation from captive power is about 3 BDT/kWh, even without utilizing waste heat recovery. This is why most industrial facilities prefer using captive power generation.

2) Steel-making and Re-rolling

Main sources of energy for iron and steel industry in Bangladesh are electricity, natural gas and HSD (high speed diesel). In fact, this subsector is the largest consumer of natural gas in Bangladesh. In general, induction furnaces use electricity from grid as their source of energy supply, whereas natural gas use is predominantly in re-rolling mills.

Most of the iron and steel factories are connected with the grid at 33 kV or 11 KV voltage level. Many iron and steel manufacturers also generate electricity through gas-fired captive power generation for sustaining factory production. The captive generation is said to be cheaper than electricity supply from distribution companies by up to 30%. HSD is predominantly kept as a source of stand-by captive power generation.

3) Cement

The source of energy supply for cement factories in Bangladesh is electricity, which is utilized to drive motors in several production processes. This electricity is either drawn from the grid or generated from onsite captive power generators using natural gas.

Factories usually have grid connection at 33 kV level. Though many factories prefer to have their own gas connection and generate electricity from natural gas, only 20% of the units have their own captive power plant. In terms of energy conversion, captive power generation is less efficient than grid electricity, as the typical efficiency of a captive power plant is only 30%. Therefore the captive power generation is not a preferred option in terms of energy economics though captive power generation may be less costly because of the government's energy price policy.

4) Glass, Sanitary and Tiles

Almost every factory has a connection to the grid at 33 kV or 11 kV. However, electricity supply mainly relies on captive power generation and grid connection is used mainly as backup power when gas supply is interrupted or is of low pressure. Natural gas is also used as the fuel for kilns, and since the natural gas in Bangladesh does not contain Sulphur, ceramic products in Bangladesh is said to have a bright color.

New gas connections have been suspended since March 2009, causing the stagnation of establishing new factories. Because of the restrictions in new connections of gas supply, some new companies use CNG or HSD (High Speed Diesel) as substitute. HSD is also used as the fuel for back-up power generation for lighting.

The ceramics industry is characterized by the fact that its manufacturing process is vulnerable to low voltage electricity and low gas pressure, and this is said to be the main reason for the recent trend of lowered quality and the slump in export. Ceramic tableware processes requires uninterrupted power and gas supply so that the 360°C temperature is maintained constantly for 24 hours, and drops in temperature needs to take at least 12 hours for recovery which causes a huge loss in production. Stable supply of electricity and gas is indispensable.

5) Chemical, Chemical Fertilizer, Pulp & Paper

Many factories in chemical, plastics and pulp & paper industries rely on electricity generation through captive power generators for sustaining factory production. About 55% of factories are said to have their own captive power plant. Factories that have both electricity and gas connections use grid electricity as backup power when gas supply is interrupted or of low pressure. HSD is used only as the fuel of backup generation for emergency lighting purposes only.
The fertilizer industry is very much reliant on natural gas as it is not only the source of energy supply but also the main raw material in the production of urea, which is one of main elements of fertilizer.
Electricity supply quality is poor and the factories frequently suffer five to six hours of load shedding in summer in Dhaka area, where SMEs in the plastics sector are located. Productivity is badly affected by shortage or fluctuations in electricity supply. Firms that have gas connections for captive power generation enjoy relatively better conditions of power supply, but after early 2009, when the government stopped new gas supply connections, firms have experienced difficulties with their planned expansion projects.

6) Jute Mills and Agro Processing

Jute mills in Bangladesh mainly use electricity for energy supply and the factories have a connection to the grid at 11 kV or 0.4 kV.
Agro processing plants usually use captive power generation as the energy source for sustaining factory production. 50% of the factories have their own captive power plant, and use gas or diesel as fuel sources. Some factories that do not have gas connection or that only receive low pressure gas utilize diesel for production and lighting. Since diesel oil is costly, the production cost of these factories is apt to be high.

7) Brick

According to the academic article published by Bangladesh University of Professionals (BUP) titled “Securing the Environment: Potentiality of Green Brick in Bangladesh” (BUP Journal, Volume 1, Issue 1, September 2012, ISSN: 2219-4851), bricks manufacturers in Bangladesh usually fire coal in fixed chimney kiln (FCK) and bull's trench kiln (BTK). It is said that 23 tons of coal is consumed for making 2 crore BDT of bricks. Kilns such as FCK and BTK have problems not only with their low energy efficiency, but also with their environmental burden of PM2.5 and CO2. These factories have become one of main reasons of atmosphere pollution in Dhaka are in dry season, because they mainly work in dry season.
Currently, government has been providing support for diffusing new manufacturing technology called “Green brick”, which only consumes 7.8-8 tons of coal for making 2 crore BDT of bricks.

8) Fishery Products (Frozen Foods)

According to the study report published by USAID called “Bangladesh Industrial Energy Efficiency Opportunities Assessment Task 1: Industry Profile – Sectors Selection Report” (March 2012”, main energy-consuming appliances at fishery food processing factories are chillers, freezing plants and frozen storage.
The source of energy supply for these fish processing plants is electricity from the grid. Because the power supply from the grid is not stable, these plants also have diesel based captive power generators as back-up.

6.3.2 Key factors that affect future prospects of energy demand

(1) Balance between Grid Electricity and Captive Power (Natural Gas) in Relation to Tariff Policy

As seen in the previous section, the current status of industrial sector energy demand is reviewed for each subsector, referring to the existing study reports. It was observed that, while there are characteristics of energy supply and demand unique to each subsector, a common issue in the industrial sector was also identified, that is, the price of natural gas for captive power generation is set at a very low level thus the cost of captive power generation is less expensive than the cost of power purchase from the grid, despite that the energy conversion efficiency is lower than grid power. According to the existing literature, there are many factories that use the electricity from the grid not because it's economically rational but because they wanted to use captive power generation but gave it up due to the gas suppliers' rejection of new connection.

As the domestic gas production is expected to deplete and the dependence on imported LNG will increase, keeping the gas price at a very low level compared to international price level is not desired in terms of national economy. Therefore, on mid- and long-term basis, electricity and gas prices will be rebalanced and both prices will be adjusted to an appropriate level so that a considerable portion of industrial sector energy consumption will naturally shift from captive power generation to grid power supply. In terms of primary energy supply, this means that certain part of natural gas supply will shift to other sources of power generation such as coal.

However, the current status is that the capacity of grid power supply is not sufficient to meet the power demand in Bangladesh hence it will take years to come for the grid power supply to cover the total power demand including the part that is currently fed by captive power. Therefore, rebalance between electricity and gas prices will occur gradually in accordance with the increased capacity of electricity supply and the shift between energy sources will also occur gradually likewise.

In addition, though the electricity price is relatively higher compared to gas price, the current level of electricity price is not sufficient for BPDB to recover the cost of power procurement from power generating companies, as explained in Chapter 19 and afterwards. And it may also need to be considered that drastic increase of electricity and gas prices at once may increase the negative impact on the national economy of Bangladesh. The revision of price policy will be progressed gradually, also from this point of view. Discussion on energy price will be made more in detail in Chapter 19 and afterwards.

In the meanwhile, there are also cases that the manufacturers in ceramics prefer captive power generation also because they need high quality of power supply in the production process but the power supply from the grid is not reliable enough. These subsectors may still choose captive power generation because of supply reliability even when gas price is raised to outperform the power supply from the grid. For motivating them to purchase electricity from the grid, not only increasing the gas price but also improving the quality of power supply to a sufficiently reliable level is needed.

(2) Structural Changes of the Industrial Sector Triggered by Economic Development

This study referred to the existing literature for obtaining basic information on the status of energy consumption in each sector in Bangladesh. However, it was confirmed that only very limited statistic data to serve for the analysis of industrial sector energy demand exist in Bangladesh. In fact, the aforementioned past literatures also obtained very few statistic data and relied a lot on their own estimation for analysis.

In this study, the JICA Survey Team also interviewed relevant stakeholders in Bangladesh such as Ministry of Industries and various business organizations that represent the main industries. However, it turned out that, though only some fragmented information about the energy consumption in each subsector was obtained and that information was basically consistent with the analysis of existing literature, no new statistic data to serve for quantitative analysis was available.

In formulating the prospects of industrial sector's energy consumption, detailed analysis with breakdown by subsectors and energy sources is effective for short-term projection (e.g. in five years, in ten years). However, because it was confirmed that no other statistical data than those obtained in the past studies are available, the methodology of energy demand forecast by analyzing the each subsector and energy source in detail would have limitations.

In addition, if the period of energy demand forecast is relatively short, making a future projection in detail based on the current industrial structure as precondition is effective, but because this study aims at making a long-term projection of energy demand up to 2041, the industrial structure of Bangladesh is expected to change drastically, as discussed in Chapter 5. In other words, the effect of changes in industrial structure itself is expected have more impact on the future prospects of energy consumption of the entire industrial sector rather than the effect of each subsector's trend.

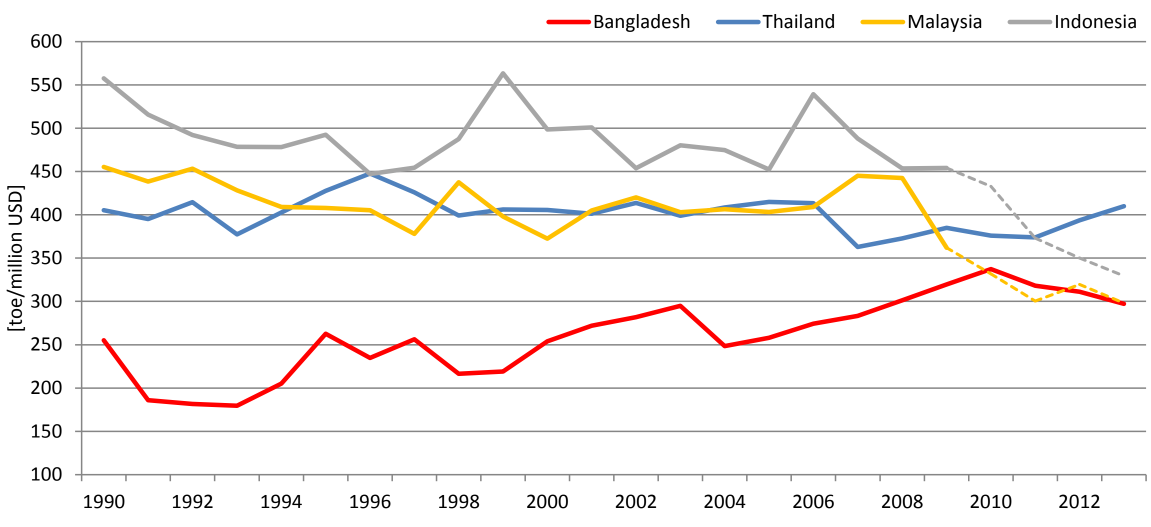
This study therefore adopted a methodology to analyze how the industrial sector's energy consumption of a country changes with the progress of economic development, referring to the experiences of other countries, and then to grasp the prospects of energy consumption of the industrial sector in Bangladesh nationwide.

6.3.3 Projection of energy consumption

In order to analyze the prospects of industrial sector's energy consumption in Bangladesh, this study calculated the industrial sector's energy intensity, i.e. energy consumption divided by the sectorial valued added (= GDP) of manufacturing (constant price). This ratio indicates how much energy (toe) is consumed for the industrial sector to yield a value of 1 million USD.

If this ratio is constant, GDP elasticity of energy consumption is 1. If this ratio increases from the previous year(s), it means that the industrial sector consumed more energy than before for yielding a same economic value, if the GDP increased during this period, the growth rate of energy consumption was much higher than that of GDP. That is, GDP elasticity in this period was higher than 1. If this ratio decreases from the previous year(s), vice versa, i.e. GDP elasticity in this period was lower than 1

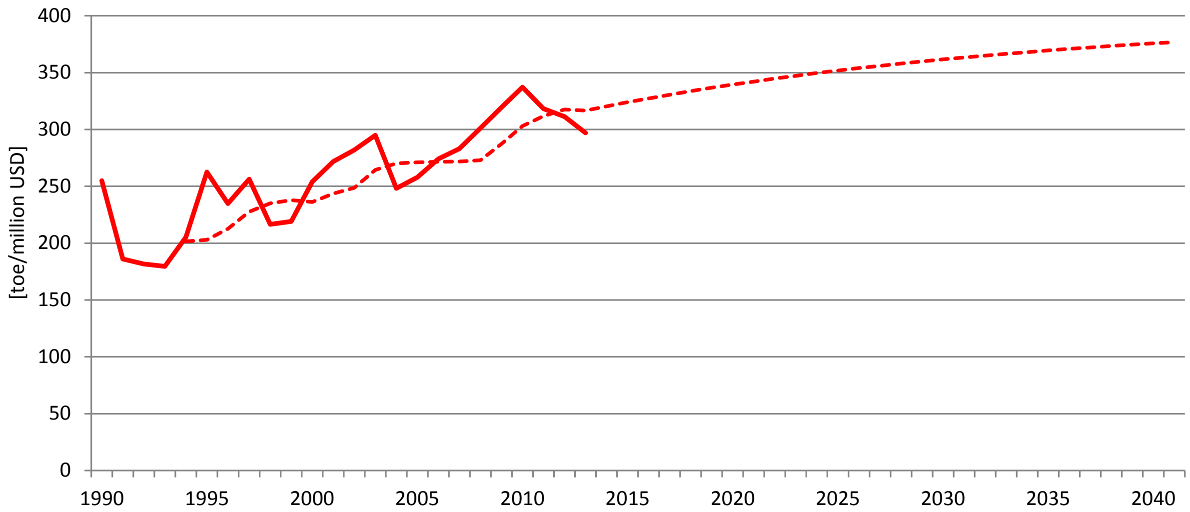
Figure 6-25 shows the historical trend of industrial sector's energy intensity in Bangladesh, in comparison with Thailand, Malaysia and Indonesia. Whereas this ratio has been relatively constant around 400 toe/million USD in Thailand, Malaysia and Indonesia, this ratio is relatively low in Bangladesh, but it has seen a gradually increasing trend.



Source: Prepared by JICA Survey Team based on World Bank database and IEA statistics
Note) Declining trend of energy consumption in Malaysia and Indonesia from 2010 is considered a statistical error

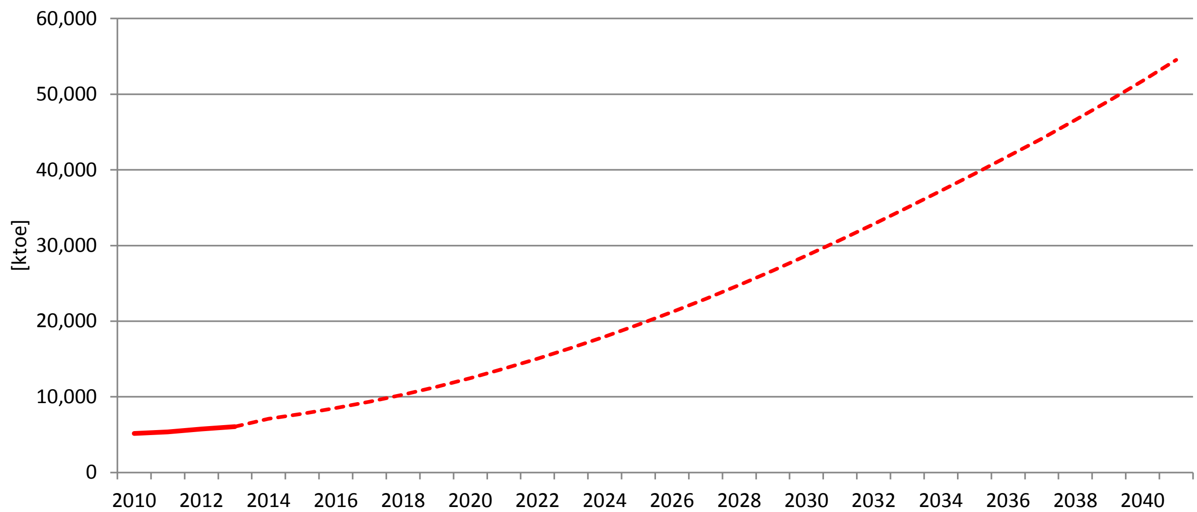
Figure 6-24 Industrial Sector's Energy Consumption per Sectorial Value Added

One of the possible reasons why the ratio of industrial sector's energy consumption to sectorial GDP is creeping up (GDP elasticity higher than 1) in Bangladesh is that the economic development (=industrialization) of this country is still at an early stage and that a shift from labor-intensive industries to energy-consuming industries is in process.
Referring to the historical trend of some ASEAN countries as benchmark, this study assumes that the gradually increasing trend of industrial sector's GDP intensity will continue to increase up to 400 toe/million USD, as shown in Figure 6-26. By multiplying the prospects of this ratio by the projection of sectorial value added (GDP), this study expects that the energy consumption of the industrial sector will reach about 54,500 ktoe in 2041, about eight times increase from 2014, as shown in Figure 6-27. The main drive of the rapid increase of the sectorial energy consumption is the rapid growth of the economy itself, but is also accelerated by the expected increase of the energy intensity.



Source: JICA Survey Team

Figure 6-25 Projection of Industrial Sector's Energy Consumption per Sectorial Value Added



Source: JICA Survey Team

Figure 6-26 Projection of Industrial Sector's Energy Consumption

6.4 Transport Sector

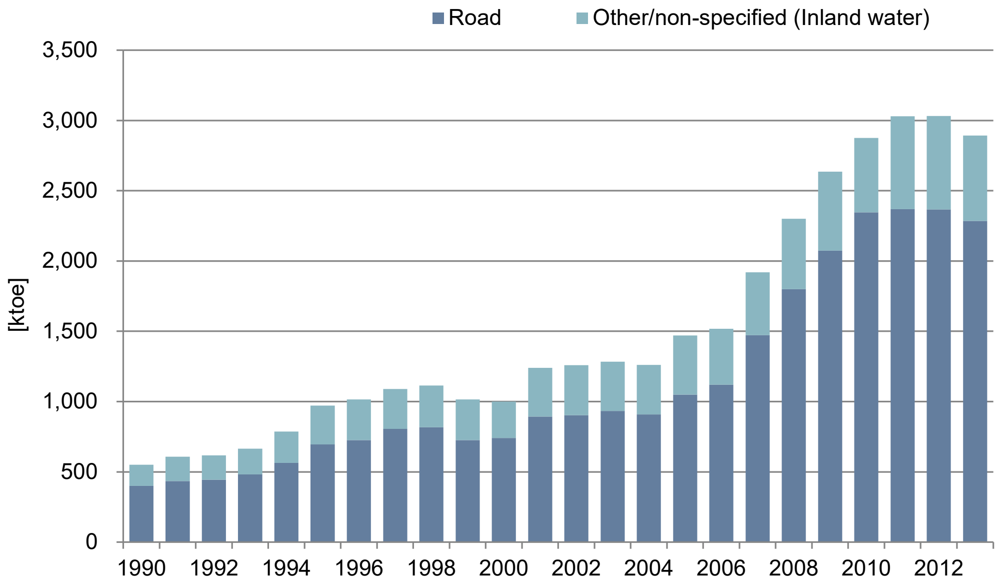
6.4.1 Current status of energy demand

(1) Structure of Transport Sector in Bangladesh

The historical trend of energy consumption of transportation sector is shown in Figure 6-28. It grew more than five times in 23 years, from 544 ktoe in 1990 to 2,893 ktoe in 2013, and especially saw a high growth in late-2000s. Though the growth appears to stop in 2010s, this is considered merely a statistical error considering the recent progress of motorization of the country, and the trend of rapid growth is supposed to continue.

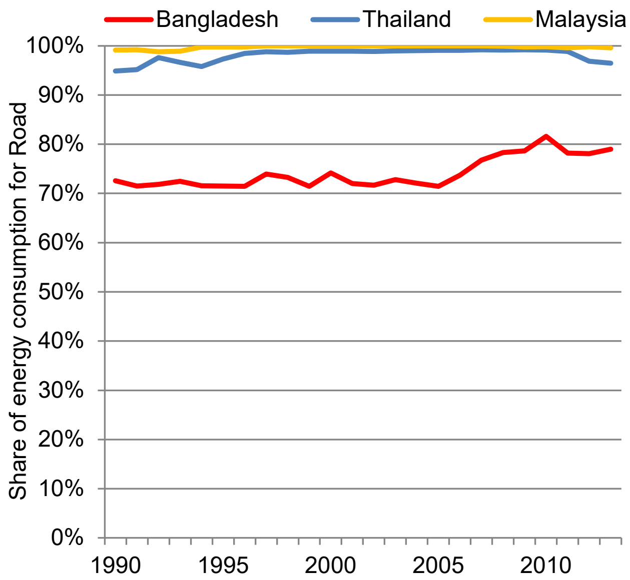
Looking at the breakdown of energy consumption by the type of transport, road transport accounts for about 80% of the total sectorial energy consumption, and the share has been creeping up as seen in Figure 6-29.

The reason why the share of road transport is relatively small compared to other countries (such as Thailand and Malaysia where its share is higher than 90%) is that Bangladesh has the large inland waterway networks and water transport has a relatively large share in total transport, though the share in sectorial energy consumption has been slightly decreasing, reflecting the progress of motorization. Development of river bridges is expected to accelerate the trend that water transport gives way to road transport.



Source: IEA Energy Balances

Figure 6-27 Historical Trend of Transport Sector's Energy Consumption in Bangladesh

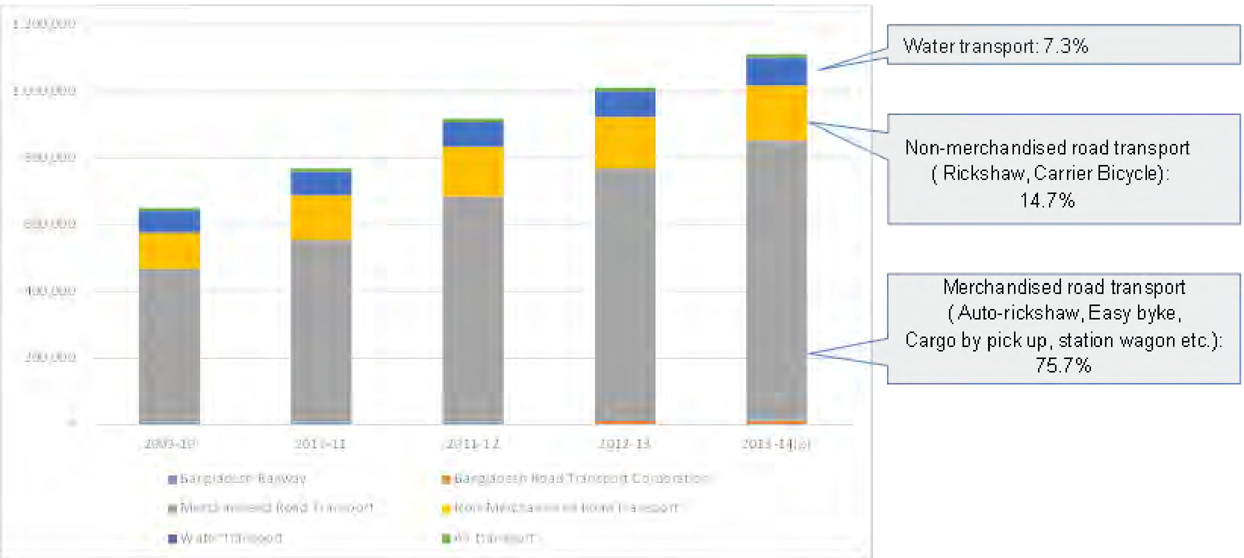


Source: IEA Energy Balances

Figure 6-28 Share of Road Transport in Transport Sector's Energy Consumption

Figure 6-30 shows the trend of modal share in transport sector in terms of economic value. More than 90% of value added in transportation sector is from road transport whereas the remaining parts are water transport and air transport, and railway.

Road transport can be broken down into non-merchandised road transport, such as rickshaw and carrier bicycle, merchandised road transport, such as automobiles. The merchandised road transport can be further broken down into passenger transport and cargo transport. At the moment, auto-rickshaw/tempo, easy bike and cargo (by pickup, station wagon etc.) mainly contributes to the value added of merchandised road transport in Bangladesh.



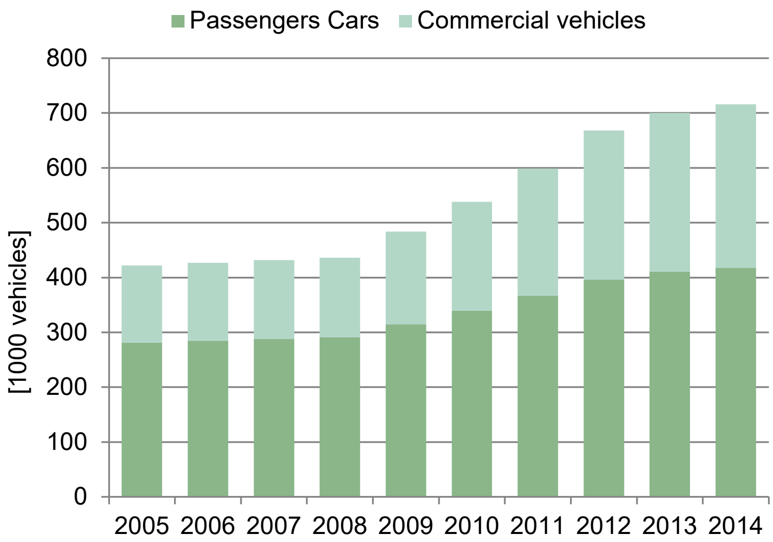
(Unit: million BDT at current price)

Source: Prepared by JICA Survey Team based on BBS "Bangladesh National Accounts Statistics"

Figure 6-29 Value Added of Transport Sector with Modal Breakdown

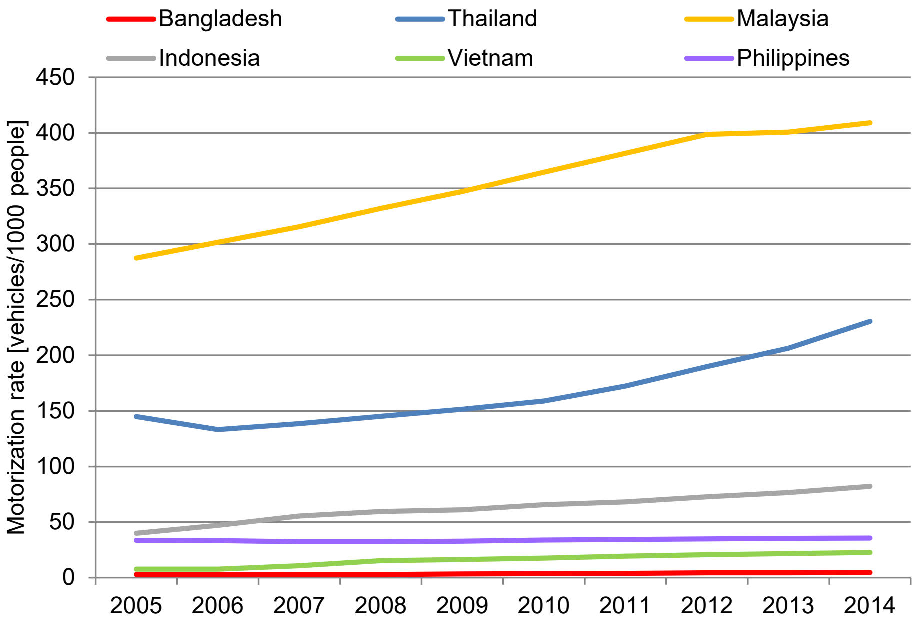
(2) General Trend of Motorization

According to International Organization of Motor Vehicle Manufacturers (OICA), the number of vehicles owned in Bangladesh has increased from 422,000 in 2005 to 716,000 in 2014, 1.7 times (6.1% p.a.) in 9 years (see Figure 6-31). However, the current level of motorization in Bangladesh, which can be expressed as the number of vehicles per 1,000 people, is still very low compared to that in ASEAN countries (see Figure 6-32).



Source: Prepared by JICA Survey Team based on World Bank database and OICA statistics

Figure 6-30 Number of Vehicles Owned in Bangladesh

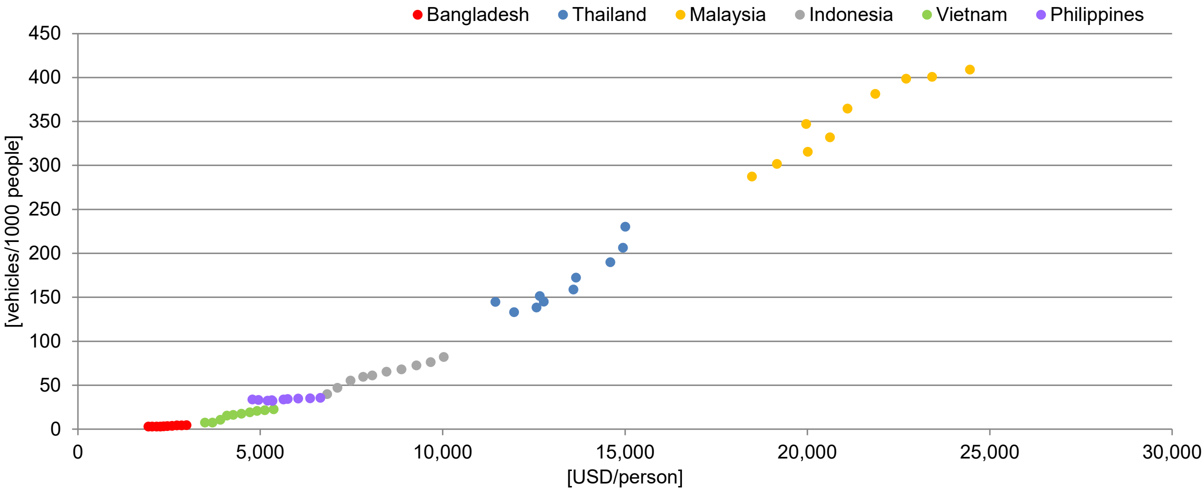


Source: Prepared by JICA Survey Team based on World Bank database and OICA statistics

Figure 6-31 Motorization Rate of Bangladesh and ASEAN Countries

The extent of car ownership can be explained by the status of economic development of each country. As seen in Figure 6-33, there's a strong correlation between GDP per capita (PPP basis) and motorization rate in ASEAN countries (Thailand, Malaysia, Indonesia, Vietnam and the Philippines). The correlation takes an S-shaped curve, i.e. the slope becomes steep when the country's GDP per capita exceeds 5,000 USD, and after taking an almost linear correlation, the slope becomes moderate when the GDP per capita reaches 20,000 USD.

As Bangladesh economy has not reached the level to trigger massive motorization, the motorization rate (vehicles per 1000 people) is still very low. But when the economic development comes to a certain level, motorization rate increases rapidly. This study expects that this rapid motorization will start around mid-2020s when GDP capita reaches 5,000 USD (see Figure 6-33).



Source: Prepared by JICA Survey Team based on World Bank database and OICA statistics

Figure 6-32 Historical Trend of GDP per Capita (PPP) and Motorization Rate

Table 6-6 is the number of registered motor vehicles in each year in Bangladesh, according to the Road Transport Authority. Main reasons for the difference from the numbers in Figure 6-31 (about 716,000 as of 2014) are the inclusion of other types of motor vehicles such as motorcycle and the possibility of vehicles that were registered in the past but are no longer in use. The total number of motor vehicles that are registration at the end of 2010 was about 1.5 million and it grew to 2.5 million as of 29th February 2016, about 1.6 times increase.

Currently the increase of motor cycles is the most conspicuous. Motor cycles not only account for more than half of total number of registration, but also it saw a rapid increase that was almost doubled during that period.

Private passenger cars accounts for the second largest share in total car registration and the number increased from about 220 thousands in 2010 to 292 thousands in February 2016. An important point to be noted about private passenger car is that the regional distribution of car registration. Out of 292 thousands in total Bangladesh, 227 thousands are registered in Dhaka. That is, most of the private passenger cars exit in Dhaka area whereas the diffusion in other areas is still far behind.

Table 6-5 Number of Registered Motor Vehicles in Bangladesh

Sl. No	Type of Vehicles	Upto-2010	2011	2012	2013	2014	2015	29-Feb-16	<Bangladesh> Grand Total	<Dhaka> Grand Total
1	Ambulance	2793	219	181	243	338	480	78	4332	2487
2	Auto Rickshaw	126763	20423	23545	15697	19897	20000	1999	228324	8435
3	Auto Tempo	14266	175	626	395	500	1095	136	17193	1664
4	Bus	27778	1761	1439	1107	1488	2391	577	36541	24565
5	Cargo Van	3522	489	282	687	608	399	64	6051	5727
6	Covered Van	5658	2354	1421	2271	2869	2354	416	17343	13742
7	Delivery Van	17063	1004	774	894	1176	1719	281	22911	16725
8	Human Hauler	6520	1152	715	385	225	1142	501	10640	4371
9	Jeep(Hard/Soft)	32286	2134	1569	1314	1870	3601	777	43551	28926
10	Microbus	66379	4051	3044	2537	4313	5224	1062	86610	63959
11	Minibus	25644	276	249	148	256	323	73	26969	10068
12	Motor Cycle	759257	114616	101588	85808	90685	240358	41467	1433779	390062
13	Pick Up (Double/Single Cabin)	32240	10460	7625	6553	9554	10257	1512	78201	54116
14	Private Passenger Car	219830	12950	9224	10472	14699	21062	3910	292147	226645
15	Special Purpose Vehicle	6371	396	226	227	172	296	78	7766	1078
16	Tanker	2706	317	195	226	362	324	64	4194	1536
17	Taxicab	44380	75	172	51	374	88	4	45144	36466
18	Tractor	20600	5200	3494	1885	1522	1699	423	34823	22066
19	Truck	82871	7327	4335	5129	8136	6330	958	115086	48258
20	Others	1317	7	1	1080	1595	2073	572	6645	3498
	TOTAL	**1498244**	**185386**	**160705**	**137109**	**160639**	**321215**	**54952**	**2518250**	**964394**

Source: Bangladesh Road Transport Authority (http://www.brta.gov.bd/statistics.html)

In comparison to that, auto rickshaws exist mostly outside of Dhaka area. Out of the 228 thousands registration countrywide, only 8,435 are registered in Dhaka. This implies that in Dhaka area, where the economic level is relatively high, ownership of private passenger cars has already outstripped the usage of auto rickshaws, whereas in other areas auto rickshaws are still dominant in passenger transport. This is in line with the fact that out of the total number of the registered taxicabs, which is currently 45 thousands, about 80% are registered in Dhaka. That is, diffusion of taxicab, which is basically used by a single or a few passengers, is advanced in Dhaka area now but it will also substitute auto rickshaws, which is basically for shared use, in other areas with the development of economic level.

This study therefore projects that the registration of auto rickshaws may still continue to increase outside of Dhaka area for years to come, but will be gradually replaced by passenger cars like in Dhaka area. It means that there is a huge potential for private car ownership to increase rapidly especially in rural area. In addition, considering the continuous migration of residents from rural areas to urban areas, the car ownership in Dhaka area is considered to increase further. The traffic congestion in Dhaka is still a serious problem but this can be worsened unless appropriate policy measures for mitigating this are not in place.

6.4.2 Key factors that affect future prospects of energy demand

(1) Long-term Policy on Transport Sector

In Bangladesh, some long-term policies on the transport sector were developed, as described below. However, it seems that these past literatures did not care much about the energy usage of the sector, much less to energy efficiency.
In addition, there obviously is not any regular statistics or information on the energy use in transport sector. Developing database on energy use of this sector is needed for grasping the status correctly and for making policy direction for rationalizing energy use and improving energy efficiency.

1) Road Master Plan (2009)

Road Master Plan was developed in response to the direction provided by the National Land Transport Policy and was intended to be the guideline for the investment in the road infrastructure over the next twenty years.
In this Master Plan, a comprehensive investment program was set to:

- Protect the value of RHD's (Road and Highways Department's) road and bridge assets;
- Improve the connectivity of the road network;
- Enhance and develop the strategic road network to meet economic and traffic growth target;
- Improve the Zila Road network to enhance connectivity to the country's growth centers;
- Improve road safety and reduce road accidents;
- Provide environmental and social protection; and
- Outline the institutional improvements required for RHD to deliver the above.

2) The National Integrated Multimodal Transport Policy (2013)

The National Integrated Multimodal Transport Policy, 2013 was prepared in order to redress the imbalance by an overemphasis on road subsector on development started taking place from the beginning of 1990. This policy is to address all modes of transport in an integrated way so that future investment can take account of the best mode in each case to meet overall government objectives including environment issues and safety.
The primary objective of the Multimodal Integrated Transport Policy is to emphasize the roles of rail, inland water transport, aviation alongside road transport in order to ensure the development of the overall transport network. The objectives of the Integrated Multimodal Transport Policy are to:

- Reduce cost of transport goods, so as to make goods and services within Bangladesh less costly;
- Aid export competitiveness, through lower transport costs;
- Improve safety;
- Reduce accident rate;
- Take advantages of Bangladesh's geographical position to trade in transport services and induce efficiency in transport sector;
- Reduce the worst environmental effects of transport;
- Ensure that transport meets social needs in terms of cost accessibility to all sectors of society;
- Improve integration of the overall transport network and foster measures to make interchange between modes easier;
- Reduce the need for travel by better land use planning;
- Use transport as means to assist poverty reduction;
- Improve fuel and energy security; and
- Increase alternative options for passenger and freight transport.

(2) Thailand's Case as a Good Practice for Reference

1) Comparison of Transport Sector Data

This study considers that the case of Thailand to deal with the issues pertaining to the transport sector can be a good reference for Bangladesh. Table 6-7 compares the data regarding the transport sector in Bangladesh and Thailand. In Thailand the number of motor vehicle with 4 or more wheels per 1000 people is 198 units, around 50 times of that in Bangladesh.

Table 6-6 Comparison of Transportation Related Data between Bangladesh and Thailand

		unit	Bangladesh	Thailand	year
motor vehicle	number of motor vehicle (4wheel or more)	1000unit	570	13,213	2012
	number of motor vehicle per 1000people	unit	4	198	
	number of motor cycle	1000unit	1,161	19,169	
road	road length of main roads	km	20,735	51,855	Thailand:2006, Bangladesh:2003
	main road density in terms of population	km/1000people	1.5	3.7	
rail	rail lines	km	2,835	5,327	2012
	passenger	million people*km	7,305	7,504	
	cargo	million ton*km	710	2,455	
air	passenger; international line	million people*km	565	8,204	2011
	passenger; domestic line	million people*km	4,630	59,159	
	passenger; total	million people*km	5,195	67,363	
waterway	Container port traffic	TEU: 20 feet equivalent units	1,571,461	7,702,476	2013

Source: Prepared by JICA Survey Team based on the data of Japan Statistics Office and WB

2) Measures for Mitigating Traffic Congestion

Bangkok, the capital of Thailand, is infamous for its traffic jams like Dhaka. According to the World Bank, the average vehicle speed during rush hours is 17.2 km/h in the morning and 24.2 km/h in the evening. Table 6-8 shows the main measures taken and considered in Thailand to mitigate traffic congestion. By introducing measures for mitigating traffic jam the following effects are expected.

- increase of the average vehicle speed;
- reduction of lost time for transportation;
- reduction of fuel consumption and fuel cost;
- reduction of CO_2 emission;
- reduction of exhausted toxic gas;
- reduction of stress of drivers;
- reduction of traffic accidents;

Table 6-7 Measures Taken in Bangkok for Mitigating Traffic Congestion

Categories	Main Measures
Mordal Shift	construction of urban railways (METRO etc.)
	introduction of Bus Rapid Transit
	introduction of Park & Ride System
Road Development	widening of a road
	develop ring road
	construction of flyover
Regulation	road pricing
	time dispersion(staggered commuting, flex time etc.)
Provision of Road Information by ICT	Smart Traffic Sign
	Traffic Signal Control

Source: JICA Survey Team

3) Introducing Eco Car Program

Thailand started the 'Eco-car program' in 2007 that offered preferential tax treatment to car manufacturers producing Eco-car. There were various requirements such as a fuel consumption of 20 km or more per liter, compliance with the European exhaust gas regulations "EURO 4", etc. Various benefits like 8 years exemption from corporation tax were provided to the approved manufacturers of "eco-cars". Also, for purchasers (consumers), a goods tax rate of 17% was introduced as a preferential tax treatment (please see table below).
The second stage of 'eco-car program' started in 2014 which requested a fuel consumption of 20 km or more per liter, compliance with the European exhaust gas regulations "EURO 5", etc. The conditions were that production must commence before year end 2019, and the production from the fourth year and beyond must be 100,000 vehicles or more p.a. (please see table below).
For the first Eco car program five Japanese manufacturers, i.e. Nissan, Honda, Mitsubishi, Suzuki and Toyota were approved. And for the second Eco car program, besides the aforementioned five manufacturers, five other manufacturers from America and Europe were newly approved.

Table 6-8 Outline of Eco car Project Conducted in Thailand

	eco car program	2nd eco car program
start year	2007	2013
main requirement	1300cc or less(gasolin car) 1400cc or less(diesel car) fuel consumption 20km/l or more clear the standard of EURO4 CO2 emission 120g/km or less	1300cc or less(gasolin car) 1500cc or less(diesel car) fuel consumption 23.3km/l or more clear the standard of EURO5 CO2 emission 100g/km or less start production by 2019
main benefit to manufacture	income tax free for maximum 8 years import tax free for production machine	income tax free for 6 years etc. import tax free for production machine
benefit to consumer	consumption tax 17% (30% for passengers car for 2000cc or more)	consumption tax 14%

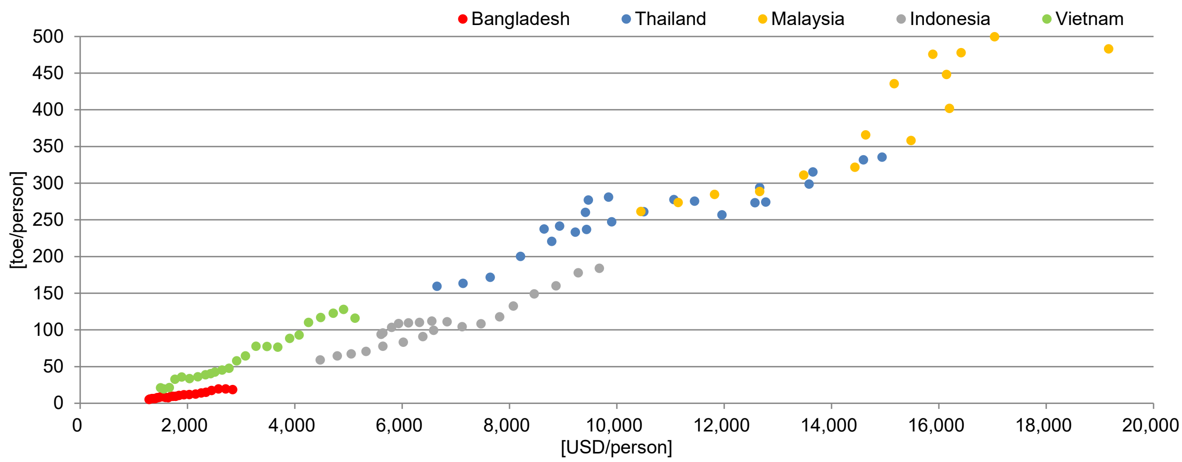
Source: JICA Survey Team

6.4.3 Projection of energy consumption

As discussed in the Section 6.4.1 , the car ownership starts increasing acceleratedly when the country's GDP per capita (PPP) reaches around 5,000 USD. Because the increased car ownership directly affects the energy consumption, the transport sector's energy consumption is expected to see a rapid growth from mid-2020.

Figure 6-34 shows the relation between GDP per capita (PPP basis) and transport sector energy consumption per capita in Bangladesh and ASEAN countries (Thailand, Malaysia, Indonesia, Vietnam and the Philippines). Like the case of motorization rate (see Figure 6-33), the overall trend of these countries is tracing an S-shaped curve, though it is not as clear as the motorization rate. That is:

- Energy consumption increases acceleratedly when the economic development comes to a certain level and the car ownership (motorization) increases rapidly, and
- The growth rate of energy consumption becomes moderate when the economic development reaches a certain level of maturity so that the growth of car ownership slows down whereas the regulation on combustion becomes stricter, and that the advanced public transport system is deployed especially in the urban area.

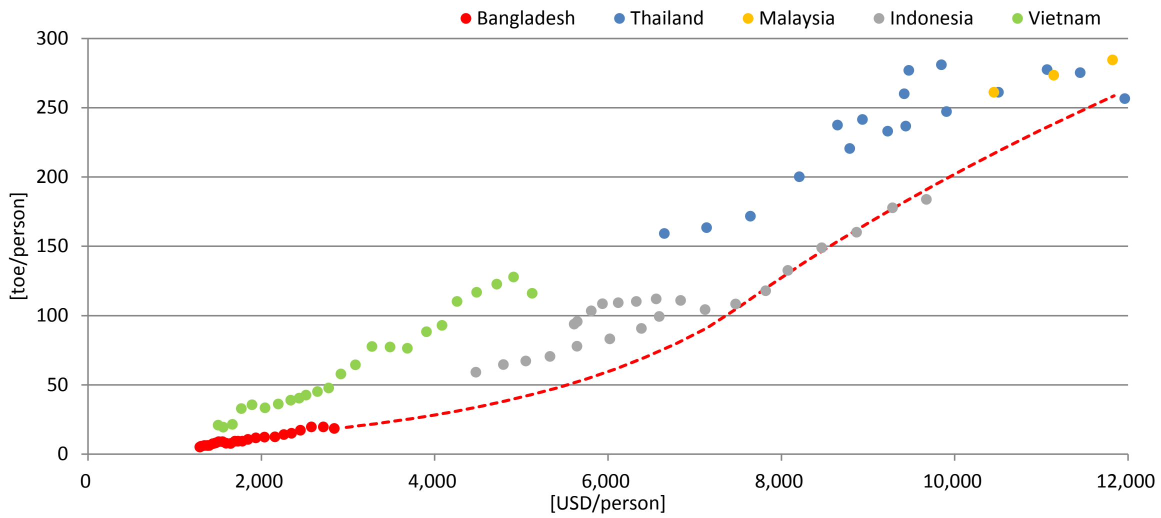


Source: Prepared by JICA Survey Team based on World Bank database and IEA energy balances

Figure 6-33 Historical Trend of GDP per Capita (PPP) and Transport Sector's Energy Consumption per Capita in Bangladesh and ASEAN Countries

According to this figure, especially the historical trend of Indonesia and Thailand that the transport sector's energy consumption per capital starts growing steeply when GDP capita reached around 5,000-6,000 USD and the growth becomes moderate when it exceeds 8,000 USD, this study considers that the car ownership increases rapidly during that period.

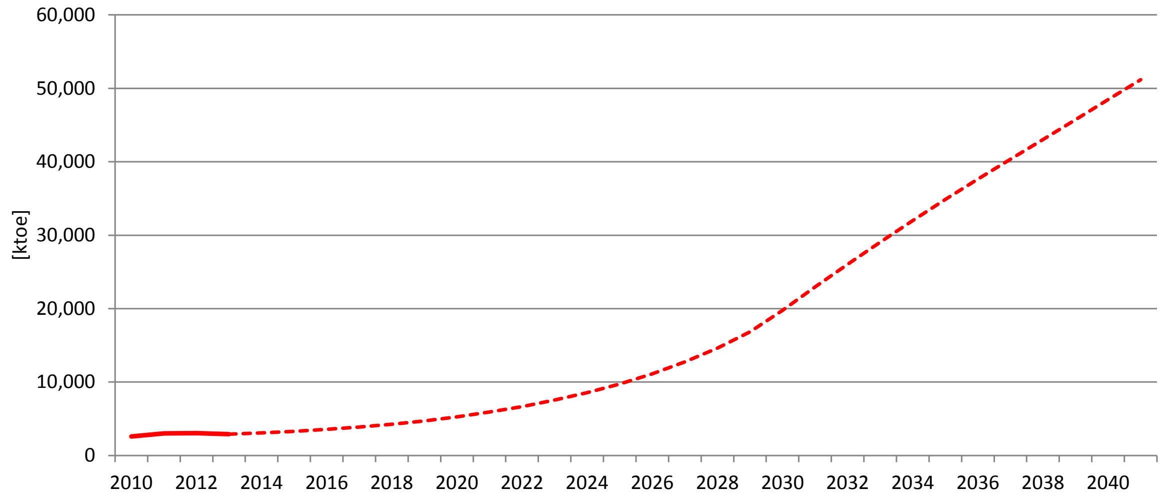
Assuming that Bangladesh will also follow this track, transport sector's energy consumption per population will increase rapidly from mid-2020s to early 2030s in accordance with the accelerated car ownership, as shown in Figure 6-35.



Source: JICA Survey Team

Figure 6-34 Projection of Transport Sector's Energy Consumption per Capita

Multiplying the projection of energy consumption per capita by the projected population (see Chapter 5), the transport sector's energy consumption in Bangladesh is expected to reach around 51,000 ktoe in 2041, about 18 time of the current level (2,893 ktoe in 2013), as shown in Figure 6-36. Rapid increase of energy consumption can be seen from mid-2020s, though the government's plan of public transport (e.g. MRT in Dhaka area) is taken into account.



Source: JICA Survey Team

Figure 6-35 Projection of Transport Sector's Energy Consumption

6.5 Agricultural Sector

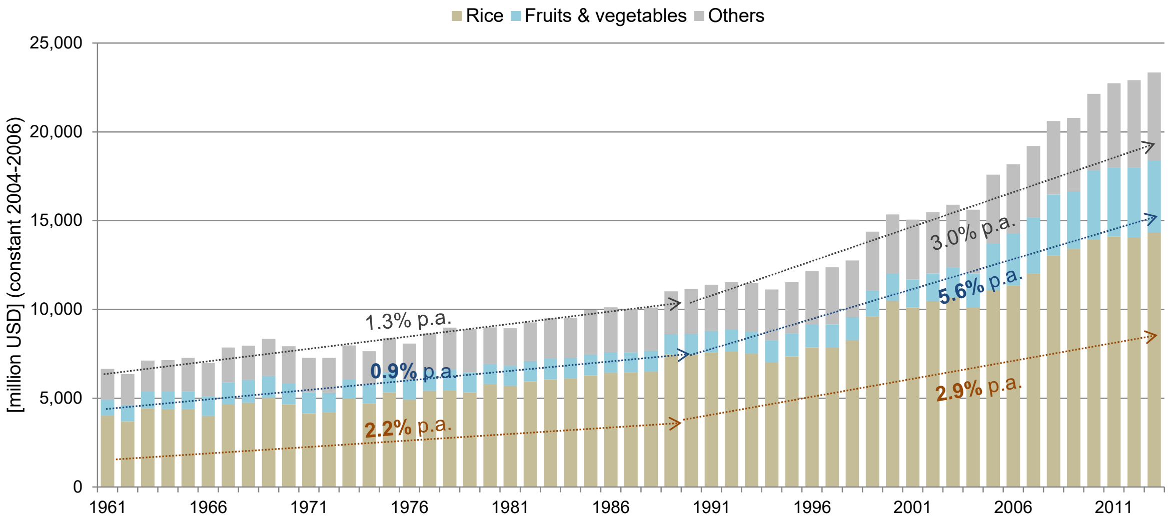
6.5.1 Current status of energy demand and key factors that affect future prospects

Figure 6-37 shows the historical trend of agricultural production in Bangladesh according to the United Nation's Food and Agriculture Organization (FAO). In Bangladesh, rice has been the major agricultural product and its share in total agricultural production has been constantly around 60% or more since 1960s.

For thirty years from 1961 to 1990, the total agricultural production increased by 1.7 times, i.e. 1.8% p.a. During that period, rice grew by 1.9 times (2.2% p.a.), fruits and vegetables by 1.3 times (0.9% p.a.) and others by 1.4% (1.3%), which indicates that rice was main driver for the growth of the country's agricultural production.

For twenty-three years from 1991 to 2013, the total agricultural production increased by 2.1 times (3.3% p.a.). The fact that the average growth rate was higher than that in previous period despite the migration from agriculture to industry driven by industrialization is considered due to the improved productivity. During this period, rice grew by 1.9 times (2.9% p.a.), whereas fruits and vegetables by 3.5 times (5.6%) and others by 2.0 times (3.0% p.a.). This indicates that the growth of fruits and vegetables replaced rice as the main driver for the production growth.

As a general trend, agricultural sector changes its structure by shifting from primitive self-sufficiency centering on grain production (rice, wheat etc.) to diversification with more value-added products, such as fruits, vegetables and dairy products. This reflects the people's preference for variety of foods with the improvement of economic standard and the shift to value added products for export driven by the improved productivity.

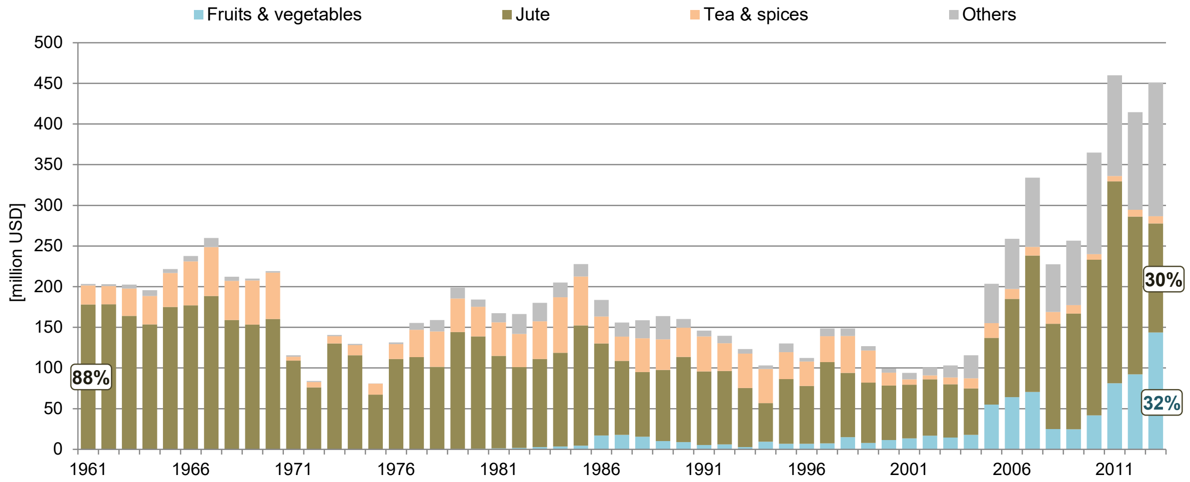


Source: FAO Statistics

Figure 6-36 Historical Trend of Agricultural Production (Turnover) in Bangladesh

Figure 6-38 shows the historical trend of agricultural products export. Until recently jute has been the main export product of Bangladesh and it accounted for 88% of total agricultural products export. In 1970, though the share of jute in total agricultural products export was still high, the export amount itself started declining, and later, along with the growth of other products, its share also started declining, down to about 30% in 2013. Export of tea leaves, which used to be the second largest agricultural product after jute, also started declining from 1990s and its export in 2013 was less than 10% of that in 1961.

In the meanwhile, the export of fruits and vegetables started expanding from mid-2000s, after a dip in late-2000 which is considered due to the Global Financial Crisis, it again started growing rapidly. In 2013, they accounted for 32% of total agricultural products export. The export value of fruits and vegetables has increased by 16 times in 23 years (12.8% p.a.) from 9 million USD in 1990 to 144 million USD in 2013.



Source: FAO Statistics

Figure 6-37 Historical Trend of Agricultural Products Export in Bangladesh

It needs to be noted that these value-added products generally require more care for preserving quality and freshness. In order to achieve this, a modernized storage system needs to be established so that these products are conserved and transported in an appropriate temperature, along with the logistic system to enable quick transport and packaging, and marketing system to support them.

In order to achieve this and to enhance the international competitiveness of export products, development of infrastructure is inevitable, especially that for electricity supply, which is also pointed out by a World Bank report[1].

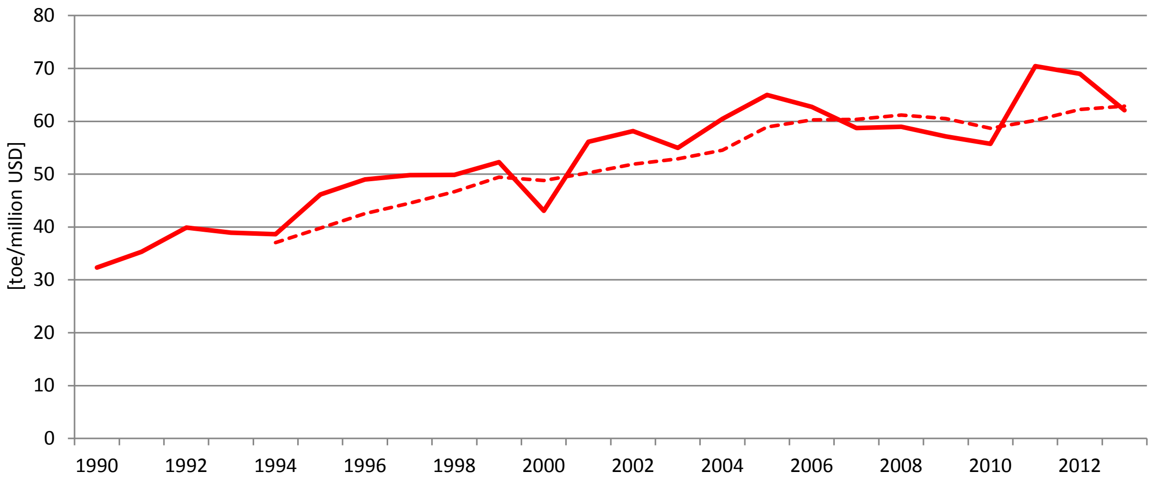
6.5.2 Projection of energy consumption

Figure 6-39 shows the historical trend of agricultural sector's energy consumption in Bangladesh divided by the sectorial value added of agriculture (constant price), along with its five-year moving average (indicated as a dotted line). Like the analysis on the industrial sector, this is a ratio of energy consumption to sectorial valued added (= GDP) to analyze how much energy (toe) is consumed for the sector to yield of 1 million USD

Though there's an increase and decrease from year to year, a gradually increasing trend can be observed. This is probably because the agricultural production is shifting to more value-added products and more energy needs to be consumed for producing a same value in the sector as discussed in the previous section.

However, this creeping trend is has been moderate since mid-2000s, probably because the increasing value-added is high enough to cover the increasing energy consumption.

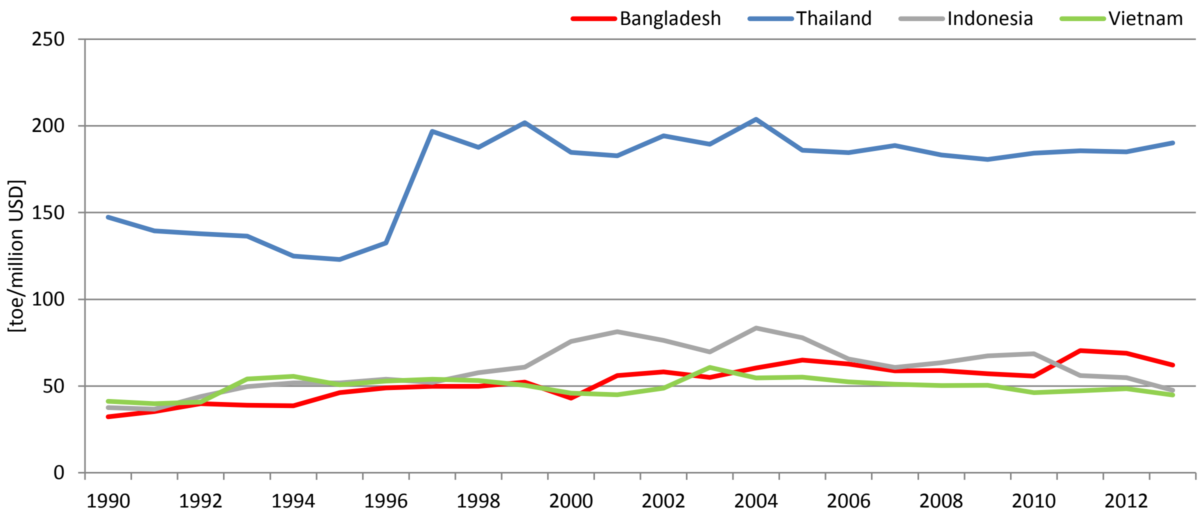
[1] World Bank "High-value Agriculture in Bangladesh: An Assessment of Agro-business Opportunities and Constraints" (2008)



Source: Prepared by JICA Survey Team based on World Bank database and IEA energy balances
Note) Dotted line is the five-year moving average

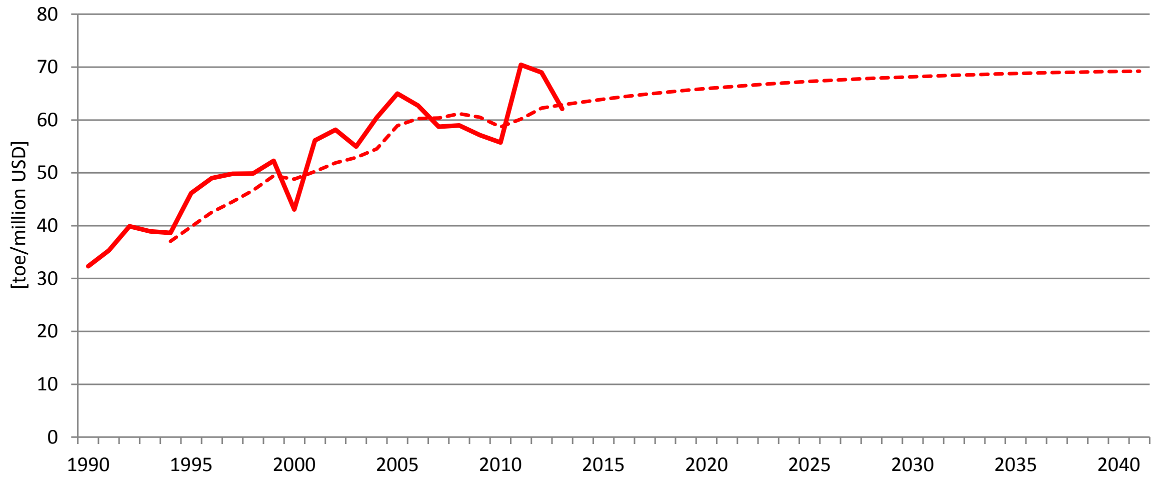
Figure 6-38 Agricultural Sector's Energy Consumption per Sectorial Value Added

Figure 6-40 compares this historical trend with ASEAN countries (Thailand, Indonesia and Vietnam). The historical trend in Indonesia and Vietnam is similar to that in Bangladesh, ranging mostly between 50 and 70 toe/million USD since 2000s.
Considering that the historical trend in Thailand has been much higher than the other three countries, the reliability of statistic data needs to be doubted, at least in terms of international comparison. However, referring to the performance in Indonesia and Vietnam, this study assumes that a creeping trend of agricultural sector's energy intensity will continue until moderately it reaches to toe/million USD, as shown in Source: JICA Survey Team
Figure 6-41.



Source: Prepared by JICA Survey Team based on World Bank database and IEA energy balances

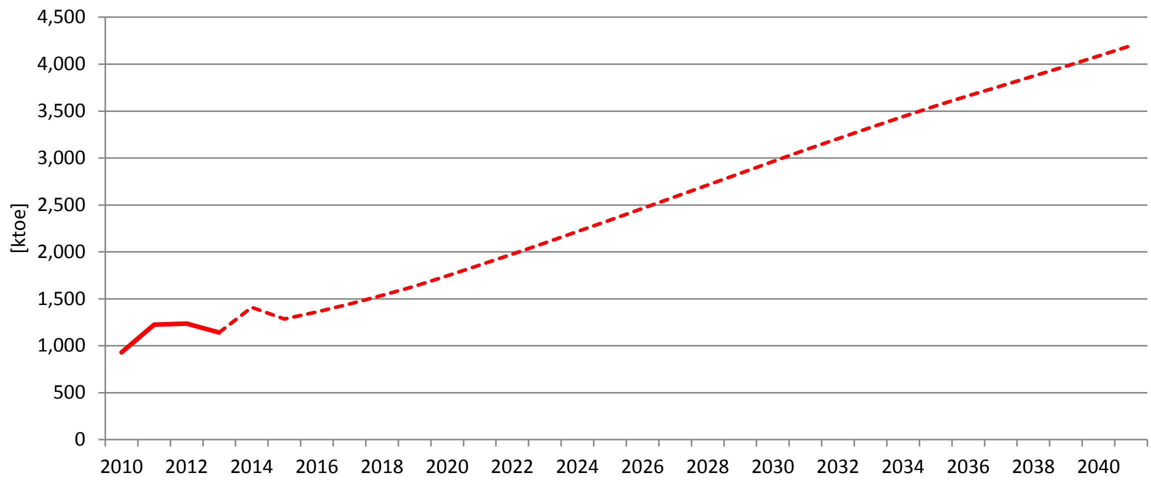
Figure 6-39 Agricultural Sector's Energy Consumption per Sectorial Value Added (Comparison with ASEAN Countries)



Source: JICA Survey Team

Figure 6-40 Projection of Agricultural Sector's Energy Consumption per Sectorial Value Added

Agricultural sector's energy consumption will reach around 4,200 ktoe in 2041, about four times increase from 2013, as shown in Figure 6-42.



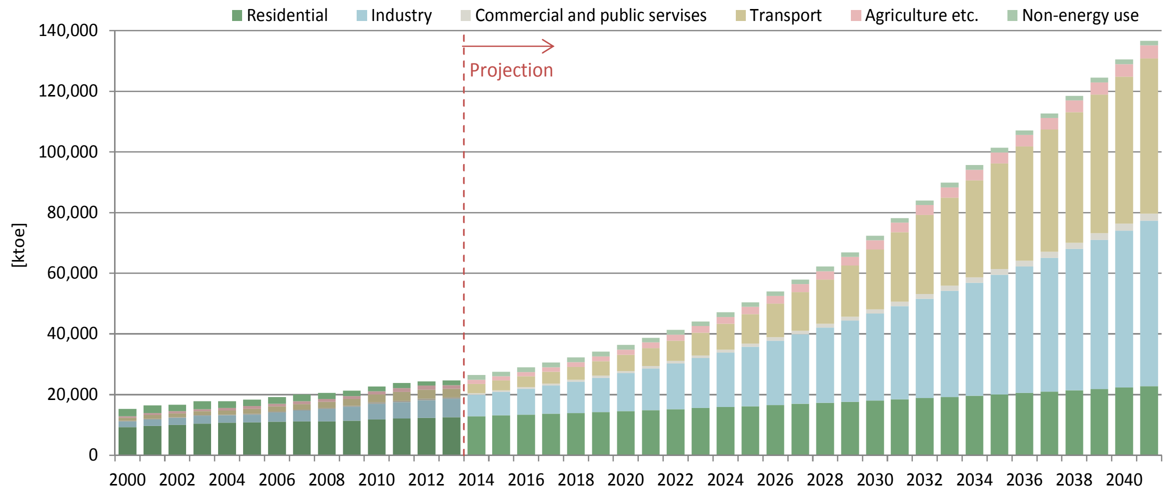
Source: JICA Survey Team

Figure 6-41 Projection of Agricultural Sector's Energy Consumption

6.6 Total Energy Supply & Demand Balance Up to 2041

6.6.1 Projection of total final energy consumption

The projection of final energy consumption in the BAU (business as usual) scenario, which is the sum of energy consumption of each sector as explained in the previous sections of this chapter, is shown in Figure 6-42 and Table 6-9.
In this BAU scenario, industrial sector, which is expected to grow by 7.8% p.a. from 2014 to 2041, will become the largest sector of energy consumption. Transport sector, which is expected to grow by 11.0% p.a., will consume almost as much energy as the industrial sector.
In the meanwhile, residential sector, which accounted for about half of the total energy consumption, will see a relatively moderate growth and its share in the total energy consumption is expected to decline.



Source: JICA Survey Team

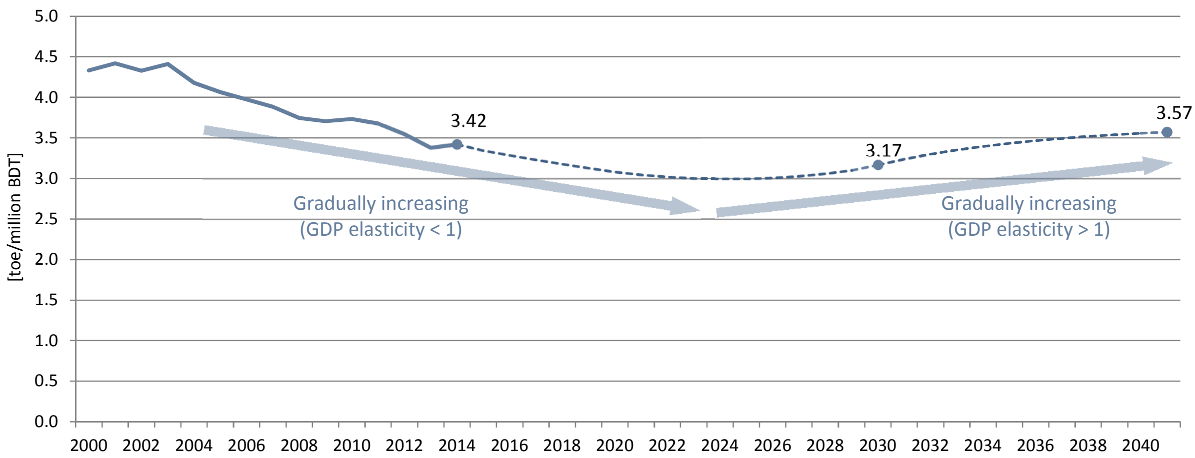
Figure 6-42 Projection of Total Final Energy Consumption – BAU Scenario

Table 6-9 Projection of Total Final Energy Consumption – BAU Scenario

Sectors	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Residential	12,815	(48%)	**22,797**	**(17%)**	**2.2% p.a.**
Industrial	7,116	(27%)	**54,525**	**(40%)**	**7.8% p.a.**
Commercial & Public Service	475	(2%)	**2,369**	**(2%)**	**6.1% p.a.**
Transport	3,080	(12%)	**51,187**	**(37%)**	**11.0% p.a.**
Agriculture	1,409	(5%)	**4,197**	**(3%)**	**4.1% p.a.**
Others	47	(0%)	**47**	**(0%)**	**0.0% p.a.**
Non-energy use	1,534	(6%)	**1,534**	**(1%)**	**-**
Total	**26,475**	**(100%)**	**136,655**	**(100%)**	**6.3% p.a.**

Source: JICA Survey Team

The total final consumption (TFC) is expected to grow by 5.1 times from 2014 to 2041, i.e. 6.3% p.a. increase. The projection of GDP growth during the same period is 6.1%, hence the GDP elasticity of energy consumption during the projection period, which is the ratio of energy consumption's growth rate divided by GDP growth rate, is slightly higher than 1 (about 1.03).
Figure 6-43 is the historical trend and projection of energy intensity, which is the ratio of total final energy consumption divided by GDP (real base). When the country's GDP is continuously growing, its GDP elasticity becomes lower than 1 when the energy intensity decreases, and the GDP elasticity becomes higher than 1 when the energy intensity increases.
Since 2000s, Bangladesh has seen a declining trend of energy intensity, i.e. GDP elasticity of energy consumption has been lower than 1, and this trend is expected to continue until mid-2020s due to the moderate growth of residential sector energy consumption that currently accounts for about half of the total energy consumption. Energy intensity will decrease from 3.42 toe/million BDT in 2014 to around 3 toe/million BDT (-12% down from 2014) during that period.
However, the energy intensity will start increasing afterwards, i.e. GDP elasticity becomes higher than 1. This is because the industrial sector and the transport sector, which are expected to grow higher than GDP, will account for a larger share in the total energy consumption. Energy intensity will increase to 3.17 toe/million BDT in 2030 (-8% down from 2014), and then 3.57 toe/million BDT in 2041 (4% up from 2014). As a result, GDP elasticity of the entire projection period (from 2014 to 2041) will become higher than 1.



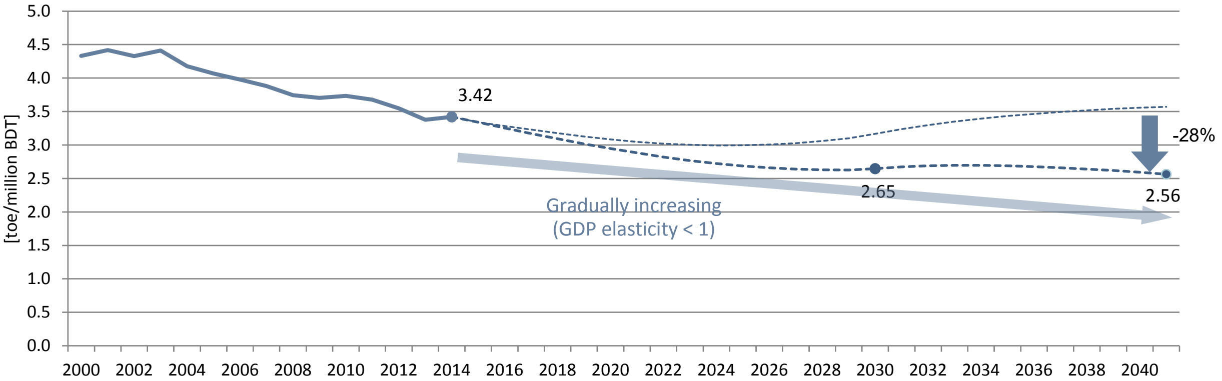
Source: JICA Survey Team

Figure 6-43 Historical Trend and Projection of Energy Intensity – BAU Scenario

Following the projection of BAU scenario, this study forecasted an "energy efficiency scenario", expecting that energy efficiency measures are to be implemented in Bangladesh for mitigating the rapid increase of energy consumption. Referring to "Energy Efficiency and Conservation Master Plan up to 2030" (EECMP), which was published by Sustainable and Renewable Energy Development Authority (SREDA) and Power Division in March 2015 with the technical assistance by JICA, this study expects that the following targets will be achieved by implementing the measures as specified in EECMP.

- 2.65 toe/million BDT in 2030 (down -23% from 2014);
- 2.56 toe/million BDT in 2041 (down -25% from 2014);

In this case, the energy intensity is expected to decrease continuously, though the pace may become moderate. GDP elasticity of the projection period will become lower than 1.



Source: JICA Survey Team

Figure 6-44 Historical Trend and Projection of Energy Intensity - Energy Efficiency Scenario

The aforementioned reduction of energy intensity appears to be different from the energy efficiency target of EECMP, which declares that "approx. 20% reduction of primary energy consumption per GDP can be achieved by 2030 (and) 15% reduction of primary energy consumption per GDP is to be achieved" by 2021. This discrepancy is due to the different definition of energy intensity. For example, energy intensity in EECMP does not include the whole energy consumption of the transport sector and biofuel consumption of the residential sector. Using the same definition as that of EECMP, the energy intensity as of 2030 is 2.46 toe/million BDT, down 20% from 3.06 toe/million BDT in 2014, that is, energy efficiency target has not been changed from EECMP. In the same definition, the energy intensity in 2041will decline to 2.36 toe/million BDT, which is 23% decrease from 2014. [2]

In order to achieve the aforementioned energy efficiency target, the total energy consumption needs to be reduced by 16% as of 2030, and by 28% as of 2041. The sector-wise target of energy efficiency to achieve this is shown in Table 6-11. EECMP set the reduction of energy consumption against BAU scenario in residential sector and industrial sector at 23.0% and 16.8% respectively as of 2030. Because this study's projection of energy consumption in both sectors is more conservative than EECMP, the reduction of energy consumption against BAU scenario in 2030 is adjusted to 21% for residential sector and 15% for industrial sector.

Energy efficiency target for transport sector was not covered in EECMP, but, as discussed in Section 6.4.2 , energy consumption of this sector is expected to grow very rapidly in BAU scenario. Hence this study suggests setting an ambitious target of 33% reduction of transport sector energy consumption against BAU scenario as of 2041. This means that this sector's energy consumption will be controlled so that is will not exceed the level in BAU scenario as of mid-2030s when the rapid growth of economy and motorization is reaching certain maturity.

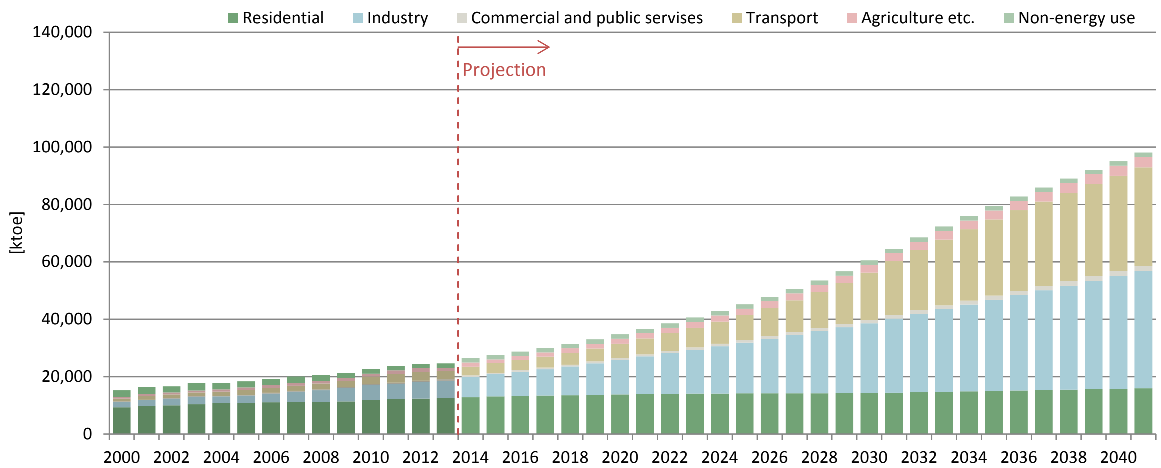
[2] Assuming that the Scenario 3 is chosen among six scenarios of power development that are discussed in Chapter 11.

Table 6-10 Sector-wise Energy Efficiency Target

Sectors	Reduction from BAU Scenario			Energy Intensity: Down from 2014		
	2021	2030	2041	2021	2030	2041
Residential	-6%	-21%	-30%			
Industrial	-5%	-15%	-25%			
Commercial & Public Service	-5%	-17.5%	-25%			
Transport	-6.6%	-16.5%	-33%			
Agriculture	-3%	-10.5%	-15%			
Total	**-5.3%**	**-16.4%**	**-28.2%**	**-15.7%**	**-22.6%**	**-25.1%**

Source: JICA Survey Team

Projection of total energy consumption considering the achievement of aforementioned energy efficiency targets is shown in Figure 6-46 and Table 6-12. The average growth rate of total final energy consumption will be 5.0% p.a. from 2014 to 2041, which is lower than GDP growth rate in the same period.



Source: JICA Survey Team

Figure 6-45 Projection of Total Final Energy Consumption – Energy Efficiency Scenario

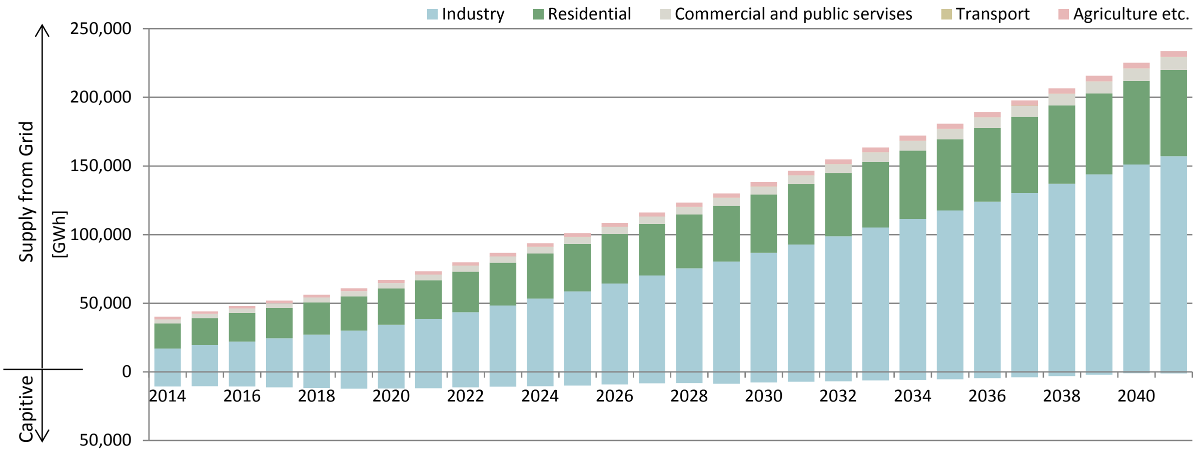
Table 6-11 Projection of Total Final Energy Consumption – Energy Efficiency Scenario

Sectors	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Residential	12,815	(48%)	**15,958**	**(16%)**	**0.8% p.a.**
Industrial	7,116	(27%)	**40,893**	**(42%)**	**6.7% p.a.**
Commercial & Public Service	475	(2%)	**1,776**	**(2%)**	**5.0% p.a.**
Transport	3,080	(12%)	**34,295**	**(35%)**	**9.3% p.a.**
Agriculture	1,409	(5%)	**3.568**	**(4%)**	**3.5% p.a.**
Others	47	(0%)	**47**	**(0%)**	**0.0% p.a.**
Non-energy use	1,534	(6%)	**1,534**	**(2%)**	**-**
Total	**26,475**	**(100%)**	**98,071**	**(100%)**	**5.0% p.a.**

Source: JICA Survey Team

Source: JICA Survey Team

Figure 6-47 shows the projection of electricity consumption in the "Energy Efficiency Scenario". The area above the "0" horizontal axis in this figure is the consumption of electricity supplied from the grid wheras the area below this line is the electricity consumption from capitive power generation. For convenience, all the captive power generation is classified in the industrial sector. Because the growth rate of the industrial sector energy demand is higher than other sectors, its share in the total electicity will become still higher. Captive power generation will be gradually decrease after 2020s when the capacity of grid power supply is strengthened.



Source: JICA Survey Team

Figure 6-46 Projection of Electricity Consumption – Energy Efficiency Scenario

6.6.2 Projection of total primary energy supply

Based on the projection of total final energy consumption in the energy efficiency scenario, which was discussed in the previous sections, the total primary energy supply (TPES) in Bangladesh up to 2041 is projected. Methodologies for projecting TPES are as follows.

- Breakdown of the modes of energy supply to end consumption, such as electricity, gas, oil products, is determined for each sector.
  - Industrial sector:
    Considering that the share of each mode of energy supply has been almost constant for the past years, the same share as the current level will be maintained for several years to come, that is “Electricity: about one-third, Natural gas: about half, Coal: about 10%, Oil: remainder”. A gradual shift from natural gas to electricity will occur in the long run, considering that the natural gas usage for captive power generation will be gradually replaced by the power supply from the grid.
  - Transport sector:
    Since 2000s, conversion to CNG has been promoted in Bangladesh, but recently opinion to review this trend has been raised, reflecting the possible shortage of domestic gas production. On the contrary, there’s also an argument that increasing dependence on oil products (including LPG) should be avoided and that continued promotion of CNG using imported LNG is preferred.
    Because there appears to be no decisive direction with this regard at the moment, this study assumes that the same share as the current level, that is “Natural gas: about one-third, Oil: two-thirds”. Decision on the fuel usage for road transport can be a big variation factor for the future primary energy supply.
    In addition, usage of electricity in the transport sector following the development of modernized railway system (including MRT in Dhaka area) is also considered, though its impact on the total energy consumption is not very large.
  - Residential sector:
    A shift from conventional energy sources (e.g. firewood etc.) will be gradually replaced by modern energy sources such as electricity and gas, as discussed in Section 6.2.3 .

This study's assumption reflected the opinion of some local stakeholders that the natural gas supply to new residential customers and that it will be substituted by LPG. As a result, the share of LPG in residential sector will be significantly increased.

- Commercial & public services sector:
  Because the historical trend of the share is "Electricity: about half, Natural gas: about half" and this ratio has been almost constant, this study assumed that the same share as the current level will be maintained.
- Agriculture, others:
  This study assumed that the same share as the current level will be maintained.

- Conversion and transfer from primary energy supply to final energy consumption
  - Regarding the energy conversion from primary to electricity supply, several scenarios of fuel mix for power generation was considered, as discussed more specifically in Chapter 11. There are six scenarios of fuel mix varying the composition of natural gas and coal for power generation, among which the Scenario 1 depends maximally on coal usage whereas the Scenario 5 relies maximally on natural gas. Scenarios from 1 to 5 assume that the power import from other countries will expand as expected and Scenario 6 is also prepared to assume that this plan is not realized as expected.
  - Loss of fuel and electricity in transferring to end consumption is considered referring to the historical trend.
  - Thermal efficiency in fuel combustion for electricity generation is considered referring to the projection as discussed in in Chapter 11.
- In this chapter, necessary volume of primary energy supply to meet the final energy consumption was calculated. How to procure this primary energy supply, such as domestic production, import, and export of energy, will be discussed in the following chapters.

Reflecting the five scenarios of power development that are evaluated in Chapter 11, the projection of primary energy supply and the table of energy supply and demand balances are shown in the following figures and tables.

- Scenario 1: Source: JICA Survey Team
  Figure 6-48, Table 6-14 and Table 6-15;
- Scenario 2: Source: JICA Survey Team
  Figure 6-49, Table 6-16 and Table 6-17;
- Scenario 3: Source: JICA Survey Team
  Figure 6-50,Table 6-18 and Table 6-19;
- Scenario 4: Source: JICA Survey Team
  Figure 6-51, Table 6-20 and Table 6-21;
- Scenario 5: Source: JICA Survey Team
  Figure 6-52, Table 6-22 and Table 6-23;

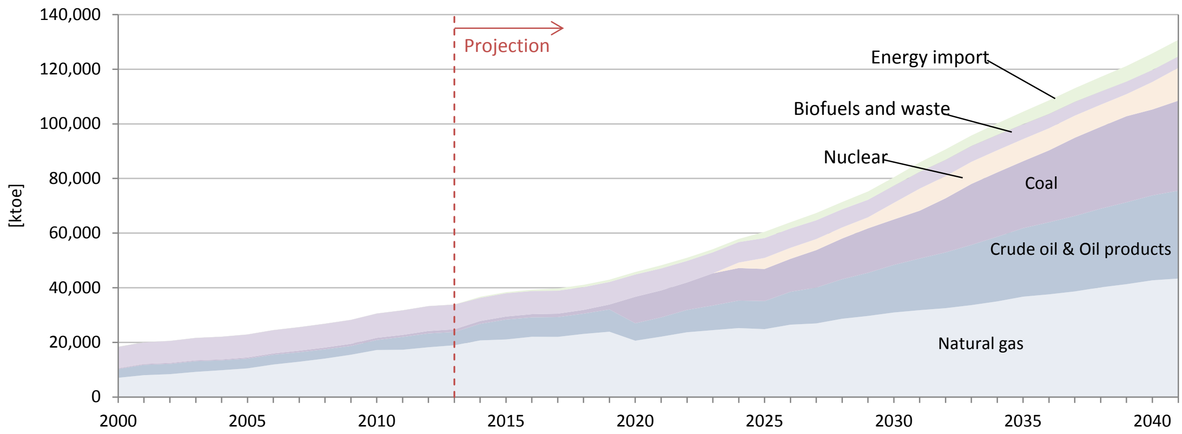
Up to mid-2020s the energy supply and demand balances are the same in all of the five scenarios of power development. For reference, the energy supply and demand balances as of 2021 is shown in Table 6-13.

Table 6-12 Energy Supply and Demand Balances in 2021 –All Scenarios

Year: 2021 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	9,723	1,361	5,625	21,925	0	36	8,030	1,507	48,207
Electricity plants	-8,281	0	-49	-8,378	0	-36	0	8,811	-7,933
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-26		-72	-346			-144	-1,450	-2,038
Total final consumption	1,416	0	6,825	13,201	0	0	7,885	7,361	36,688
Industry	1,416		330	6,958				4,341	13,045
Transport			3,756	1,769				3	5,528
Residential			1,028	2,654			7,885	2,420	13,987
Commercial and public services			0	350				394	743
Agriculture/forestry			1,619	28				157	1,804
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-47 Projection of Total Primary Energy Supply –Scenario 1

Table 6-13 Projection of Total Primary Energy Supply –Scenario 1

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**44,149**	**(33%)**	**2.8% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(24%)**	**6.2% p.a.**
Coal	1,361	(4%)	**33,747**	**(26%)**	**13.8% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**129**	**(0%)**	**4.9% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**132,233**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-14 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 1

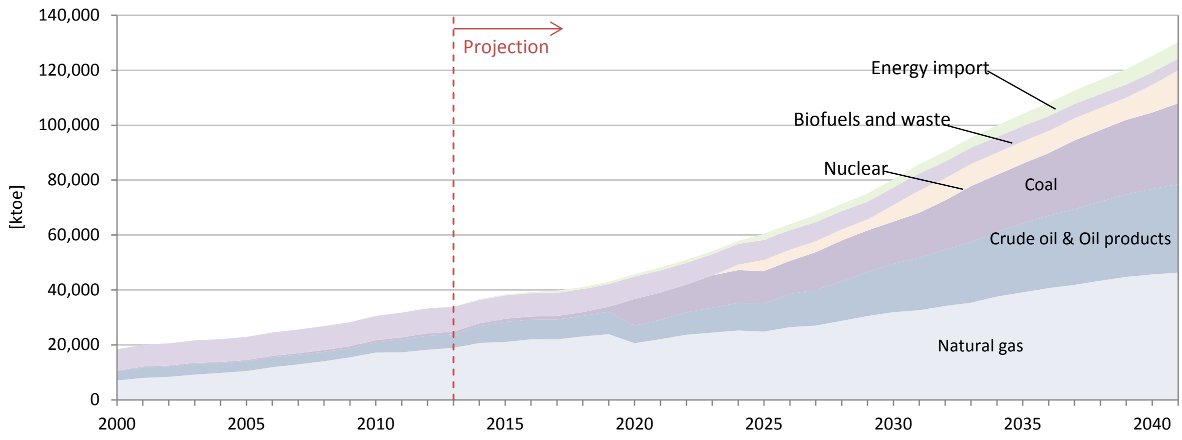
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,637	1,361	17,448	33,119	7,953	172	6,009	3,390	86,090
Electricity plants	-13,782	0	-365	-8,234	-7,953	-172	0	15,967	-14,539
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	33,747	1,361	30,792	44,149	11,942	129	4,086	6,027	132,233
Electricity plants	-29,226	0	-1	-5,803	-11,942	-129	0	24,333	-22,768
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-48 Projection of Total Primary Energy Supply –Scenario 2

Table 6-15 Projection of Total Primary Energy Supply –Scenario 2

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**46,627**	**(35%)**	**3.0% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(24%)**	**6.2% p.a.**
Coal	1,361	(4%)	**30,641**	**(23%)**	**13.4% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**143**	**(0%)**	**5.3% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**131,619**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-16 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 2

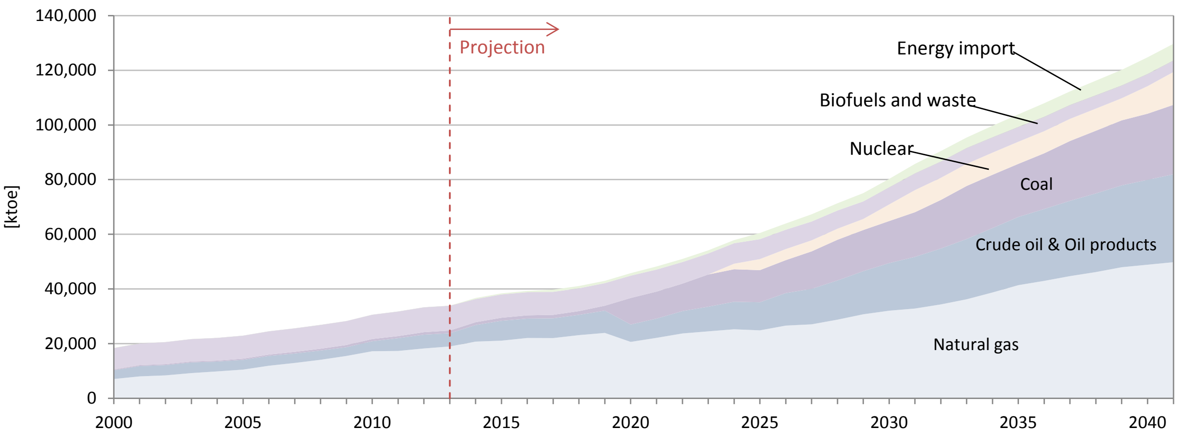
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,637	1,361	17,448	33,119	7,953	172	6,009	3,390	86,090
Electricity plants	-13,782	0	-365	-8,234	-7,953	-172	0	15,967	-14,539
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	30,641	1,361	30,792	46,627	11,942	143	4,086	6,027	131,619
Electricity plants	-26,120	0	-1	-8,281	-11,942	-143	0	24,333	-22,153
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-49 Projection of Total Primary Energy Supply –Scenario 3

Table 6-17 Projection of Total Primary Energy Supply –Scenario 3

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**50,149**	**(38%)**	**3.3% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(25%)**	**6.2% p.a.**
Coal	1,361	(4%)	**26,273**	**(20%)**	**12.7% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**197**	**(0%)**	**6.5% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**130,827**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-18 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 3

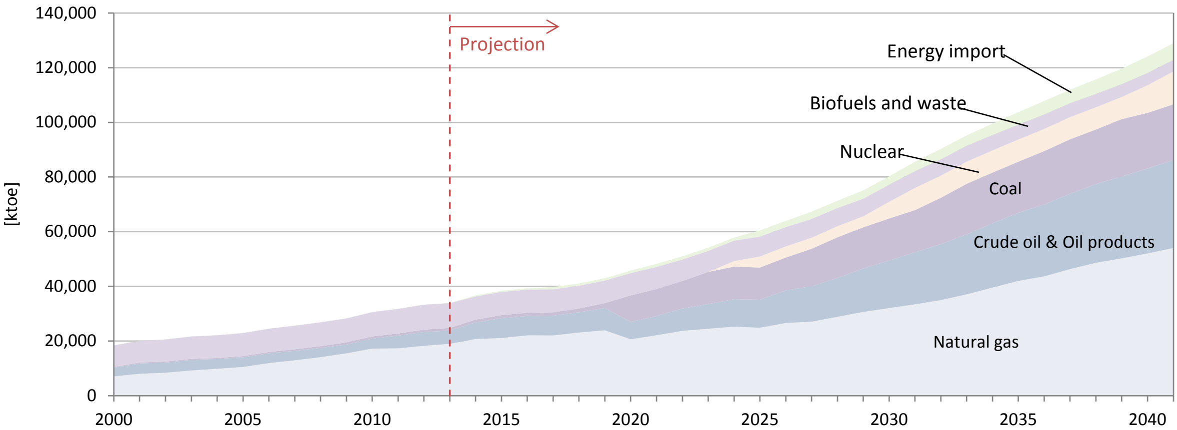
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,637	1,361	17,448	33,119	7,953	172	6,009	3,390	86,090
Electricity plants	-13,782	0	-365	-8,234	-7,953	-172	0	15,967	-14,539
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	26,273	1,361	30,792	50,149	11,942	197	4,086	6,027	130,827
Electricity plants	-21,752	0	-1	-11,803	-11,942	-197	0	24,333	-21,362
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-50 Projection of Total Primary Energy Supply –Scenario 4

Table 6-19 Projection of Total Primary Energy Supply –Scenario 4

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**54,493**	**(42%)**	**3.6% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(25%)**	**6.2% p.a.**
Coal	1,361	(4%)	**20,922**	**(16%)**	**11.8% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**204**	**(0%)**	**6.7% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**129,826**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-20 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 4

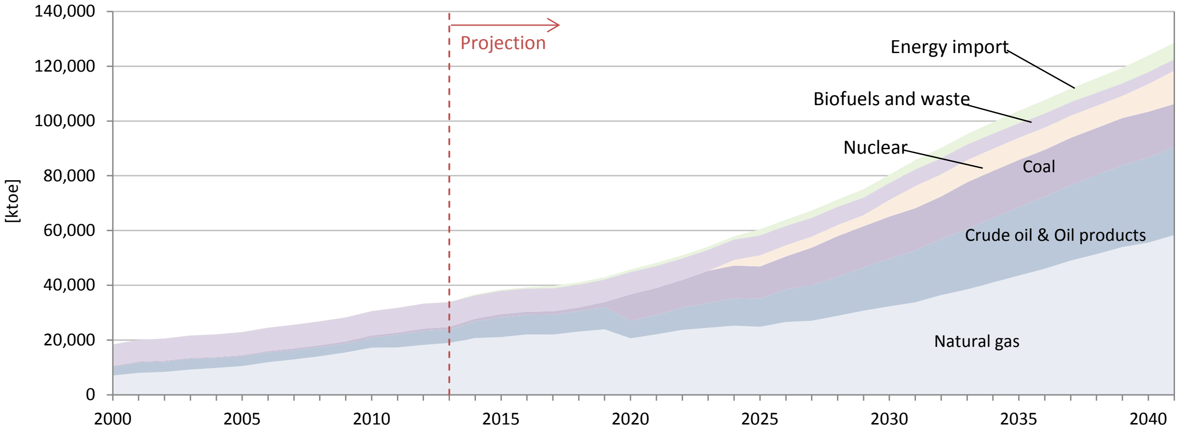
Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	16,573	1,361	17,348	33,277	7,953	163	6,009	3,390	86,075
Electricity plants	-13,718	0	-265	-8,392	-7,953	-163	0	15,967	-14,524
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	20,922	1,361	30,792	54,493	11,942	204	4,086	6,027	129,826
Electricity plants	-16,401	0	-1	-16,146	-11,942	-204	0	24,333	-20,361
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Source: JICA Survey Team



Source: JICA Survey Team

Figure 6-51 Projection of Total Primary Energy Supply –Scenario 5

Table 6-21 Projection of Total Primary Energy Supply –Scenario 5

Primary Energy	2014		2041		Average growth rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural gas	20,726	(56%)	**58,726**	**(46%)**	**3.9% p.a.**
Oil (crude oil + oil products)	6,263	(17%)	**32,153**	**(25%)**	**6.2% p.a.**
Coal	1,361	(4%)	**15,677**	**(12%)**	**10.6% p.a.**
Nuclear	-	-	**11,942**	**(9%)**	**-**
Hydro, Solar, Wind etc.	36	(0%)	**207**	**(9%)**	**6.7% p.a.**
Biofuels & Waste	8,449	(23%)	**4,086**	**(3%)**	**-2.7% p.a.**
Electricity (import)	377	(1%)	**6,027**	**(5%)**	**10.8% p.a.**
Total	**36,888**	**(100%)**	**128,817**	**(100%)**	**4.8% p.a.**

Source: JICA Survey Team

Table 6-22 Energy Supply and Demand Balances in 2031 and 2041 –Scenario 5

Year: 2031 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	15,228	1,361	17,683	34,121	7,953	171	6,009	3,390	85,917
Electricity plants	-12,373	0	-600	-9,236	-7,953	-171	0	15,967	-14,366
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-52		-124	-627			-108	-2,627	-3,538
Total final consumption	2,803	0	18,280	24,259	0	0	5,901	13,340	64,582
Industry	2,803		653	13,777				8,596	25,828
Transport			12,776	6,019				12	18,807
Residential			2,291	2,406			5,901	3,801	14,399
Commercial and public services			0	572				645	1,217
Agriculture/forestry			2,467	42				240	2,749
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

Year: 2041 (ktoe)

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro & renewables	Biofuels & waste	Electricity	Total
Total Primary Energy Supply	15,677	1,361	30,792	58,726	11,942	207	4,086	6,027	128,817
Electricity plants	-11,156	0	-1	-20,379	-11,942	-207	0	24,333	-19,352
Oil refineries		-1,361	1,320						-41
Own use, losses etc.	-83		-210	-955			-73	-4,004	-5,326
Total final consumption	4,438	0	31,900	37,391	0	0	4,013	20,330	98,071
Industry	4,438		1,033	21,813				13,609	40,893
Transport			23,298	10,976				21	34,295
Residential			4,274	2,271			4,013	5,401	15,958
Commercial and public services			0	835				941	1,776
Agriculture/forestry			3,202	54				311	3,568
Non-specified			1	0				46	47
Non-energy use			92	1,442				0	1,534

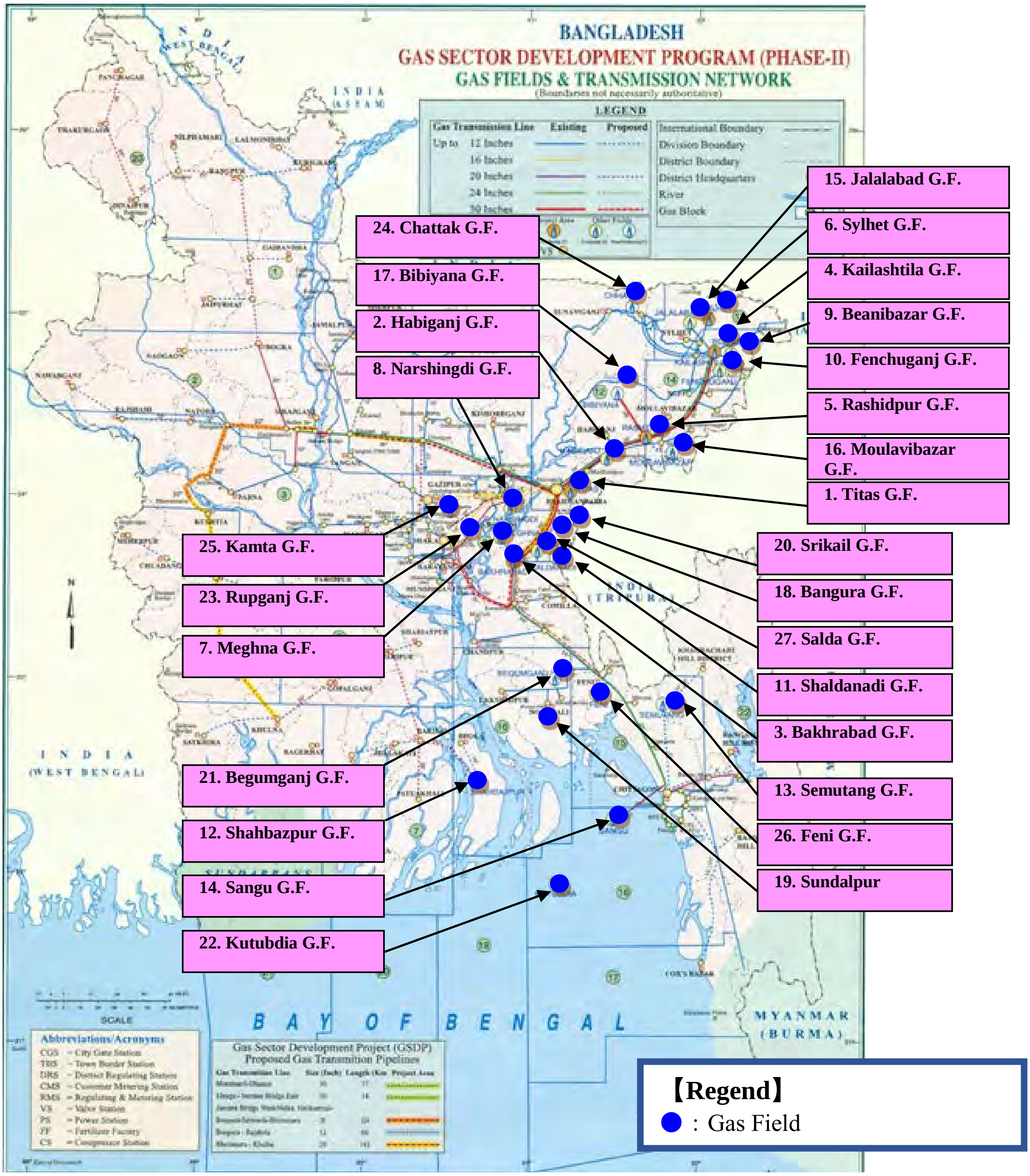
Source: JICA Survey Team

Chapter 7 Domestic Natural Gas Supply

7.1 Natural Gas Reserve

7.1.1 Gas field location

To date 26 gas fields has been discovered in Bangladesh as shown in Figure 7-1



Source: Domestic Gas Field Location Map for "Proved Reserves" provided by Petrobangla

Figure 7-1 Gas Field Location Map

Geology of Bangladesh started from Upper Paleozonic time when eastern Gondwanaland was broken up. Part of the fragment, Indian Plate, drifted and collided with Asian Plate, and subsided in the period of Oligocene-Holocene Orogenic, and up to now.

The country is divided into three major lithostratigraphic units as follows:

- Folding Bed in the Eastern part of Bangladesh
- Fore Deep in the Central part of Bangradesh
- Stable Shelf and Hinge Zone in the West and North West part of Bangladesh

Majority of gas fields discovered in Bangladesh to date are located in the Folding Bed and adjacent eastern part of Foredeep areas.

These areas are extended from east part of Dhaka to the west and Sylhet Division to the north and Comilla, Chittagon and Cox's Bazar to the south.

The gas of this area has been generated at the depth of 6,000-8,000 m below the surface and migrated up through multi-kilometer sand shale sequence for long vertical distance before being accumulated in the Mio-Pliocene sand reservoirs at the depth of 1,000-4000 m. Some amounts of gases are accumulated at the depth of 1,000 m, known as Pocket Gas.

Special care is required to develop gas in this area due to a fragile nature of strata and reservoir sandstones. They are young and not fully solidified. Four major blowouts have occurred in the Sylhet area, and lost significant amount of gas resources. Gas is still leaking out to the atmosphere from these blown out wells.

Stable Shelf and Hinge Zone in the West and North West part of the country is covered by a sedimentation deposit of Upper Paleozonic to Lower Cretazeous era. According to the report by USGS/Petrobangla 2001, potential of gas and oil deposit in the area is not as high as Folding Bed area, and commercial scale gas field has not been discovered in this area so far.

Natural gas produced in Bangladesh contains 95-99% methane and all others are hydrocarbon components. It contains almost no other impurities such as hydrogen sulfide, carbon dioxide and/or nitrogen.

Produced gas entrains significant amount of condensate. Production of condensate in Bangladesh is 7,800 bpd, with the gas production of 2,500 mmscfd, or 3 bbl/mmcf, in December 2014. Rate of condensate production per unit gas production is higher in the Sylhet area, and Beanibazar produces 16 bbl/mmcf.

7.1.2 Gas reserve evaluation

The gas reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019" prepared by Petrobangla is provided as a basis for production forecasts in this study.

Data of gas reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019" is considered updates of those used in the Petrobangla Annual Report 2013. The updated points are as follows:

- Addition of the data on the Rupganj gas field discovered in 2014
- Remaining 2P reserves are as of January 2015

Gas reserves used for production forecasts in PSMP2010 were based on the report by Hydrocarbon Unit (HCU) (2011) (called as "HCU report" hereafter).

On the other hand, the gas reserves in this Study are based on the "Draft Five Year Gas Supply Strategy 2015-2019"

The reserves (except for the Rupganj field) shown in the draft policy are updates of those shown in Petrobangla Annual Report 2013 and are also the same as those shown in Petrobangla Annual Report 2014.

Comparison of the gas reserves between the HCU report and Petrobangla's "Draft Five Year Gas Supply Strategy 2015-2019" was shown in the Figure 7-1. The summary is as follows:

- The gas reserves shown in the HCU report were originally prepared by Gustavson Associates, US-based consulting company. On the other hand, the gas reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019" were prepared by updating those in the Petrobangla Annual Report 2013, which were derived from different sources such as RPS Energy, a UK-based consulting company, and Petrobangla.

- The HCU report was prepared in 2011, whereas the RPS Energy's report was prepared in 2009, which was cited for the estimates of the gas reserves on most of the fields shown in the Petrobangla Annual Reports 2011 to 2014. Note that some of the gas reserves shown in the "Draft Five Year Gas Supply Strategy" (or Petrobangla Annual Report 2014) are updated.

- Recoverable gas reserves estimated by HCU are slightly larger than that of Petrobangla's "Draft Five Year Gas Supply Strategy 2015-2019" due presumably to a difference of reserve modeling/production philosophy.

Table 7-1 Comparison of Natural Gas Reserves Estimated by HCU (2011) and Petrobangla (2015)

Unit: BCF

Sl. No.	Gas Field	Year of Discovery	Reserves Estimated by				GIIP		Recoverable Reserves Proved (1P)		Recoverable Reserves Proved + Probable (2P)		Remaining 2P Reserves	
			HCU (2011)		Petrobangla (2015)		HCU	Petrobangla	HCU	Petrobangla	HCU	Petrobangla	HCU	Petrobangla
			Company	Year	Company	Year	Dec. 2009	Dec. 2014	Dec. 2009	Dec. 2014	Dec. 2009	Dec. 2014	Dec. 2009	Jan. 2015
A. Producing														
1	Titas	1962	Gustavson Assoc.	2010	RPS Energy	2009	9,039	8,148.9	6,838	5,384.0	7,582	6,367.0	4,514	2,515.7
2	Habiganj	1963	Gustavson Assoc.	2010	RPS Energy	2009	3,981	3,684.0	2,413	2,238.0	2,787	2,633.0	1,116	523.8
3	Bakrabad	1969	Gustavson Assoc.	2010	RPS Energy	2009	1,825	1,701.0	1,201	1,052.9	1,387	1,231.5	689	456.4
4	Kailashtila	1962	Gustavson Assoc.	2010	RPS Energy	2009	3,463	3,610.0	2,553	2,390.0	2,880	2,760.0	2,400	2,163.6
5	Rashidpur	1960	Gustavson Assoc.	2010	RPS Energy	2009	3,887	3,650.0	2,416	1,060.0	3,134	2,433.0	2,677	1,889.8
6	Sylhet/Haripur	1955	Gustavson Assoc.	2010	RPS Energy	2009	580	370.0	323	256.5	408	318.9	219	113.6
7	Meghna	1990	Gustavson Assoc.	2010	RPS Energy	2009	122	122.1	76	52.5	101	69.9	65	16.8
8	Narshingdi	1990	Gustavson Assoc.	2010	RPS Energy	2009	405	369.0	317	218.0	345	276.8	239	116.4
9	Beani Bazar	1981	Gustavson Assoc.	2010	RPS Energy	2009	225	230.7	108	150.0	137	203.0	77	115.3
10	Fenchuganj	1988	Gustavson Assoc.	2010	RPS Energy	2009	483	553.0	195	229.0	329	381.0	258	256.2
11	Saldanadi	1996	Gustavson Assoc.	2010	RPS Energy	2009	393	379.9	156	79.0	275	279.0	215	197.4
12	Shahbazpur	1995	Gustavson Assoc.	2010	Petrobangla	2011	415	677.0	214	322.0	261	390.0	260	379.5
13	Semutang	1969	Gustavson Assoc.	2010	RPS Energy	2009	654	653.8	318	151.0	318	317.7	318	308.0
14	Sundulpur Shahzadpur	2011	Gustavson Assoc.	2010	BAPEX	2012	—	62.2	—	25.0	—	35.1	—	27.1
15	Srikail	2012	Gustavson Assoc.	2010	BAPEX	2012	—	240.0	—	96.0	—	161.0	—	135.6
16	Jalalabad	1989	Gustavson Assoc.	2010	D & M	1999	1,346	1,491.0	1,013	823.0	1,128	1,184.0	583	281.2
17	Moulavi Bazar	1997	Gustavson Assoc.	2010	Unocal	2003	630	1,053.0	402	405.0	494	428.0	342	160.5
18	Bibiyana	1998	Gustavson Assoc.	2010	D & M	2008	5,321	8,350.0	4,075	4,415.0	4,532	5,754.0	4,056	3,873.2
19	Bangura	2004	Gustavson Assoc.	2010	Tulllow	2011	730	1,198.0	558	379.0	621	522.0	522	241.0
B. Non-Producing														
20	Begumganj	1977	Gustavson Assoc.	2010	BAPEX	2014	47	100.0	10	14.0	33	70.0	33	70.0
21	Kutubdia	1977	Gustavson Assoc.	2010	HCU	2003	65	65.0	46	45.5	46	45.5	46	45.5
22	Rupganj	2014	—	—	BAPEX?	2014	—	48.0	—	—	—	33.6	—	33.6
C. Production Suspended														
22	Chhatak	1959	Gustavson Assoc.	2010	HCU	2000	677	1,039.0	265	265.0	474	474.0	448	447.5
23	Kamta	1981	Gustavson Assoc.	2010	Niko/BAPEX	2000	72	71.8	21	50.3	50	50.3	29	29.2
24	Feni	1981	Gustavson Assoc.	2010	Niko/BAPEX	2000	185	185.2	63	125.0	130	125.0	67	62.6
25	Sangu	1996	Gustavson Assoc.	2010	Cairn/Shell	2010	976	899.6	678	544.4	771	577.8	304	89.9
Total (A + B + C) in BCF							**35,522**	**38,952.2**	**24,255**	**20,770.1**	**28,222**	**27,121.1**	**19,476**	**14,549.4**
Total (A + B + C) in TCF							**35.5**	**39.0**	**24.3**	**20.8**	**28.2**	**27.1**	**19.5**	**14.5**

Source: Prepared based on HCU (2011) and Petrobangla (2015) (“Draft Five Year Gas Supply Strategy 2015-2019”)

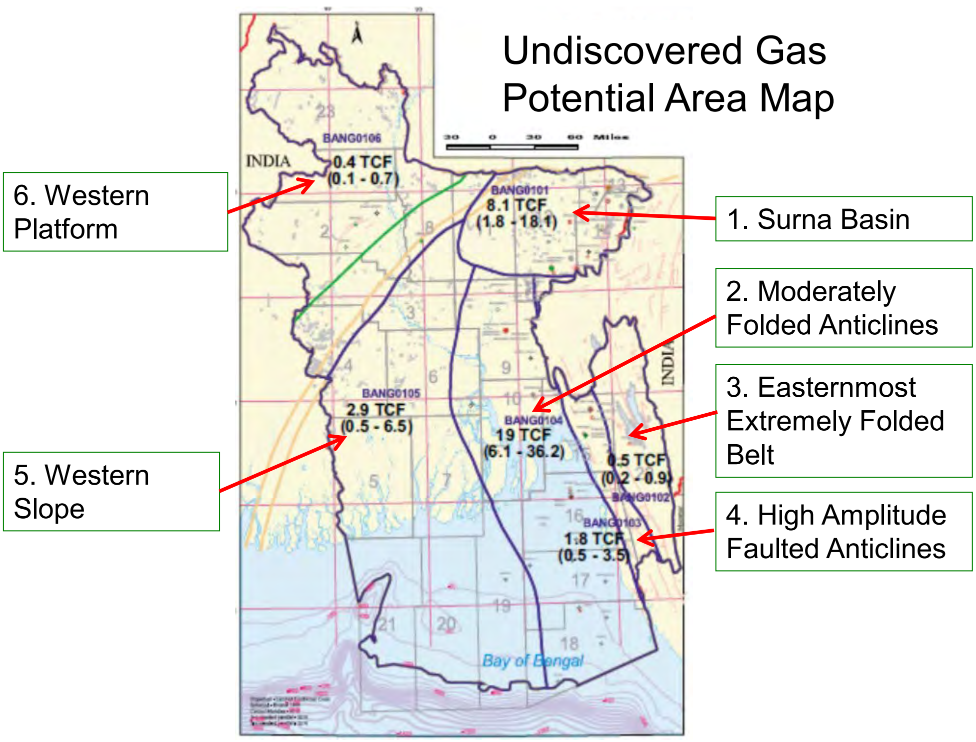
7.1.3 Gas Reserves and Resources

(1) Yet to find resources

According to the report by USGS/Petrobangla joint Study in 2001, Gas resources Yet to Find is considered as follows:

- 8.4 TCF（95% probability）
- 65.7 TCF（5% probability）
- 32.1 TCF（mean）

A geological characteristic of Bangladesh described in the previous section is further broken down by the report of USGS/Petrobangla 2001. Figure 7-2 shows potential of Yet to Find Resources in Bangladesh estimated by a joint effort of Petrobangla and USGS in 2001.



Source: Petrobangla/USGS Bulletin 2208-A, 2001

Figure 7-2 Yet to Find Resources

According to USGS Report, higher probability is indicated in the Eastern Folding Bed area and assumed 90% of Yet to Find resources in the area. On the other hand, Western and North Western area shows lower probability than eastern Folding Bed. The report indicates that main target area for gas exploration should be in the Folding Bed and East part of Foredeep area.

Table 7-2 Yet to Find Resources

Geological Characteristics	USGS Classification	Mean Probability (TCF)	95% Probability (TCF)	5% Probability (TCF)
East Folding Bed	Surma Basin	8.1	1.8	18.1
	Easternmost Extremely Folded Belt	0.5	0.2	0.9
	High Amplitude Faulted Anticlines	1.8	0.5	3.5
	Moderately Folded Anticlines	18.5	6.1	36.2
Central Foredeep	Western Slope	2.9	0.5	6.5
West and North West	Western Platform	0.4	0.1	0.7
[illegible]		32.1	8.4	65.7

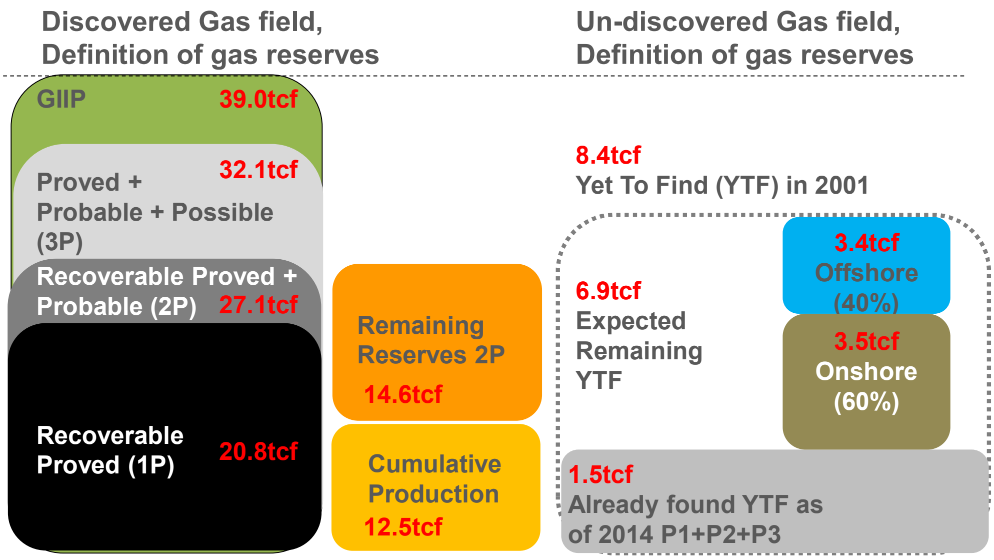
Source: Petrobangla/USGS Bulletin 2208-A, 2001

Note that Onshore portion of mean Yet to Find reserve is estimated 23.3 TCF out of 32.1 TCF of mean probability resources, and Offshore portion is remaining 8.8 TCF. Higher probability is indicated in onshore areas.

After the USGS/Petrobangla Joint Study in 2001, four gas fields, i.e., Bangura, Srikail, Sundalpur and Rupganj were discovered in the Folding Belt and east of Foredeep areas, and total of these confirmed reserves is 1.5TCF.

According to a draft Five year Gas Supply Strategy (2015-2019) by Petrobangla, GIIP of existing gas field is estimated 39 TCF, Recoverable Proved (1P) is 20.8 TCF, Recoverable Proved + Probable (2P) is 27.1 TCF and Recoverable Proved + Probable + Possible (3P) is 31.3TCF. Produced gas to date is 12.1 TCF and remaining 2P Reserve is estimated 14.5 TCF. Undiscovered Conventional gas resources are also estimated by Petrobangla and USGS in 2001. According to the report, undiscovered gas with 95% confidence is estimated 8.4TCF. Since the time 1.5TCF was newly discovered and the balance would be 6.9TCF.

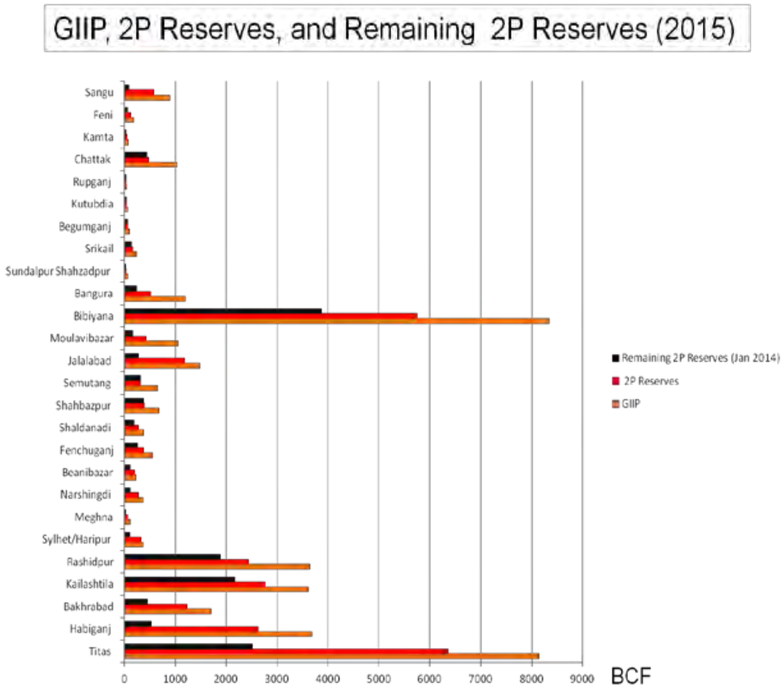
Gas Reserve Balance in Bangladesh is illustrated as follows. Undiscovered gas is assumed based on a statistical approach covering all of the Bangladesh. On the other hand, GIIP, 1P, 2P, and 3P are based on existing gas fields. Based on the reasonable assumption that higher potential of undiscovered gas can be reserved in the existing gas field area, the illustration is useful to understand the gas reserve situation in Bangladesh.



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

Figure 7-3 Gas Resource Balance

Following is a comparison of GIIP, Recoverable 2P gas Reserves, and Remaining 2P Gas Reserves. This illustrates that major gas fields of Titas、Habiganj、Bakrabad、Jalalabad are aging and the largest gas field of Bibiyana is coming to the peak of production.



Source: Petrobangla2013

Figure 7-4 GIIP, 2P Gas Reserves 2P and Remaining 2P Gas Reserves

(2) Gas reserves of suspended wells/ gas fields

According to Draft Five Year Gas Supply Strategy 2015-2019, gas production from some of the gas bearing sands have been suspended mainly due to an excessive water production from wells in those sands. Amount of such reserve is 761.13 BCF and might be or might not be deducted from the reserves shown in the Table 7-1. The report indicates that systemic study would be required to ascertain the status of these suspended sands.

(3) Non-conventional gas

For non-conventional gas potential such as coal bed methane (CBM), underground coal gasification (UCG) (these are described in Chapter 9) and shale gas, there are many uncertainties in terms of resources, locations and legal framework such as surface right and underground right. At this stage it is not recommended to include shale gas potential in the supply plan.

7.1.4 Discovery of new gas field and probability

Probability of discovery of new gas fields are higher in Folding Bed area and recommended to forcus more on this area. On the other hand, unexploited area will also need to be explored although statistics indicates negative. The JICA report entitled the "Preparatory Survey on the Natural Gas Efficiency Project in the People's Republic of Bangladesh (March 2014)" (hereinafter "JICA (2014) Report"), the following exploration programs are proposed.

- Underexplored areas: 2D seismic survey over the Bogra-Lalmai low amplitude broad regional structure and exploratory deep drilling
- Underexplored areas: 2D seismic survey and exploration drilling in the Madarganj and Sariakandi

areas
- Difficult areas: 2D seismic survey over the marshy-swampy areas of the Sunamganj-Kishorganj and surrounding areas and deep drilling
- High resolution 2D seismic survey to identify CBM potential in Gondwana basin

Further accumulation of date is required to evaluate the probability of these areas.

7.2 Petrobangla Companies and Cost Structure

7.2.1 Petrobangla companies

Activities of Petrobangla have expanded to manage from gas exploration, production, transmission, distribution, to product marketing. Currently there are following specialized companies operating under Petrobangla.

(1) BAPEX (Bangladesh Petroleum Exploration and Production Company)

Exploration right for new onshore gas fields or concessions is granted to BAPEX exclusively. BAPEX owns six gas fields (Saldanadi, Fenchuganj, Shahbazpur, Semutang, Sundalpur and Srikail) and producing 105 mmscfd of gas in 2014 FY. This accounts for 4% of gas supply in Bangladesh. In addition to six existing gas fields, two other gas fields, Rupganj and Begumganj, are about to produce gas, on completion of pipeline infrastructure.

BAPEX owns and operates drilling rigs and develops its own gas fields, and also provides drilling services to other gas producing companies under Petrobangla. BAPEX has 2D/3D seismic survey units and provides also services to other gas producing companies under Petrobangla in addition to its own concession exploration activities.

(2) Gas producing company

Role of gas production is assigned to BAPEX、BGFCL (Bangladesh Gas Field Company Ltd), SGFL (Sylhet Gas Field Limited), and also to Chevron and Tullow, called IOC (International Oil Company) under Petrobangla.

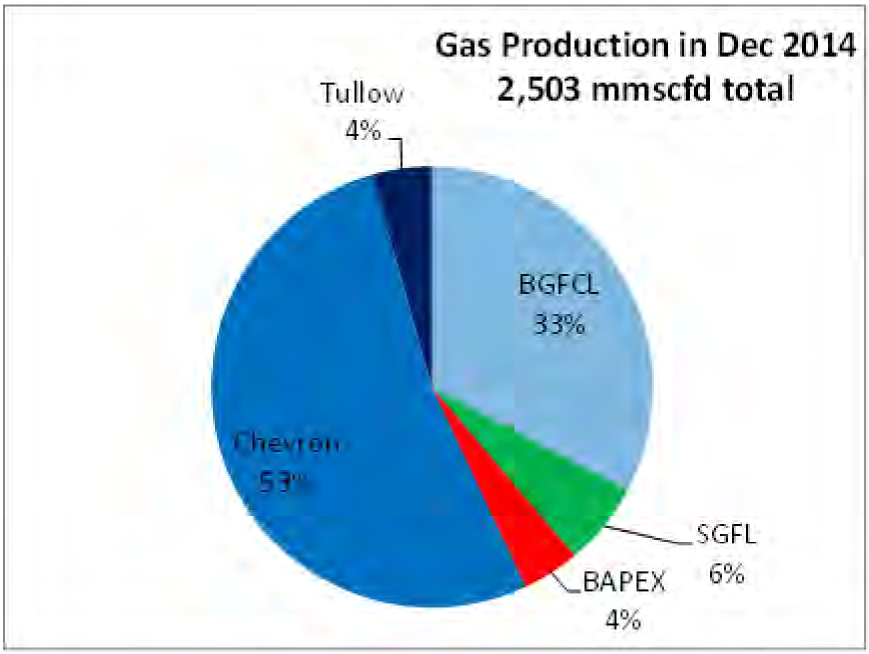
BGFCL owns and operates five gas fields, including Titas, Bakrabad, Habigan, Narshingdi and Meghna.

SGFL owns and operates four gas fields including Sylhet, Kailashtila, Rashidpur and Beani Bazarin.

Chevron and Tullow produces gas based on Product Sharing Contract (PSC) in 1996.

Chevron operates three gas fields including Bibiyana, Jalalabad and Moulavi Bazar and started production in 2006. Cheveon is known as the first company that introduced 3D seismic survey in Bangradesh. Tullow operates Bangura gas field.

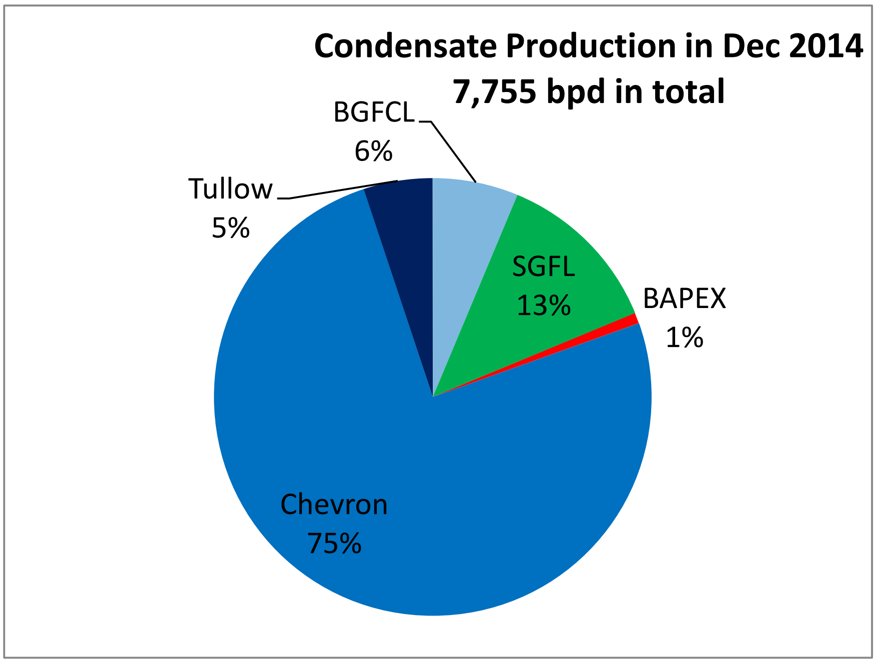
Following figure shows that contribution by Chevron and Tullow is significant in gas production in Bangladesh and accounts for 60 % of overall production.



Source: Petrobangla Annual report 2014

Figure 7-5 Gas Production in Dec 2014- by Company

Significant amount of condensate is associated with gas production. Production rate of the condensate was 7,755 bpd in Dec 2014. Revenue from the sale of condensate is contributing the economics of gas producing companies, in addition to gas revenue. SGFL relies on 75% of revenue from the sale of oil products produced from condensate.



Source: Petrobangla Annual report 2014

Figure 7-6 Condensate and NGL Production in Dec 2014- by Company

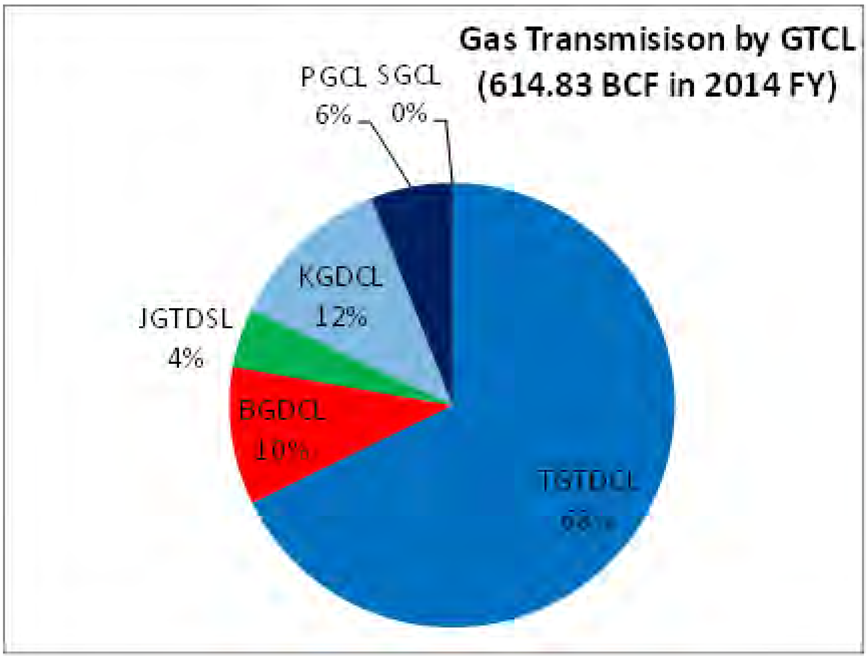
Produced condensate is transported via. Pipeline to Titas Gas Field and Bakhrabad Gas Field for refining and produced oil products are sold national and private oil marketing companies.

SGFL is constructing new fractionators and reformer (gasoline production) by its own finance.

(3) Gas Transmission Company

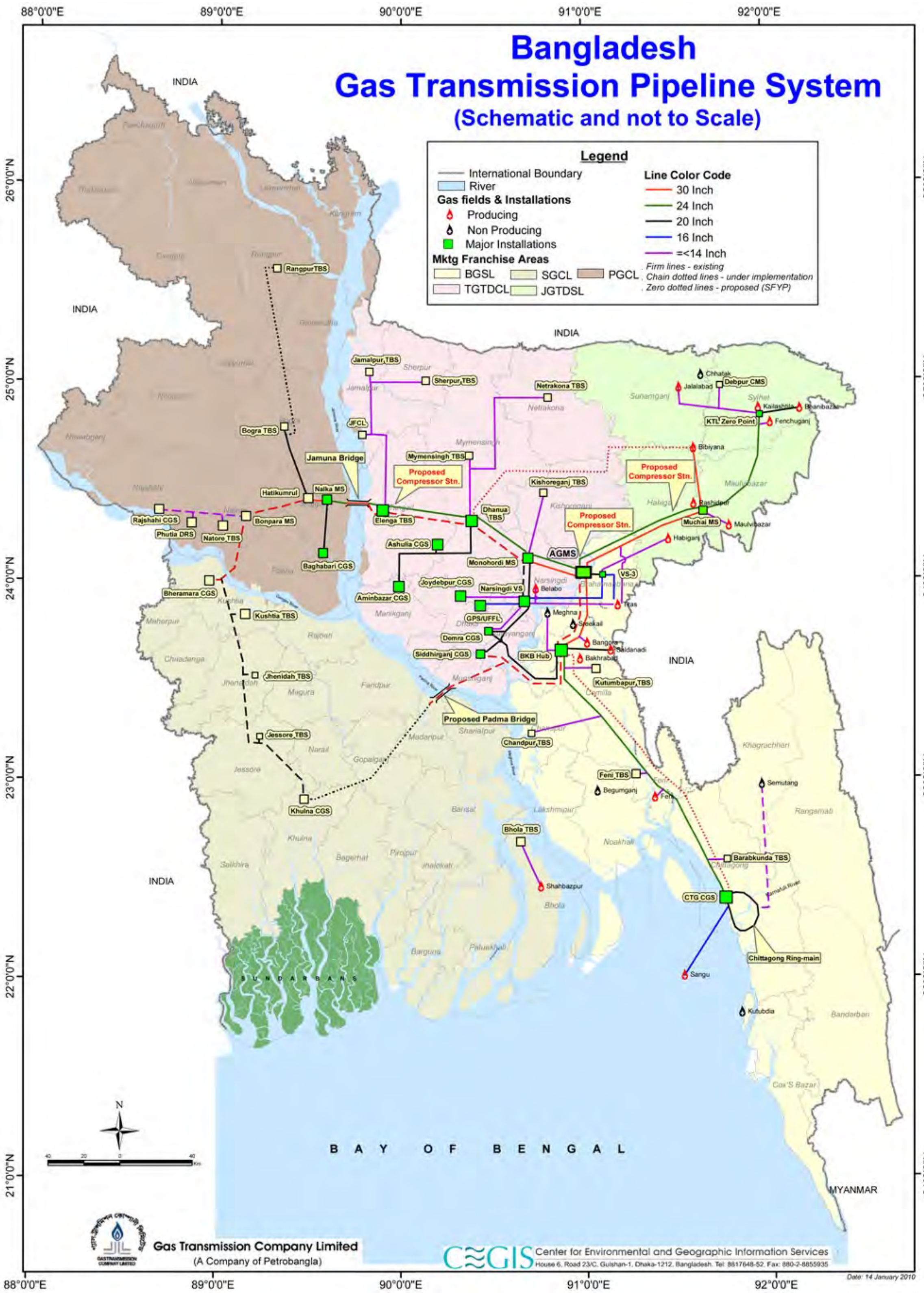
GTCL (Gas Transmission Company Limited) was incorporated in 1993 with the objectives of centralized operation and maintenance of national grid, and expanding the system as required, ensuring balanced supply and usage of natural gas in all regions of the country.

GTCL transported 614.83 BCF of gas in 2014 FY and this account for 70 % of gas produced in Bangladesh (the rest 30% are directly transported by local gas distribution and marketing companies). Gas transmission infrastructure has improved significantly since the time of GTCL incorporation. In near future volume of gas from LNG will increase significantly and reinforcement of the current infrastructure may be required to cater to an increasing gas volume from LNG.



Source: Petrobangla Annual Report 2014

Figure 7-7 Gas Transmission by GTCL- by Customer 2014 FY



Source: GTCL

Figure 7-8 GTCL Gas Transmission System

(4) Gas distribution and marketing company

There are six regional gas distribution companies under Petrobangla. These companies are given gas quota allocated sector-by-sector and/or project-by-project basis under the limited supply situation. Total supply of gas to end users was 826.65 BCF in 2014 FY[1], and considered much lower than actual demand.

1) Titas Gas Transmission Distribution Company Limited (TGTDCL)

TGTDCL is supplying gas to Dhaka Division, and the largest gas distribution and Sale Company. Gas supply is 520.28 BCF in 2014 FY

2) Karnaphuli Gas Distribution Company Limited (KGDCL)

KGDCL is supplying gas to Chittagong, Rangamati, and Cox's Bazar divisions. Gas supply to endusers in 2014 FY was 82.32 BCF.

3) Bakhrabad Gas Distribution Company Limited (BGDCL)

BGDCL is supplying gas to Comilla, Brahamanbaria, Feni, Noakhali and Lakxmipur provinces. Gas supply to end users in 2014 FY is 110.31 BCF.

4) Jalalabad Transmission and Distribution Systems Limited (JTDSL)

JTDSL is supplying gas to Sylhet Division. Gas supply to end users in 2014 FY was 75.68 BCF.

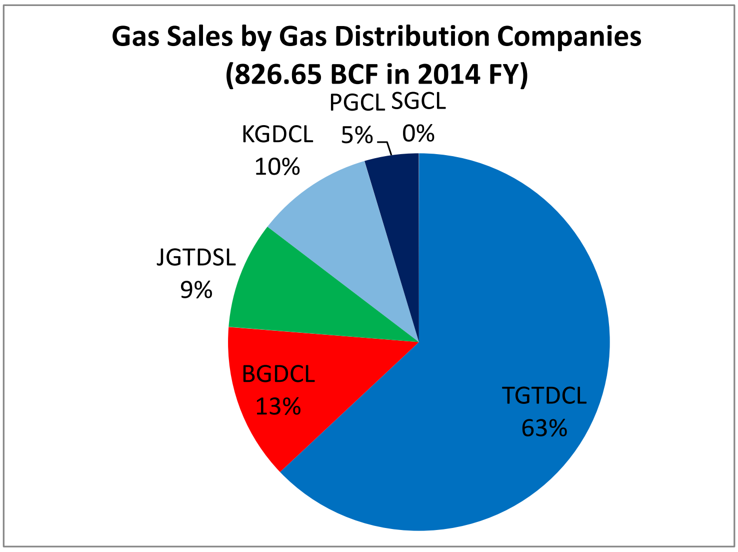
5) Pashchimanchal Gas Company Limited (PGCL)

PGCL is supplying gas to Rajshahi Division. Gas supply to end users in 2014 FY is 38.06 BCF. PGCL is expected to supply gas to Rangpur Division also.

6) Sundarban Gas Company Limited (SGCL)

SGCL is formed in Nov 2009. Its franchise areas is Khulna and Barisal Division

[1] The gap between the quantity transported by GTCL (614.83 BCF) and the total sales volume (826.65 BCF) is what local gas distribution and marketing companies directly transport and supply to customers.



Source: Petrobangla Annual Report 2014

Figure 7-9 Gas Sale by Gas Distribution Companies in 2014FY

(5) CNG and LPG

Pupantarita Prakritik Gas Company Limited (RPGCL) was formulated in 1987 to promote the use of CNG and LPG. RPGCL and private entrepreneurs have set up 587 CNG filling stations and 180 conversion workshop as of June 2014. These filling stations are supplying CNG to almost 220 thousand vehicles daily. This account for 3.58 BCF per month or 5% of total gas supply. RPGCL owns and operate LPG Extraction Plant in Golapgonj, Sylhet. Further details of LPG can be referred in Chapter 10.

(6) Gas infrastructure design standard

Early gas infrastructure was constructed before independence and it is still in service. It appears that condition of old infrastructure has not been systematically investigated and design standard has not been updated. To modernize the gas infrastructure, these need to be reviewed and investigated further.

7.2.2 Gas price and cost structure

Gas pricing system is prepared and decided by the Bangladesh Energy Regulatory Commission (BERC). There are eight market sectors and each has its own pricing structure. These price figures are revised from time to time under the circumstances to suit.

Table 7-3 Gas Price by Sector

	Sector	BDT/M3	USD/MMBTU
1	Power	2.820	1.02
2	Captive Power	8.360	3.03
3	Fertilizer	2.580	0.94
4	Industry	6.740	2.44
5	Tea Garden	6.450	2.34
6	Commercial	11.360	4.12
7	CNG	27.000	9.79
8	Domestic	7.000	2.54

Source: BERC September 2014

Cost component and profit mergine of each sector consists of following:

(1) Profit to the Government: 55% (2)Profit to Petrobangla: 45%

1) Petroleum Development Fund: Petrobangla is custodian of the fund and used for petroleum development
2) BAPEX Margin: Allocated to BAPEX as a revenue
3) Price Deficit Wellhead Margin: Created in Dec 1998 to meet up the deficit arisen from sale of gas at a rate lower than the purchase rate by Petrobangla from IOCs
4) Wellhead Gas Margin: Gas producer receive as a revenue
5) Transmission Charge: Wheeling fee for gas transmission. Revenue for GTCL
6) Distribution Charge: Distribution fee for gas distributors
7) Gas Development Fund Margin: In Aug 2009, BERC ordered to create GDF which currently in use for oil and gas exploration and production activities. Petrobangla is custodian of the fund.
8) Gas Asset Price: BERC ordered gas marketing and distribution companies in Sep 2015 to create fund kept in a separate account. This fund will be used for future energy project such include LNG etc.

Table 7-4 Gas Price Component

Unit: BDT/M3

	Sector	Government Tax	Petroleum Development Fund	BAPEX Margin	Price Deficit Wellhead Margin	Wellhead Gas Margin	Transmission Charge	Distribution Charge	Gas Development Margin	Gas Asset Price	End User Price
1	Power	1.4363	0.3170	0.0480	0.0400	0.2250	0.1565	0.2650	0.2087	0.1235	2.8200
2	Captive Power	4.3519	0.4560	0.0480	0.0400	0.2250	0.1565	0.1550	0.4474	2.4802	8.3600
3	Fertilizer	1.2362	0.2680	0.0000	0.0400	0.2250	0.1565	0.2650	0.3358	0.0535	2.5800
4	Industry	3.3621	0.7660	0.0480	0.0400	0.2250	0.1565	0.2450	0.6279	1.2695	6.7400
5	Tea Garden	3.2026	0.7660	0.0480	0.0400	0.2250	0.1565	0.2450	0.6279	1.1390	6.4500
6	Commercial	5.5710	1.3355	0.0480	0.0400	0.2250	0.1565	0.2450	1.2350	2.5040	11.3600
7	CNG	14.8500	6.1000	0.1100	0.2000	0.3000	0.1565	0.1550	3.1640	1.9645	27.0000
8	Domestic	3.5344	0.7090	0.0480	0.0400	0.2250	0.1565	0.2450	0.5739	1.4682	7.0000

Source: BERC Sep 2014

Translation to USD/MMBTU is as follows:

Table 7-5 Gas Price Component

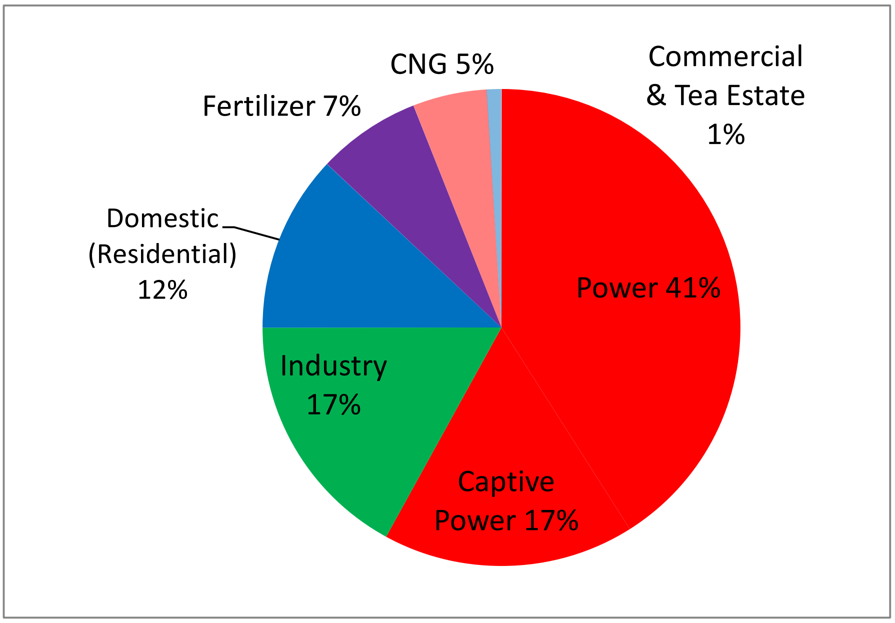
Unit: USD/MMBTU

	Sector	Government Tax	Petroleum Development Fund	BAPEX Margin	Price Deficit Wellhead Margin	Wellhead Gas Margin	Transmission Charge	Distribution Charge	Gas Development Margin	Gas Asset Price	End User Price
1	Power	0.52	0.11	0.02	0.01	0.08	0.06	0.10	0.08	0.04	1.02
2	Captive Power	1.58	0.17	0.02	0.01	0.08	0.06	0.06	0.16	0.90	3.03
3	Fertilizer	0.45	0.10	0.00	0.01	0.08	0.06	0.10	0.12	0.02	0.94
4	Industry	1.22	0.28	0.02	0.01	0.08	0.06	0.09	0.23	0.46	2.44
5	Tea Garden	1.16	0.28	0.02	0.01	0.08	0.06	0.09	0.23	0.41	2.34
6	Commercial	2.02	0.48	0.02	0.01	0.08	0.06	0.09	0.45	0.91	4.12
7	CNG	5.38	2.21	0.04	0.07	0.11	0.06	0.06	1.15	0.71	9.79
8	Domestic	1.28	0.26	0.02	0.01	0.08	0.06	0.09	0.21	0.53	2.54

Source: BERC Sep 2014

7.2.3 Financial status of companies under Petrobangla

In FY 2013-2014 by sector gas consumption shows that more than 60% of total gas consumption went for the power generation (including captive power).



Source: Petrobangla Annual Report 2014

Figure 7-10 Gas Consumption by Sector in FY2014

Due to a shortage of gas supply and also under the gas quota system, actual gas demand for each sector will be potentially larger than current consumption, and demand spectrum may also be different.

Gas producing companies under Petrobangla receives Wellhead Margin of USD 0.08/MMBTU, while IOC receives USD 2.48/MMBTU. SGFL has worked to maximize the recovery of condensate and produce oil products produced for sale. 75% of revenue comes from the sale of oil product. In order to enhance the revenue further, SGFL is constructing 4,000 bpd fractionators and 3,000 bpd reformer to manufacture gasoline by its own finance.

GTCL receives Gas Transmission Charge. The rate has reduced to half i.e., USD 0.06/MMBTU after Sep 2014, assuming that growth of flow rate would compensate the reduced unit rate. GTCL is constructing 36 inch Bibiyana-Dhanua pipeline with the length of 137 Km by its own finance. GTCL expects that this project will bring some more revenue and contribute to the financial status of the company. GTCL is caring out other investment projects supported by dinners such includes ADB, World Bank, and JICA, and also government funding.

Major portion of revenue for Gas distribution companies comes from Distribution Charge, which varies from sector to sector but no significant difference among the sectors. Since there are no significant differences between large scale customers and Residential customers, major marketing effort favors large customers.

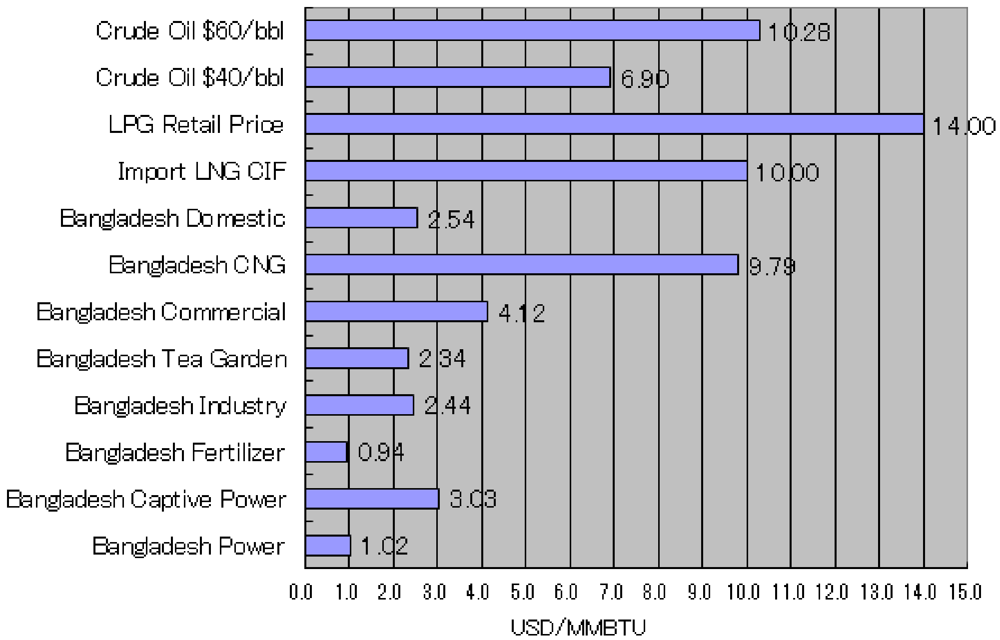
Gas distribution companies are trying to increase the revenue by making investment on Transmission Pipeline Project and receive Transmission Charge if economics favors. They are also utilizing Security Charge from their customers to raise revenue from fund operation.

Government of Bangladesh is promoting LPG for domestic (residential) use, discouraging the use of natural gas. Petrobangla is also promoting the use of gasoline in lieu of CNG to save natural gas.

To balance out the price difference between natural gas and alternative fuels, Distribution Charge for domestic (residential) sector and CNG to be raised.

Average gas market price in Bangladesh in 2014FY in terms of USD/MMBTU is USD 2.34 /MMBTU, and on the other hand, purchase price from IOC is USD 2.48/MMBTU.

Comparison of Energy Price in Bangladesh is shown in the Figure 7-11. Gas price for power and fertilizer are significantly low in comparison and need to be adjusted considering envisaged future introduction of LNG. Raising the gas price might necessitate the enhancement of gas use efficiency for these sectors. Discussion on future gas tariff should be referred in Chapter 20 and Chapter 21.



Source: BERC Sep 2014and others

Figure 7-11 Gas Price Comparison

7.3 Gas Production Forecast

7.3.1 Assessment of existing gas fields and fast track program

(1) Assessment of existing gas fields

Tracing of production record of the existing gas fields helps to make forecast of future gas production. A comparison of actual production (average daily production) from each gas field over the years from 2010 to 2014 and the production forecast by PSMP2010 is shown in Table 7-6.

Table 7-6 Comparison between Actual Average Daily Production and PSMP2010 Forecasts

Unit: mmscfd

Sl. No.	Gas Field	Average Daily Production							
		Actual					PSMP2010 Forecasts		
		2010	2011	2012	2013	2014	2010	2014: Case1	2014: Case 2
1	Titas	404	445	450	490	515	408	578	560
2	Habiganj	235	260	227	225	225	240	260	260
3	Bakhrabad	35	33	32	41	41	36	51	51
4	Kailashtila	91	86	89	84	74	87	97	97
5	Rashidpur	49	49	47	47	61	49	84	85
6	Sylhet/Haripur	3	10	9	9	8	7	30	30
7	Meghna	0	10	10	11	10	0	5	5
8	Narshingdi	33	30	30	28	28	35	25	25
9	Beanibazar	15	9	11	10	10	15	15	15
10	Fenchuganj	25	23	36	37	39	24	65	60
11	Saldanadi	8	18	16	15	12	8	8	8
12	Shahbazpur	6	0	7	7	8	8	10	10
13	Semutang	0	14	8	6	5	0	15	15
14	Sundalpur	0	0	10	10	4	0	60	60
15	Srikail	0	0	0	42	39	0	60	60
16	Sangu	37	14	23	0	0	40	0	0
17	Jalalabad	163	165	232	249	246	130	250	200
18	Moulavi Bazar	58	42	94	77	63	60	160	80
19	Bibiyana	658	753	792	822	1,007	716	900	850
20	Bangura	105	102	86	111	110	120	120	120
21	Begumganj	0	0	0	0	0	0	0	0
22	Kutubdia	0	0	0	0	0	0	0	0
23	Chattak	0	0	0	0	0	0	0	0
24	Kamta	0	0	0	0	0	0	0	0
25	Feni	2	0	0	0	0	2	2	2
Total		**1,926**	**2,062**	**2,210**	**2,323**	**2,435**	**1,995**	**2,765**	**2,563**

Note: A production rate of 60 mmscfd for Sundalpur and Srikal by the PSMP2010 forecasts means that the sum of production from Sundalpur and Srikail should be equal to 60 mmscfd in this case.

Source: Prepared based on Petrobangla Annual Reports 2010 to 2014 and PSMP2010 report (JICA, 2011)

Based on the information/data about remaining 2P reserves shown in the "Draft Five Year Gas Supply Strategy 2015-2019", and also description about the drilling and work-over activities shown in the Petrobangla Annual Reports, assessment of current gas field status and the future outlook are investigated (refer to the Attachment 7-1)

As a result of study, followings are understood.

- Only Bibiyana gas field has shown a steady increase in production since 2010 in Bangladesh.
- The Jalalabad gas field also significantly increased production in 2012, but after that production from the field has not increased significantly.
- Production from the Sangu gas field was suspended from October 1, 2013.
- Measures to be taken (e.g. meticulous casing and cementing work) to prevent incidents such as xcessive water production from sands
- Develop new gas field for further gas production while maintaining current production level as much as possible.
- Installation of wellhead gas compressors to maintain gas production.

(2) First truck program

To meet the increasing gas demand within the soonest possible time, decision was made as per Government directives and under the Speedy Supply of Power and Energy-Special Provision- Act 2010, to drill a total of 10 wells by Gazprom EP, Russia. The Contract was signed in April 2012 and Drilling work was carried out 2013-2014, as follows:

Titas Gas Field (BGFCL): Well No.19, 20, 21, 22
Rasidpur Gas Field (SGFCL): Well-No.8
Semutang gas Field (BAPEX): Well No. 6
Begumganji Gas Field (BAPEX): Well No. 3
Shrikail Gas Field (BAPEX): Well No. 3
Shahbazpur Gas Field (BAPEX): Well No. 3, 4

Expected gas production by the contract was 300 MMCFD, however, actual confirmed gas production ended up with 150 MMCFD. Five wells are producing gas. Three wells are waiting for completion of processing facilities and connecting pipeline infrastructure. Titas No. 21 well produced gas at 10 MMCFD for the first 6 months, and suspended due to an excessive water production. Work-over is underway by BAPEX at the cost of Petrobangla. Semutang No. 6 well was relinquished due to an excessive water production.

Additional contract was signed in end 2015 with Gazprom to drill following five wells:

Bhakrabad Gas Field (BGFCL): Well No. 10
Rashidpur Gas Field (SGFCL): Well No. 9, 10, 12
Shrikail Gas Field (BPEX): Well No. 4

(3) Introduction of "Best Industrial Practice" through competitive bidding

BGFCL has introduced "Best Industrial Practice" through competitive bidding for Titas Gas Field Well No. 23、24、25、26, financed by ADB under "Gas Seepage Control and Appraisal and Development of Titas Gas Field" As a result, SINOPEC China was awarded the contract at the price of 25% lower than that of Gazprom paid for the First Truck Program, and the result was satisfactory. This project indicates that there is an alternative way for the future exploration project in addition to the First Truck Program.

7.3.2 Production forecast for existing gas fields 2015-2019

Production forecast for the existing gas fields for the next five years will provide a base for preparing long-term production forecast. In this Study, production forecasts for the period of 2015 to 2019 are prepared by reviewing the Draft Five Year Gas Supply Strategy 2015-2019 (Petrobangla Five Year Plan 2015).

As a result of the review, it is considered that the production rate shown in the Draft Five Years Gas Supply Strategy is considered a little too optimistic. And therefore, correction factor is introduced. (Refer to Attachment 7-1)

(1) Review of schedule and performance of wells in the Petrobangla Five-Year Plan

Well completion schedule and production rate shown in the in the "Gas Evacuation Plan 2010-2015" prepared in 2010 was reviewed by comparing against Petrobangla Five year Plan 2015. The summary of the review outcome is as follows:

- Times of well completion: At least one year behind the schedule
- Production rates for new wells: About 70% of initial estimates (Gazprom performance is reflected)

(2) Correction factors for schedule delay and production rate is introduced as follows:

Impact of schedule delay on the production rate is expressed as a discount factor for production rate. One-year delay in a five-year period is discounted by 20% from the initial estimate.

- Times of well completion: 80% of the initial estimates
- Production rates for new wells: 70% of the initial estimates

The values of production rates are corrected by multiplying 0.8 and 0.7 for all wells scheduled to be completed after 2016.

(3) Production forecasts for 2015-2019

Taking above review result into account, Production forecast in Petrobangla Five year Plan was modified. The modified production forecasts are shown in Table 7-7.

Note that:

- Production profiles are basically the same as those shown in the Petrobangla Five-Year plan 2015.
- According to the Petrobangla Five-Year Plan 2015 include the production of 5 mmscfed from Shahbazpur gas field after 2018 is not taken into consideration in this study because there is no clear development plan is publicized yet.
- Peak gas production will be in July-December 2016 and the rate is estimated 2,811 mmscfd. While production forecasts by the Petrobangla Five-Year Plan 2015 also shows a peak production in the same period with the estimated rate of 2,916 mmscfd. Differential of Production rate between the cases are about 100 mmscfd, or discounted by 5% .

Table 7-7 Daily Gas Production Forecast for 2015-2019

Unit: mmscfd

Company	Field	2015		2016		2017		2018		2019		Remarks
		Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	
1. BGFCL	Titas	525	520	520	510+56	556	546	489	489	441	441	Production start-up: Jul-Dec 2016—Well nos. 23, 24, 25 and 26
	Bakrabad	40	38	36	34	30	26	23	23	30	30	
	Habiganj	224	224	224	224	220	218	215	215	200	200	
	Narsingdi	28	28	28	28	26	25	24	24	23	23	
	Meghna	10	10	10	10	10	10	9	9	9	9	
	Sub-total	**827**	**820**	**818**	**862**	**842**	**825**	**760**	**760**	**703**	**703**	
2. SGFL	Sylhet	8	8	7	7+6	12	11	11	10	10	9	Production start-up:Jul-Dec 2016—Well no. 9
	Kailashtila	72	70+8	78+14	92+8	100	96	96	92	92	88	Production start-up: Jul-Dec 2015—Well no. 1&5, Jan-Jun 2016—Well no. 9, Jul-Dec 2016—Well no. 7
	Rashidpur	60	59	58	57	56	61	72	70	67	67	Production start-up: Jul-Dec 2017--Well no. 9, Jan-Jun 2018--Well nos. 10 & 11
	Beani Bazar	9	9	9	9	8	8	8	8	8	8	
	Sub-total	**149**	**154**	**166**	**179**	**176**	**176**	**187**	**180**	**177**	**172**	
3. BAPEX	Saldanadi	10	6+10	16	13	12	11	10	10	10	10	Prpduction start-up: Jul-Dec 2015—Well no. 4
	Fenchuganj	35	34	32	30	30	29	28	28	28	28	
	Shahbazpur	10	10+9	29	29	29	29	29	29	29	29	Production start-up: Jul-Dec 2015—Well no. 4
	Semutang	4	3	2	2	2+4	6+4	10	10	10	10	Production start-up: Jan-Jun 2017—Well no. 7, Jul-Dec 2017—Well no. 8
	Sundalpur	3	3	2	0+4	4	4	4	4	4	4	Production start-up: Jul-Dec 2016—Well no.2
	Srikail	38	36	35+11	46	41	41	41	41	36	36	Production start-up: Jan-Jun 2016—Well no. 4
	Rupganj	0	8	8	8	8	8	7	7	7	7	
	Begumganj	4	4+8	12	12	10	10+8	16	16	12	9	Jan-Jun 2015: Actual production, Production start-up: Jul-Dec 2015—Well no. 3, Jul-Dec 2017—Well no. 4
	Sub-total	**104**	**141**	**147**	**144**	**140**	**150**	**145**	**145**	**136**	**133**	
	Sub-total (1+2+3)	**1,080**	**1,115**	**1,131**	**1,185**	**1,158**	**1,151**	**1,092**	**1,085**	**1,016**	**1,008**	
4. Chevron	Jalalabad	250	250	250	250	220	220	220	220	220	220	
	Maulavibazar	50	50	50	50	45	45	45	45	45	45	Jan-Jun 2015: Actual production
	Bibiyana	1,100	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	Jan-Jun 2015: Actual production
5. Tullow	Bangora	110	110	109	109	81	81	69	69	58	58	Jan-Jun 2015: Actual production
	Sub-total (4+5)	**1,510**	**1,610**	**1,609**	**1,609**	**1,546**	**1,546**	**1,534**	**1,534**	**1,523**	**1,523**	
6.	Feni				6	6+6	12	12	11	9	8	Resumption of production: Jul-Dec 2016—Well no. 6, Jan-Jun 2017—Well no. 7
7.	Chhatak				11	11+11	22	22	19	19	16	Resumption of production: Jul-Dec 2016—Well no. 3, Jan-Jun 2017—Well no. 4
Ground Total (1+2+3+4+5+6+7)		**2,590**	**2,725**	**2,740**	**2,811**	**2,738**	**2,731**	**2,660**	**2,649**	**2,567**	**2,555**	

Note: 1) Production rates in yellow cells were modified from those shown in the Petrobangala's five-year plan based on the actual production data or corrected production rates shown in Table 1.4-2.
2) The expression such as "510+56" means a daily production rate without additional production plus an additional daily production rate.

Source: Petrobangla's "Draft Five Year Gas Supply Strategy" (2015) and JICA SurveyTteam

(4) Gas production forecast 2020 and after

Gas production forecast from 2020 through to 2041 is calculated:

- based on the data (such includes GIIP, 1P, 2P, and Remaining 2P of all of the existing gas fields-Producing, Non-Producing, Production Suspended) shown in "Draft Five Year Gas Supply Strategy 2015-2019" and other publication materials by Petrobangla,
- using formula for estimating gas production profile as shown below.

Note that the calculation methodology is agreed upon with Petrobangla.

JICA Team further uses discount factor of 95% to estimate gas production profile till 2041, since the estimate by petrobangla has tended to be larger than actual as stated in the previous section.

Formula used for Gas Production Profile:

Estimation expression	Expalnation variable (Pn) =	
	IF((RV_0−CP_{n-1})*Sc > (Pn−1*365/1000*5.5, Pn−1, IF(Pn−1*(100−Dc)/100<3, 0, Pn−1*(100−Dc)/100,0))*Gc	
Structure of the expression for production in the year	Expalnation variable (Pn) =	
	IF(RV_0-CP_{n-1})*Sc>(P_{n-1}*365/1000)*5.5)	Y → P_n = P_{n-1}
		N → IF(P_{n-1}*(100-Dc)/100 < 3)
		Yes → P_n = 0
		No → P_n = Pn−1*(100− Dc)/100
Variable explanation	RV_0	Remaining P1+P2+P3 Reserve
	0 year	The base year in the study is 2013
	CP_{n-1}	Cumulative Production up to "n-1" year
	Sc	Probability of the production from remaining reserves, The Value 0 < Sc <1.0
	RV_0-CPn-1	Remaining P1+P2+P3 Reserves in "n-1" year
	P_n	Natural gas production in the year of "n"
	Pn-1*365/1000)	Convert from Production unit with mmcfd to Bcfa
	5.5	Depletion rate in the deciline period, the vale is summation of "1.0+0.9+0.8+0.7+0.6+0.5+0.4+0.3+0.2+0.1"
	Dc	Depletion rate, when the remaining reserves are not enough for annual production, the production is declined with Dc
	P_{n-1}*(100-Dc)/100<3	When declining production become less than 3 mmcfd, the production is fixed by 0.
	Gc	Production expansion plan factor, Gc is set by 1.1 (10% per year up per yaer) when the remaining reseves have allowance of production expansion

Source: JICA Survey Team

Figure 7-12 Formula for Estimating Gas Production Profile

a) Explanation of IF(RV0-CPn-1)*Sc > (Pn-1*365/1000)*5.5)

The above expression means whether the previous year production operations can be continued for the next 10 years or not.

By the expression of (RV0-CPn-1), the remained probable reserves are calculated. RV0 indicates GIIP and CPn-1 indicates accumulative production of the fields.

"Sc" means the existing probability of the remained probable reserves, "1.0"is set for all " Sc" of the fields.

The expression of "Pn-1*365/1000)*5.5" means the accumulative production for the next 10 years. "5.5（＝1.0+0.9+0.8+0.7+0.6+0.5+0.4+0.3+.2+0.1）" is a coefficient for calculating accumulative production for the next 10 years under condition of depletion rate 10%.

b) When "IF(RV0-CPn-1)*Sc > (Pn-1*365/1000)*5.5) " is true

When field production for the next 10 years can be continued by the previous year production operation, the current production (Pn) is defined by the following expression.

Current production (Pn)= Previous year production(Pn_{-1})

c) When "IF(RV0-CPn-1)*Sc > (Pn-1*365/1000)*5.5) " is not true

It means that the previous year production operation cannot be continued for the next 10years. The future field production is calculated in line with production decline factor. The decline factor is externally estimated by the remained probable reserve and the previous year production. The decline factor for each field is defined from 10% to 30%. By the decline factor, the annual productions of the fields gradually are declined year by year.

d) IF(Pn-1*(100-Dc)/100 < 3)

The above expression means to stop the productions of the fields when the previous production (Pn_{-1}) becomes less than the threshold of the production. In the study, the threshold is defined by "3 mmcfd ".

Following table shows the result of calculation, showing gas production profile of each Producing Gas fields, Gas Production Profile based on Petrobangla data, and JICA Team assumption using 95% of discount factor till 2041.

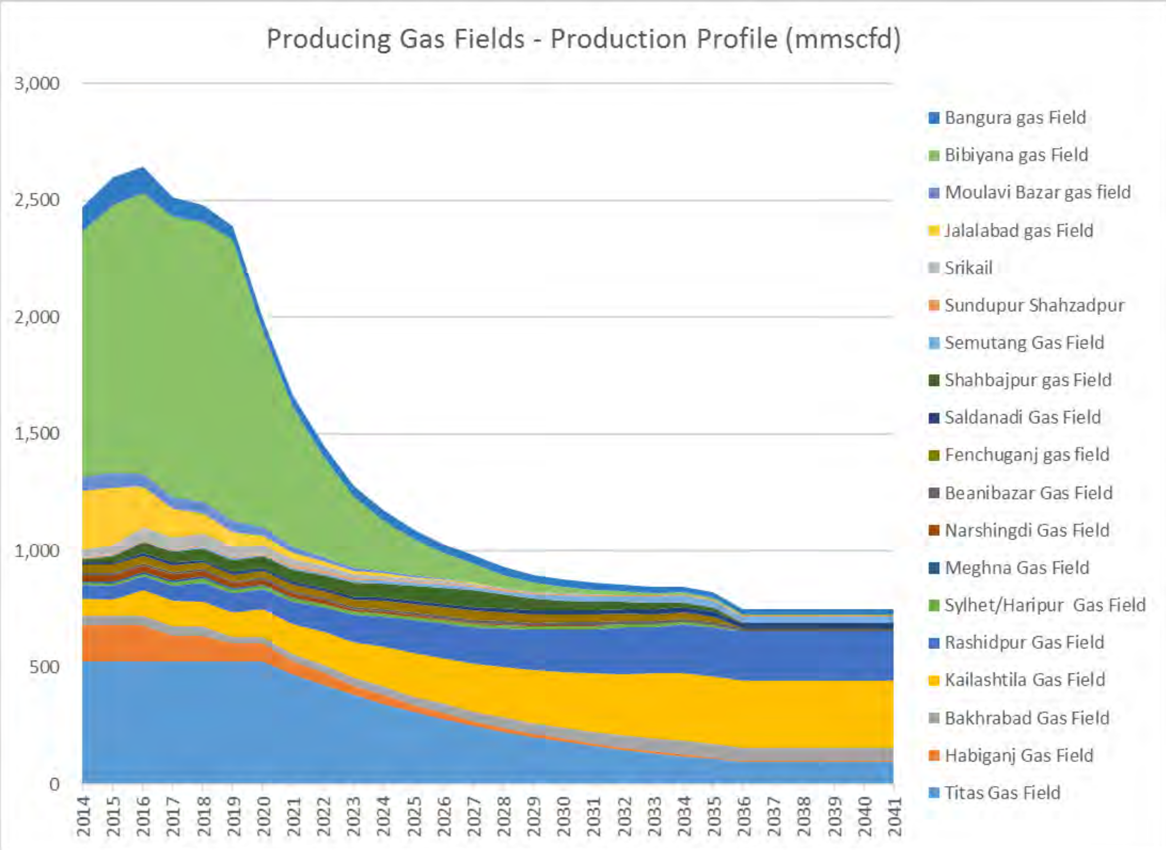
Note that the table include non-producing gas field and production suspended gas field. These gas fields are capable of produing gas, and contributing gas production in future. JICA estimate is considered to include production of these gas fields.

Table 7-8 Estimate of Gas Production Profile 2016～2041

Sl. No.		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
1	Titas Gas Field	525	525	525	525	525	473	425	383	344	310	279	251	226	203	183	165	148	133	120	108	97	97	97	97	97	97
2	Habiganj Gas Field	157	110	110	77	77	54	54	38	38	26	26	18	18	13	13	9	9	9	6	6	4	4	4	4	4	4
3	Bakhrabad Gas Field	40	40	40	30	30	32	33	35	36	38	40	42	44	47	49	51	54	57	59	59	53	53	53	53	53	53
4	Kailashtila Gas Field	110	110	108	105	116	127	140	154	169	186	195	205	215	226	237	249	262	275	289	289	289	289	289	289	289	289
5	Rashidpur Gas Field	57	65	83	80	88	97	106	117	129	142	149	156	164	172	181	190	199	199	209	209	209	209	209	209	209	209
6	Sylhet/Haripur Gas Field	12	15	14	13	13	13	13	13	13	13	13	13	13	13	13	13	13	12	11	9	0	0	0	0	0	0
7	Meghna Gas Field	10	10	9	9	6	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Narshingdi Gas Field	28	25	24	23	23	18	15	12	12	9	8	6	5	5	4	3	0	0	0	0	0	0	0	0	0	0
9	Beanibazar Gas Field	9	8	8	8	8	8	9	9	10	10	11	11	12	12	13	14	14	15	16	14	13	13	13	13	13	13
10	Fenchuganj gas field	30	29	28	28	28	29	31	32	34	36	38	39	37	35	33	31	30	28	25	23	0	0	0	0	0	0
11	Saldanadi Gas Field	15	13	12	12	12	13	13	14	15	15	16	17	18	19	20	21	22	23	23	23	23	23	23	23	23	23
12	Shahbajpur gas Field	45	45	50	50	50	53	55	58	61	64	67	70	59	50	42	35	29	25	21	17	0	0	0	0	0	0
13	Semutang Gas Field	5	8	8	8	8	9	10	11	12	13	14	16	17	19	21	23	25	28	30	30	30	30	30	30	30	30
14	Sundupur Shahzadpur	4	4	4	5	5	5	6	6	6	6	6	6	6	5	5	5	5	5	5	5	4	4	4	4	4	4
15	Srikail	55	50	50	45	36	29	23	18	15	12	9	8	6	5	4	3	0	0	0	0	0	0	0	0	0	0
16	Jalalabad gas Field	175	123	86	60	42	29	21	14	10	7	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Moulavi Bazar gas field	55	50	50	50	35	25	18	13	9	7	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Bibiyana gas Field	1,200	1,200	1,200	1,200	840	600	428	306	218	156	111	79	57	41	29	21	15	11	8	5	4	4	4	4	4	4
19	Bangura gas Field	114	85	72	60	54	51	48	46	43	41	38	36	34	32	31	29	27	26	24	23	21	21	21	22	23	24
A Producing Total		2,645	2,514	2,481	2,388	1,995	1,669	1,451	1,278	1,173	1,091	1,030	981	932	897	877	862	853	845	846	821	748	748	748	749	750	751
20	Begumganj Gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Kutubdia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Rupganji																										
B Non-Producing		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Chattak	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Kamta Gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	Feni gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	Sangu gas Field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C Production suspended		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total of Domestic production		2,645	2,514	2,481	2,388	1,995	1,669	1,451	1,278	1,173	1,091	1,030	981	932	897	877	862	853	845	846	821	748	748	748	749	750	751
	Additional production	8	202	181	175	551	519	454	403	374	351	335	323	309	299	294	291	289	289	291	283	248	248	248	248	249	249
PSMP2015 Estimate (95% of Petrobangla Forecast)		2,653	2,716	2,662	2,563	2,547	2,188	1,905	1,681	1,547	1,441	1,366	1,305	1,240	1,196	1,171	1,153	1,142	1,133	1,137	1,104	996	996	996	997	999	999
Natural Gas Production Forecast by Petrobangla		2,793	2,859	2,802	2,698	2,681	2,303	2,005	1,769	1,628	1,517	1,437	1,373	1,306	1,259	1,233	1,213	1,203	1,193	1,197	1,162	1,048	1,048	1,048	1,050	1,051	1,052

Source: Perobangla "Draft Five Year Gas Supply Strategy" (2015) and JICA Survey Team

Gas Production Profile of Producing Gas Fieldis are shown in the following Figure. Note that the Figure does not include Non-Producing Gas Field and Production Suspended Gas Fields.



Source: JICA Survey Team

Figure 7-13 Gas Production Profile of Each Producing Gas Field

7.3.3 Natural gas supply scenario 2015-2041

(1) Narutal gas supply scenario

Natural gas Supply Scenario 2015-2014 is based on the following assumptions:

1) Primary supply scenario is based on the existing gas production profile by Petrobangla.
2) 95 % of discount factor is introduced based on the assessment by PSMP2015.
3) Assuming new Onshore Gas Fields are developed as follows:
   - 2022 and After: Supply of 170 mmscfd by BAPEX as shown in the Petrobangla Five Year Plan
   - 2024 and after: 30 mmscfd from new gas field
   - 2025 and after: 100 mmscfd from new gas field
   - 2026 and after: 100 mmscfd from new gas field
   - 2027 and after: 100 mmscfd from new gas field
4) Assuming new Offshore Gas Field are developed as follows:
   - 2034 and after: 500mmmscfd from new gas field
5) FSRU Project
   - 2018and after: 500 mmscfd is supplied by FSRU Phase 1
   - 2022 and sfter: Additional 500mmscfd is supplied by FSRU Phase 2
6) Onshore LNG Terminal
   - 2027 and after: 500 mmscfd at the initial phase with 3 x 180,000 kl tanks
   - By 2041, Capacity is increased to 3,000 mmscfd
7) Gas Introduction from abroad
   - 2019 and after: 200 mmscfd from India

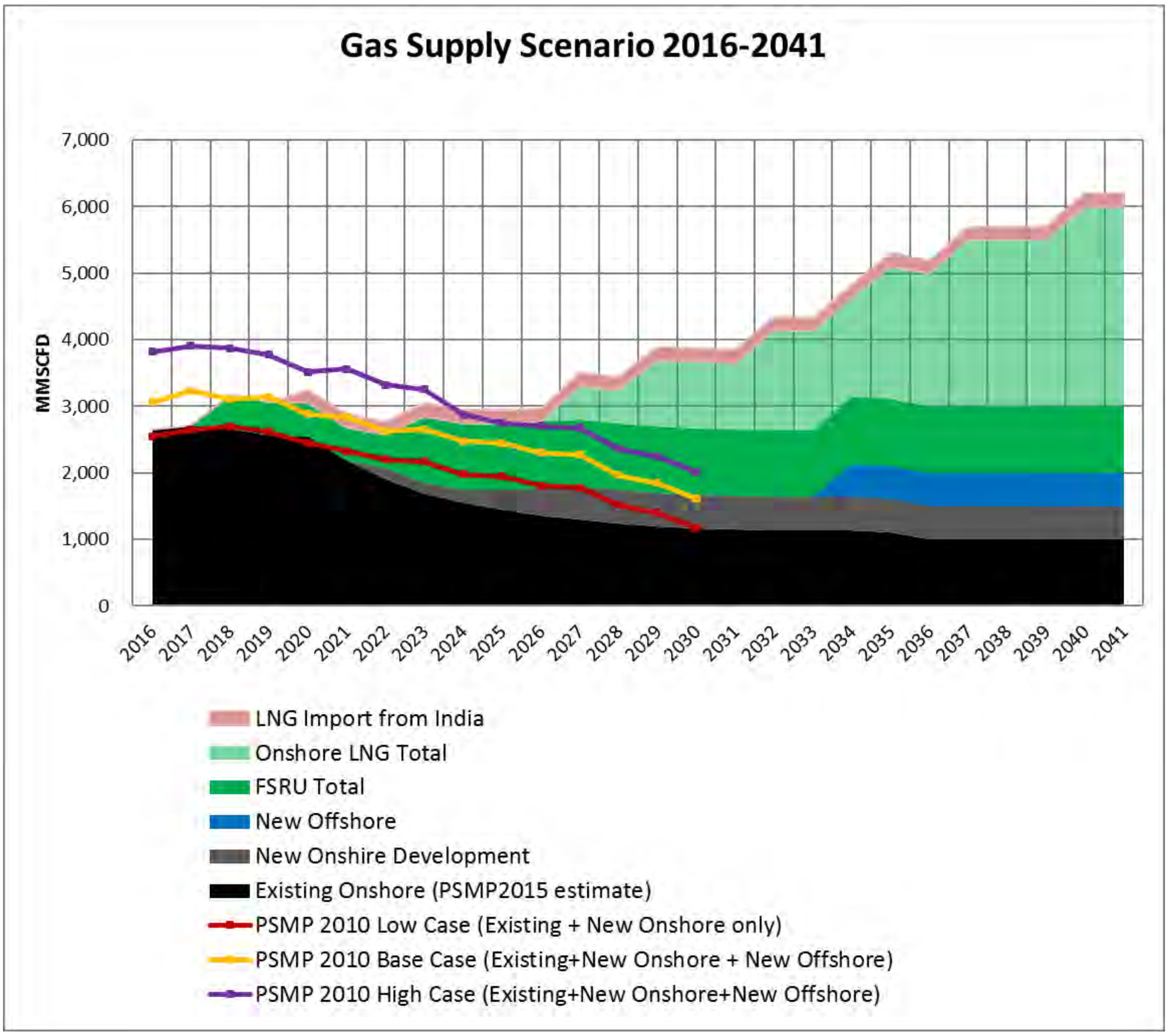
Gas supply from future possible gas field from Onshore and offshore and gas from overseas are summarized in the following table.

Table 7-9 Gas Supply Scenario -New Domestic Gas Field and Gas Import 2016～2041

	Unit	ity	COD	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Existing (PSMP2015 estimate)	mmcfd			2,653	2,716	2,662	2,563	2,547	2,188	1,905	1,681	1,547	1,441	1,366	1,305	1,240	1,196	1,171	1,153	1,142	1,133	1,137	1,104	996	996	996	997	999	999
New (5 wells)	mmcfd	500		0	0	0	0	0	0	170	170	200	300	400	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
1st Well	mmcfd	170	2,022	0	0	0	0	0	0	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
2nd Well	mmcfd	30	2,024	0	0	0	0	0	0	0	0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
3rd Well	mmcfd	100	2,025	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
4th Well	mmcfd	100	2,026	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
5th Well	mmcfd	100	2,027	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Offshore	mmcfd	500	2,034	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500
Total Domestic	mmcfd			2,653	2,716	2,662	2,563	2,547	2,188	2,075	1,851	1,747	1,741	1,766	1,805	1,740	1,696	1,671	1,653	1,642	1,633	2,137	2,104	1,996	1,996	1,996	1,997	1,999	1,999
FSRU Total	mmcfd	1,000		0	0	500	500	500	500	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Energy Divisoin	mmcfd	500	2018	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Energy Division	mmcfd	500	2022	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Onshore LNG Total	mmcfd	4,000		0	0	0	0	0	0	0	0	0	0	0	500	500	1,000	1,000	1,000	1,500	1,500	1,500	2,000	2,000	2,500	2,500	2,500	3,000	3,000
Energy Divisoin	mmcfd	3,000		0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	1,000	1,000	1,000	1,500	1,500	2,000	2,000	2,000	2,500	2,500
Phase 1	mmcfd	500	2029	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500
Phase 2	mmcfd	500	2032	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500
Phase 3	mmcfd	500	2035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500
Phase 4	mmcfd	500	2037	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500
Phase 5	mmcfd	500	2040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	500
Power Division	mmcfd	1,000		0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Phase 1	mmcfd	500	2027	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
LNG Import from India	mmcfd	200	2019	0	0	0	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Total Import	mmcfd	5,200		0	0	500	700	700	700	1,200	1,200	1,200	1,200	1,200	1,700	1,700	2,200	2,200	2,200	2,700	2,700	2,700	3,200	3,200	3,700	3,700	3,700	4,200	4,200
Supply Total	mmcfd			2,653	2,716	3,162	3,263	3,247	2,888	3,275	3,051	2,947	2,941	2,966	3,505	3,440	3,896	3,871	3,853	4,342	4,333	4,837	5,304	5,196	5,696	5,696	5,697	6,199	6,199

Source: JICA Survey Team

Overall Gas supply scenario including existing gasfields, future domestic gas field, and gas import is shown in the following Figure. It appears that it is inevitable to introduce significant amount of LNG in near future.



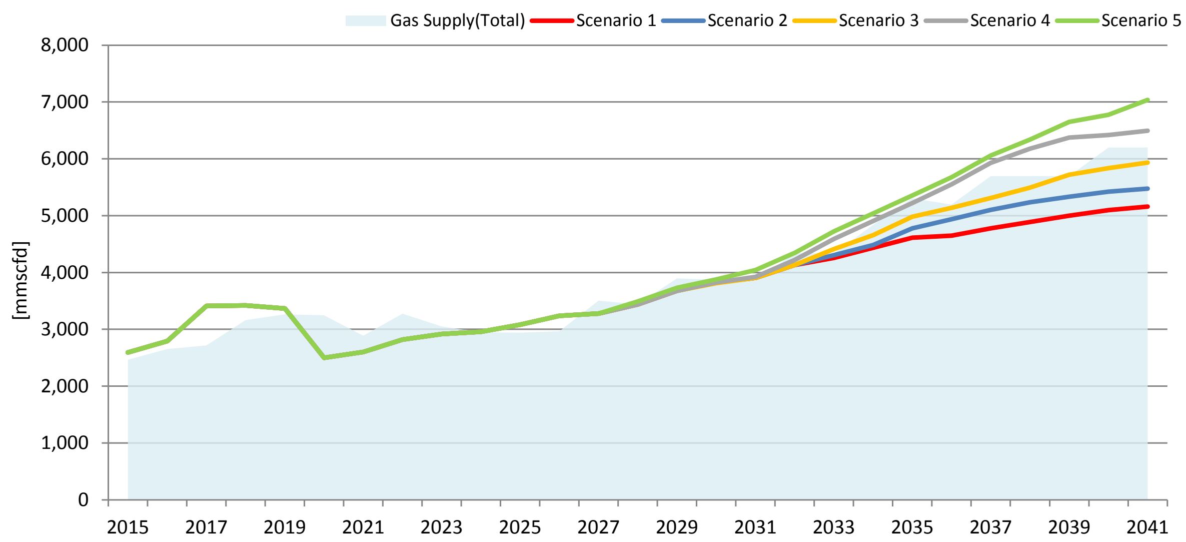
Source: JICA Survey Team, based on Petrobangla data and projection

Figure 7-14 Gas Supply Scenarios 2016-2041

(2) Comparison with the natural gas demand projection

In order to evaluate whether the gas supply scenario in the previous section asures the necessary supply of natural gas (mmscfd) to satisfy the growing demand, the future gas demand is formulated based on the projection of energy consumption (ktoe) that was discussed in Chapter 6 is compared with the gas supply scenario, as shown in Figure 7-15. Because the future gas demand varies depending on the five scenarios of power development that are evaluated in Chapter 11, the necessary supply is calculated for each of these scenarios.

This figure shows that, though both demand and supply has a charactereristic to increase or decrease from year to year, the increased gas supply based on the gas supply scenario generally satisfies the necessary demand from 2020 in power demand cenarios from 1 to 3. However, in scenarios 4 and 5, where the share of gas-fired thermal power generation is higher than in the previous three scenarios, the gas supply constantly falls below the demand from mid-2030s, additional power supply plans need to be considered besides the aforementioned gas supply scenario.



Source: JICA Survey Team

Figure 7-15 Comnparison between Gas Supply Scenarios and Gas Demand Projection

7.3.4 Cost estimate for future investment on gas field development

The investment costs required for the exploration, drilling, and constructions of the gas production facility till 2027 were estimated. The construction costs for the new gas production facility were estimated based on Bangladesh's gas field development plan. Cost Estimate was made by using cost estimate software developed by SIMENS. (See Attachment 7-2 for detail)

Some area is not covered by the Software and these are assumed based on the following figures:

1) Significant labor works and time/cost will be required to identify oil and gas deposit in the green field in general, and cost for these area will also differ from country to country and also to the local conditions. In case of Bangladesh, it is assumed that potential of gas borne area is identified already, and actual cost information used for particular field is used as a benchmark cost, i.e., 2D Seismic Survey: USD 3 million (80 L Km), 3D Seismic Survey: USD 28 million (400 km2)

2) Drilling cost assumes four development wells and used as a production well at later stage. Based on the recent experience by BGFCL, total of 4 wells cost USD 60 million.

3) Assuming that production rate from future onshore wells is 500 mmscfd, cost for production facilities will be assumed USD 90 million as per SIMENS Cost Estimate Software.

4) LNG Receiving Onshore terminal assumes 3x 180,000 M3 LNG tanks at the initial phase, with jetty and re-gasification facilities. Total estimated cost is USD 760 million.

Table 7-10 Total Investment Costs for Gas Development

	Item	Cost [mill. USD]
A	**Domestic Gas Development Costs for the Remaining Reserves 2P**	
A1	Field Exploration Costs	*30*
A2	Field Development Costs	
A2.1	Drilling Costs	*60*
A2.2	Facility Construction Costs	
(1)	Facility construction costs for domestic gas which has already been discovered	302.8
(2)	Gas transmission pipelines from gas production facilities for domestic gas which has already been discovered	9.0
(3)	Facility construction costs for domestic gas which has not been discovered	*90*
(4)	Gas distribution pipelines for future power plants	5.0
	Subtotal (A)	*496.8*
B	**Import Gas Development Costs**	
B1	Facility Construction Costs	
(1)	LNG Receiving Terminal	*760*
(2)	LNG transmission pipeline	115.1
	Subtotal (B)	*875.1*
C	**Contingency (= (A+B) x 50%)**	
	Subtotal (C)	*686*
	Total (A+B+C)	***2057.9***

Source: JICA Survey Team

Numbers of assumptions were made to make cost estimate and the result is not necessarily close enough to predict future cost.

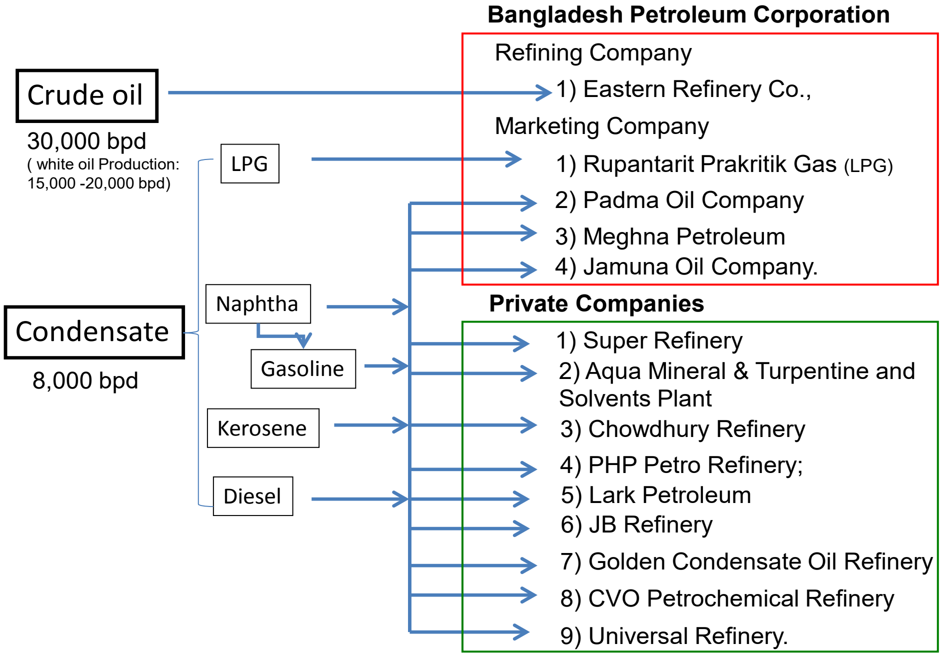
(1) Reinforcement cost for Existing Pipeline Infrastructure is not included in the cost estimate.
(2) Impact of LNG introduction to existing gas infrastructure and to gas field processing facilities/wellhead compressors is not included.
(3) All the cost data and assumed infrastructure models used for cost estimate to be reviewed.

7.3.5 Condensate production

Significant amount of condensate has been produced from gas field in Bangladesh. Revenue from the sale of oil product from condensate has been an important side revenue for gas producing companies. Investment for condensate fractionation facilities has been made to recover and monetize the condensate.

Recovered condensate is fractionated to LPG, Gasoline, Kerosene and Diesel products and soled to National Oil and/or LPG Marketing Companies and private oil refining and marketing companies

Production rate for condensate in Dec. 2014 was 7,800 BPD. On the other hand, Eastern Refining Co., National Refining Company with 30,000 BPD throughput capacity, produces 15,000-20,000 BPD of white oil products. This translates that 30-35% of white oil products are supplied from the distillates of condensate.



Source: JICA Survey Team

Figure 7-16 Overview of Condensate Marketing

Condensate recovery relies on the pressure differential. Recovery of the condensate has not necessarily been maximized yet. Once wellhead pressure declines, recovery of the condensate will also decline and flooding the transmission pipeline/ downstream distribution systems with condensate. Enhancement of the condensate recovery should be also be considered at the time of wellhead compressor installation, considering the impact of the LNG introduction.

7.4 Gas Field Development and PSC

7.4.1 Future gas field development

As discussed, hydrocarbon bearing potential in Bangladesh is divided into three onshore areas geologically. Offshore areas are categorized into Shallow Water and Deep Water as indicated in the model PSC.

- Folding Bed area in the east
- Foredeep area in the central
- Stable Shelf and Hinge Zone area in the west and north west
- Offshore (Shallow and Deep Waters)

Current operating gas fields are mostly in the Folding Bed area. Production from these existing gas fields are declining. Higher probability of new gas field discovery is expected in this Folding Bed area. On the other hand, Probability of the discovery in Central and West/North West part of the country is considered not high. No commercial scale gas field has been discovered in these areas.

Regarding offshore exploration in Myanmar, Daewoo of Korea discovered Shwa gas field on the east side of Bengal Bay in 2004. Confirmed reserve is 9.1 TCF with significant production of associated condensate. Commercial operation commenced in 2014 and all the gas and condensate are sold to CNPC China, via pipeline. Production rate is 700 MMCFD. Some new gas field discoveries were also reported at adjacent area of this Shwa Gas Field. Due to a geological similarity, there would be a potential of new gas field discoveries on the east part of Bengal Bay.

Oil and gas exploration has been exercised on the west side of Bengal Bay for a decade. No significant discovery has been made yet except Krishna-Godavari basin

Gas development in future areas will be more difficult and risky. It requires higher technological skills and financial backup to manage the oil and gas exploration. In the 1990's and after, significant advancement has been made in the oil and gas development area. A performance in exploration, and gas and oil recovery has been improved significantly.

In order to minimize exploration risks and maximize the recovery of resources, it is worth to consider partnership with internationally known IOCs, through attractive PSC, both for onshore and offshore exploration.

The recently adopted 7th Five Year Plan claims that Petrobangla undertake onshore exploration and development "on its own" to explore "relatively lower cost" and seek for a "strategic partnership" with experienced IOCs for offshore. However, it should be noted that the poor performance of the recent explorations and production implies that Petrobangla requires not only more financial resources, but also state-of-art well exploration and development skills and experiences for onshore resources as well. It is recommendable that Petrobangla take strategic partnership with the internationally renowned IOCs and utilize their technologies, not only off-shore, but for onshore resources too. Measures for the more involvement of IOCs will be discussed in the next section.

7.4.2 2012 model PSC

Gas pricing in 2012 Model PSC offered by Bangladesh shows that Government of Bangladesh (GoB) has the first right to purchase Contractor's Gas. The Contractor will be assumed a domestic market outlet within 6 months of commercial discovery of gas failing which the Contractor would be free to find outlet within the country. Gas Pricing is as follows;

(1) Onshore Gas Field: 75% of Market Price with biddable discount. The price will have a floor of USD 100 /metric ton and ceiling of USD 200 /metric ton of HSFO. (Note that these figures translate that gas floor price would be USD 2.25 /MMBTU and ceiling price will be USD 4.5/MMBTU.)
(2) Offshore (Shallow Water): 100% of Market Price
(3) Offshore (Deep Water): 110% of Market Price
(4) Onshore Western area: 90% of Market Price

With the development of oil and gas market in US and UK, world oil and gas prices have been linked with these market prices, and affected world oil and gas development activities. Fiscal terms of PSC by the GoB may need to be linked with the international market pricing system to make the PSC attractive.

After the lift of economic sanction on Myanmar, oil and gas exploration through PSC has been accelerated. Recent PSC prepared by the Government of Myanmar require that 25% of product to be supplied to domestic market (domestic Requirement) at 90% of Fair Market Value but the rest volume can be sold by Contractor by its own free will. This indicates that natural gas from Myanmar can be exported to Bangladesh. The price may be at Fair Market Value.

After the resolution of the maritime boundary dispute with Myanmar by virtue of the judgment awarded in March 2012 by the International Tribunal for the Law of the Sea (ITLOS), the Deep Water blocks on the eastern part were re-arranged.

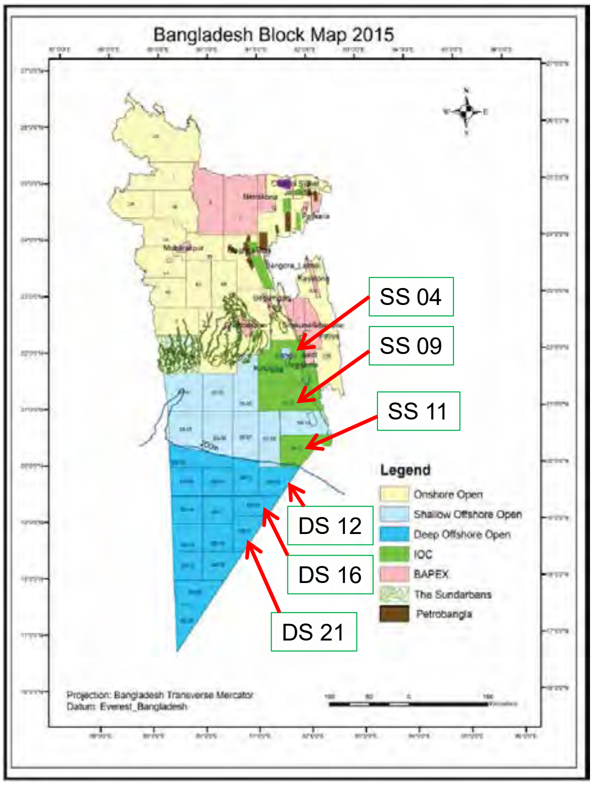
Current PSC for offshore blocks are as follows:

(1) Shallow Water Blocks

- JV of ONGC Videsh, Oil India, and BAPEX signed PSC with GoB for Block SS-04 and SS-09
- JV of Santos, Kris Energy, and BAPEX signed PSC with GoB for Block SS-11

(2) Deep Water Blocks

JV ConocoPhillips and Statoil negotiated with GoB for DS-12, DS-16 and DS-21, however, did not reach agreement.



Source: Petrobangla Annula Report 2014

Figure 7-17 Offshore Concession Blocks

7.4.3 Attractive PSC and partnership

Current target for gas exploration and development activates can be as follows:

1) Maintain production rate from existing gas field as much as possible
2) Develop new gas field in the Folding Bed area

To maximize the production and recovery of gas and condensate, the latest technologies need to be introduced. It is worth to consider preparing attractive terms of PSC and formulate partnership with experienced IOCs.

7.4.4 Role of BAPEX

There may be a resource limitation to achieve i) Enhancement of technological capabilities, ii) Own and operate 2D/3D survey units and drilling rigs, and iii) Produce oil and gas at the same time. Speed of advancement in technology is so fast to catch up. It is the management skill needed to be developed, not to use its own resources for operating drilling rigs.

Role of national oils has been changed responding to changing times and social needs. ONGC of India, Petronas of Malaysia, and CNPC of China are typical example how they have been evolved. These national oils are responsible for developing their own resources and also acquire recourses in overseas. As a result, they have increased the "Domestic Energy Resources" and contribute to the energy supply security of the country.

BAPEX has played a very important role in the area of domestic oil development and provision of associated services. BAPEX has made significant effort to build up capability of 2D and 3D seismic survey and operating drilling rigs, however, the performance of these may not necessarily be satisfactory. On the other hand, there may be opportunities to work jointly with other national oil companies in neighboring countries, or develop oil and gas fields jointly with the international oil companies in overseas. It may be a time to review role of BAPEX thoroughly.

7.5 Improvement of Gas Supply Infrastructure and Gas Use Efficiency

7.5.1 Improvement of gas supply infrastructure

There are following issues for gas transmission and distribution system in Bangladesh to be solved and improved.

(1) Condensate recovery

It appears that gas heating value may differ from location to location due to a condensate fraction in the pipeline system. Gas Transmission Company and Distribution Companies need to evacuate the built up condensate regularly. It is recommended to dry the gas as much as possible at the wellhead gas treatment facilities. Benefit of the improvement will be:

1) Increase the revenue by the sale of oil products produced from condensate
2) Save investment cost for installation of knock out drums and/or heaters
3) Life time of the pipeline infrastructure can be extended

(2) Gas meter installation and gas leak monitoring

Gas will be a very valuable energy resource and it should be used efficiently and safely, and inflow and outflow of gas must be monitored. All of the gas inlet and outlet points must have gas meters. Gas leak monitoring works will contribute to the process safety, protecting the people from fire/explosion, and also preventing energy loss from the system.

The Residential (Domestic) sector customers have long been indulged with a fixed tariff system, which encourage the overuse of natural gas. To address this issue, JICA is assisting in the installation of gas meters (pre-paid) to Dhaka Area (200,000 locations for residential customers) and Chittagong Area (60,000 locations for residential customers).

Under the gas allocation system, gas supply quota to each captive facility is manually controlled against a reading of volumetric flow meter located at the facility gate. Overdrawn facility will be subject to a penalty due to a violation of rule. Flow meter inspection and capitulation is conducted by each regional gas distribution company. Measurement accuracy may need to be improved.

(3) Digitized and Computerized Gas Infrastructure Management System

Digitized and Computerized Gas Infrastructure Management System should be installed sooner since "older the infrastructure is higher the risk of accident can be".

Gas transmission and distribution system is considered as a lifeline Infrastructure. All the process information including gas flow rate and pressure, and abnormal signals need to be collected and stored and processed, and all the history of maintenance, expansion/replacement record need to be stored. All of these data should be made available for all the parties concerned.

Significant advancement has been made in the area of such lifeline Infrastructure Management System for the last two decades. Appearance of new technology, a concept of Object-Oriented Database applied for Infrastructure Management, will be one of the choices to be introduced.

(4) Improvement of Gas Transmission System

Significant volume of gas will be supplied from LNG in near future and the system need to be reinforced to accommodate the increasing volume of gas. Integrated gas flow and pressure monitoring system (or SCADA system) will need to be introduced. In addition to advanced SCADA system, introduction of gas flow simulator to predict gas flow and pressure in the system will also be required.

(5) Impact of LNG introduction

After LNG introduction, gas flow rate and pressure balance will change. This could affect the performance of gas field production facilities and condensate recovery system. Also affect plan for wellhead compressor installation projects. Impact of LNG introduction will need to be studied further.

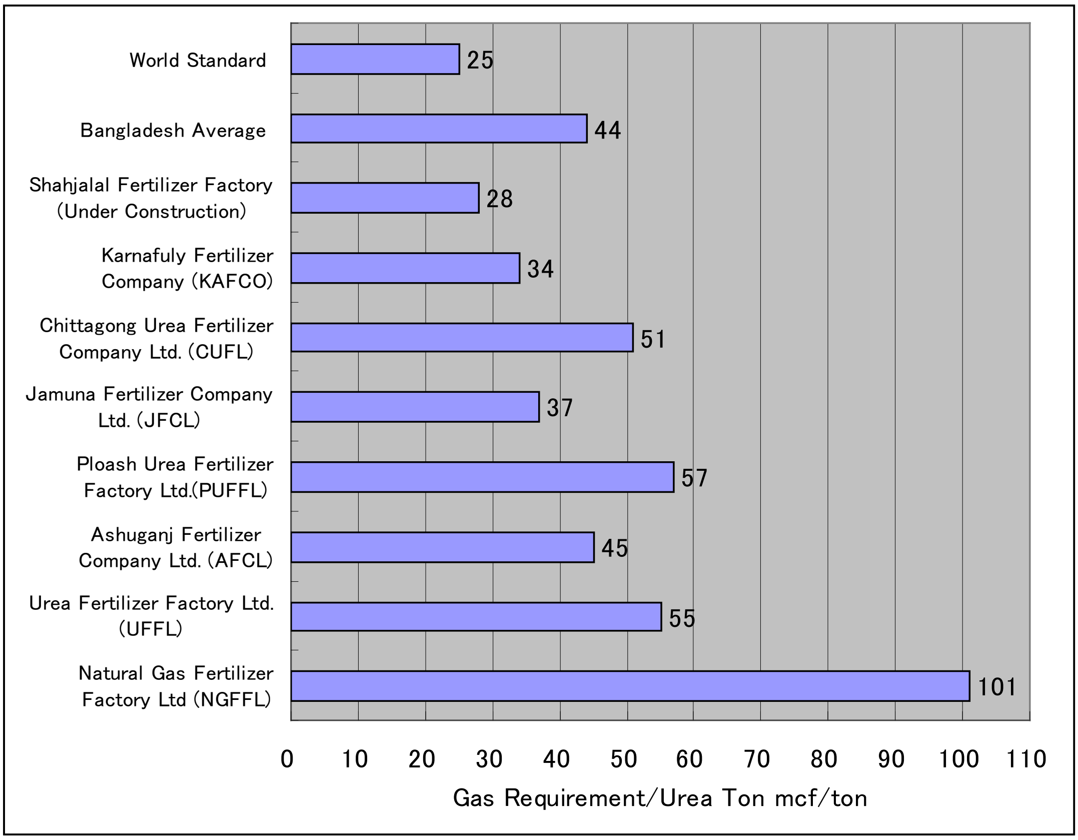
7.5.2 Improvement of gas use efficiency

Gas Use Efficiency is one of the critical issuers need to be addressed. "Cheap gas" will not be available in future and gas users need to enhance the efficiency to save indigenous gas resource in the country. It appears that both Urea Manufacturing and Power Sectors have a significant room for energy efficiency enhancement.

(1) Efficiency Enhancement in Urea Manufacturing

Urea is manufactured from natural gas. As seen in the below figure, the world benchmark efficiency in Urea Manufacturing is 25mcf/ton. On the other hand, average efficiency in Bangladesh is 44 mcf/ton as of 2014 FY, and much lower than that of international benchmark. Specifically the existing public fertilizer factories largely lag behind the world benchmark efficiency.

Provided that annual Urea production in Bangladesh is 2,375,000 ton, 130 mmcfd of natural gas is wasted due to an inefficient use of gas. This figure will be translated into the equivalent of 1000 MW of power plant.



Source: Five Year Gas Supply Strategy 2015-2019

Figure 7-18 Comparison of Urea Efficiency

(2) Efficiency enhancement in power sector

Gas Consumption for Power Sector (under BPDB) is 337.4 BCF in 2014 FY while Power Generation Capacity was 8,340 MW and Generated Power was 42,200 GWh. From these figures, it is assumed that current power generation efficiency is around 38%. Provided that efficiency can be raised to 45%, which is considered as a international benchmark as a gas based power plant, Energy gas consumption will be reduced to 285 BCF, and differential of 52 BCF is wasted. This is equivalent of 1,300 MW power plants.

The further details of gas-fired thermal plant efficiency issue are addressed in Chapter 17 and Chapter 18. JICA-supported "Power System Master Plan 2010" (February 2011) also well describes the public power plant efficiency issue.

7.6 Possible Assistance from Japan

Gas supply in Japan is highly dependent on LNG import. Japan has developed the technological and organizational system to use the gas efficiently and safely from the time of beginning stage of LNG development.

True economic value of the hardware, i.e., gas pipeline and distribution system, depends on the existence of the appropriate operation system, sustainable maintenance system and technology, and supporting organization.

With the development of the economic globalization, discussion about the construction of cross-country gas and power infrastructure has started. This will involve globally extended areas, and therefore, it is very important to introduce and utilize IT system to operate the infrastructure effectively and efficiently and manage various operational risks.

To meet with the needs of the above, technology transfer based on the BOT (build, Operate, Transfer) approach will be listed as one of the best idea to be considered.

Through the BOT approach, technology and management system can be transferred as a sustainable business scheme, attaining human resource development and technology transfer the same time. This Business unit will work as a platform for operation and maintenance of gas infrastructure and support various expansion projects, and more importantly providing job opportunities to young talented people in Bangladesh.

7.7 Environmental and Social aspects of Natural Gas development

7.7.1 Environmental Impact Assessment

Basic rules of Environmental Impact Assessment are given by Environment Conservation Act 1995. The clause 12 of the Act "No industrial unit or project shall be established or undertaken without obtaining, in the manner prescribed by rules, an Environmental Clearance Certificate from the Director General". Environment Conservation Rules 1997 (subsequent amendments in 2002 and 2003) stipulate the procedures and required documents by categories (see Table 7-11).

Table 7-11 EIA Categories and Required Clearance and Documents

Category	Required clearance	Required documents
Red	Location clearance, Environmental Clearance	Feasibility Study report (FS report), IEE or EIA, Resettlement Action Plan (RAP), No Objection Certificate of the local authority (NOC), Emergency and pollution minimization Plan
Orange B	Location clearance, Environmental Clearance	FS report, IEE, NOC, Emergency and pollution minimization Plan, RAP
Orange A	Location clearance, Environmental Clearance	General Info, Raw materials and the manufactured product, NOC, Process flow, Layout, Effluent discharge arrangement, RAP
Green	Environmental Clearance	General Info, Raw materials and the manufactured product, NOC

Source: Environment Conservation Rules 1997

MOE has prepared various guidelines of EIA such as Guidelines for Industries in 1997, EIA Guideline for Project in the Natural Gas Sector, Guideline for Gender Responsive Environmental Management. All the coal and gas development projects have to apply Environmental Clearance to DOE of Dhaka, Chittagong, Khulna, or Rajshahi Division. It is not clear that which categories should be applied to various kinds of Gas and coal projects (see Table 7-12)

Table 7-12 EIA Guidelines for Gas and Coal Sector

Activities	Category	Guidelines to be referred
Gas and Oil exploration	?	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil extraction	Red	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil refinery	Red	EIA Guideline for Project in the Natural Gas Sector
Gas pipeline	Red	EIA Guideline for Project in the Natural Gas Sector
Gas distribution line	?	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil storage	Red	EIA Guideline for Project in the Natural Gas Sector
Gas and Oil Power Plant	Red	EIA Guideline for Project in the Natural Gas Sector

Source: JICA Survey Team

7.7.2 Experienced environmental and social impact of gas development

(1) Impact during exploration

Bangladesh Petroleum Exploration Company (BAPEX) is the only company which is conducting exploration work in Bangladesh. BAPEX has conducted more than ten exploration works so far. It is not clear how many EIAs have been prepared for the exploration works.

(2) Impact during construction and operation

There are more than 20 gas fields are operating in Bangladesh. Environmental, Health, and Safety Guidelines for Onshore Oil and Gas Development (IFC, 2007) identifies major environmental impact as air emissions, wastewater discharges, solid and liquid waste management, Noise generation, Terrestrial impacts and project footprint and Spills. But in terms of the gas development in Bangladesh water and air pollution issues are relatively lower than the other countries like Middle Eastern countries, Indonesia, and Australia. It is because the component of the Gas in Bangladesh is very pure. Gas of Middle Eastern countries contains hydrogen sulfide. But no hydrogen sulfide is contained in the gas in Bangladesh. Then there is no need to install hydrogen sulfide recovery unit and no production water is discharged in Bangladesh. The content of CO_2 is very lower in Bangladesh than the other countries (see Table 7-13). Then there is no need to install CO_2 recovery unit and recharge in the aquifer layer. pH of the production water in Middle Eastern countries is very low but it is near-neutral in Bangladesh. Then neutralization facility is not required too. Heavy metal such as mercury is not found in produced water in Bangladesh.

Table 7-13 Rates of Gas Component by Gas Fields

	Australia A	Australia B	Sakhalin	Bangladesh Titas
Methane（CH_4）	76.8	66.6	92	96.76
Ethane（C2）	3.5	3.8	4.62	1.8
Propane（C3）	1.3	1.3	1.73	0.36
Butane（C4）	0.5	0.4	0.62	0.14
Pentane (+C5)	0.6	0.7	0.32	0.26
N_2	4.3	15.4	0.46	0.37
CO_2	13	11.8	0.25	0.31

Source: JICA Survey Team

When it comes to biological and social issues not so serious problems are reported during operation. Hearing survey at Bangladesh Gas Fields Company Ltd.(BGFCL), Sylhet Gas Fields Limited (SGFL), Gas Transmission Company Limited (GTCL) did not find any serious problem during operation. The reasons of the little impact on biological and social issues are that the drilling holes can be angled and houses and ecological important areas can be avoided at the location selection stage.

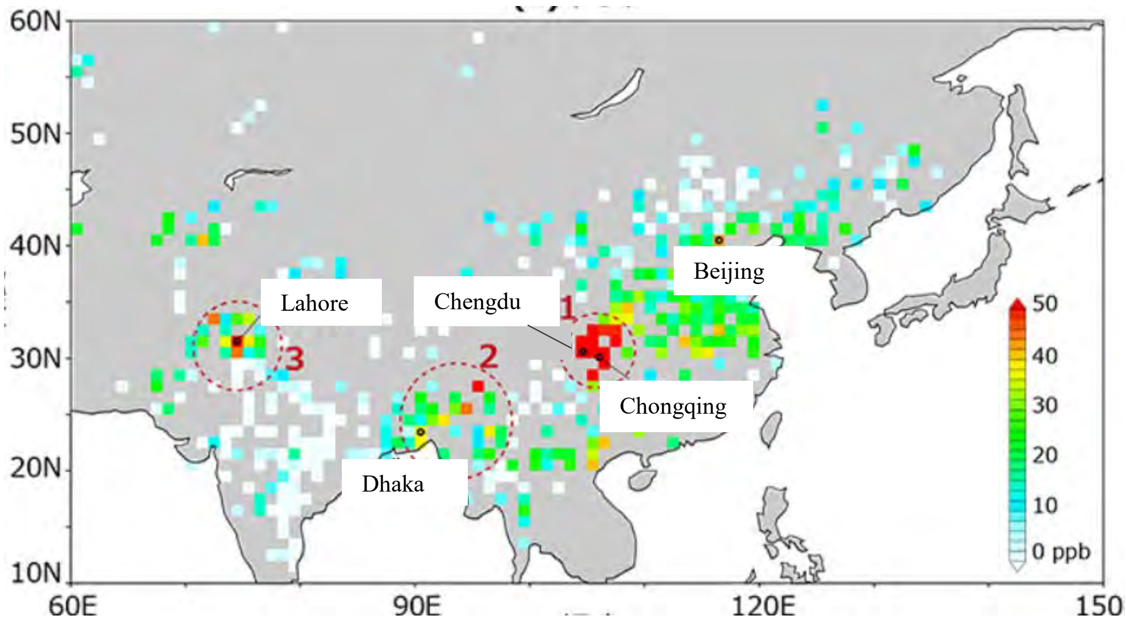
(3) Blowout accident

According to Khan (2014) there are some serious blowout accidents happened during exploration activities which are Sylhet 1, Sylhet 4, Moulvibazar-1 and Chattak-2. The impacts are furious and wide expanses of areas are affected (see Table 7-14). Unfortunately the killing well activities are failed and compensation is not enough. Then the effects are continuing still now. And to make matters worse the methane gas which keeps running out still now is one of the global warming gas. The satellite observation result also shows the high concentration of methane gas over the Sylhet area too (see Figure 7-19). The blowout during exploration is the highest risk of the gas development in Bangladesh.

Table 7-14 Main Blowouts in Bangladesh

Well	Year	Blowout type	Reasons	Effect
Sylhet-1	1955		Drilling mistake	A crater was formed and filled with water, creating a large pond which is still there today and vent gas from the subsurface into the year
Sylhet-4	1962		Drilling mistake	Well was abandoned then and gas is still venting out from the fissures in the well site and nearby hill side which often cause fire.
Moulvibazar-1	1997		Casing mistake	About 96 acres of Lawachara forest were completely burnt. Fifty percent of the forest resources on 111.15 acres of land and 30 percent resources on 106.21 acres of land were also damaged. An estimated Tk 9000 crore loss to the nation and gas reserve of about 245 billion cubic feet was burnt in the explosion while the environment, ecology and wildlife of the area were also severely affected.
Chattak-2	2005	Surface type	Casing mistake	Homestead area, forest trees, and hilly fruit bearing trees were affected by the fire. Underground sand and clay soil were throughout with gas from the main field to 2-3 km areas of the Tengratila.

Source: Md. Ashraful Islam Khan, Fuad Bin Nasir (2014) Review Over Major Gas Blowouts In Bangladesh, Their Effects And The Measures To Prevent Them In Future (INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 3, ISSUE 9)

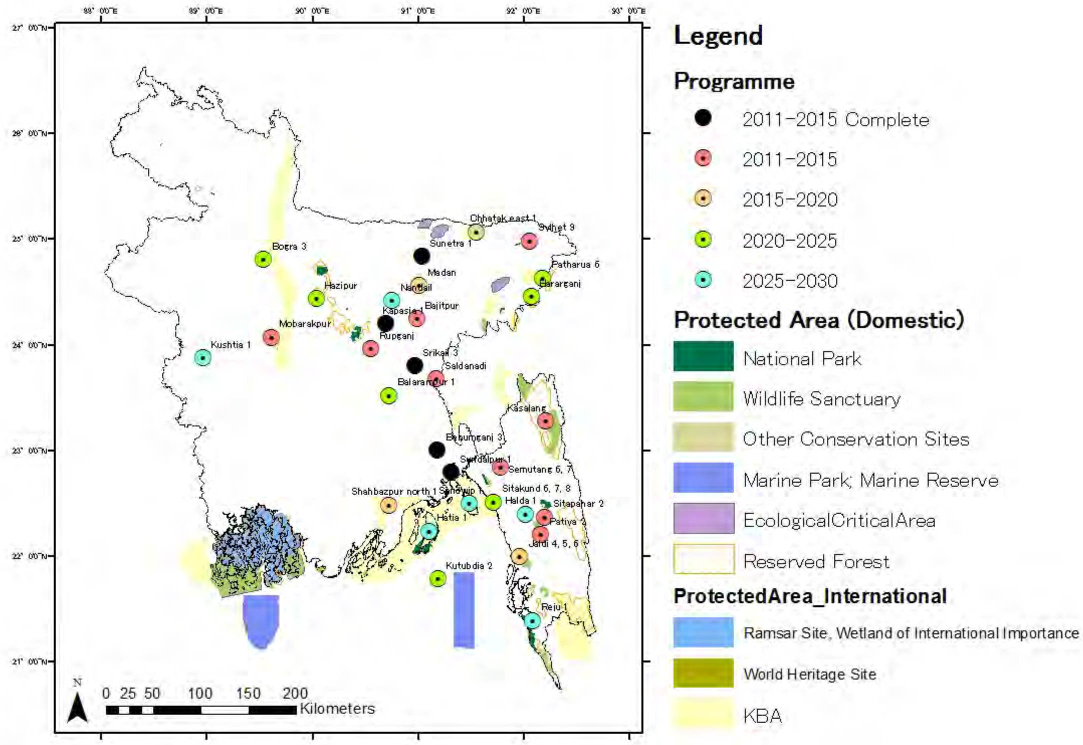


Source: JAXA (2015) Greenhouse gases Observing Satellite "IBUKI" (GOSAT)

Figure 7-19 Methane Gas Concentration by Human Activities in Asia

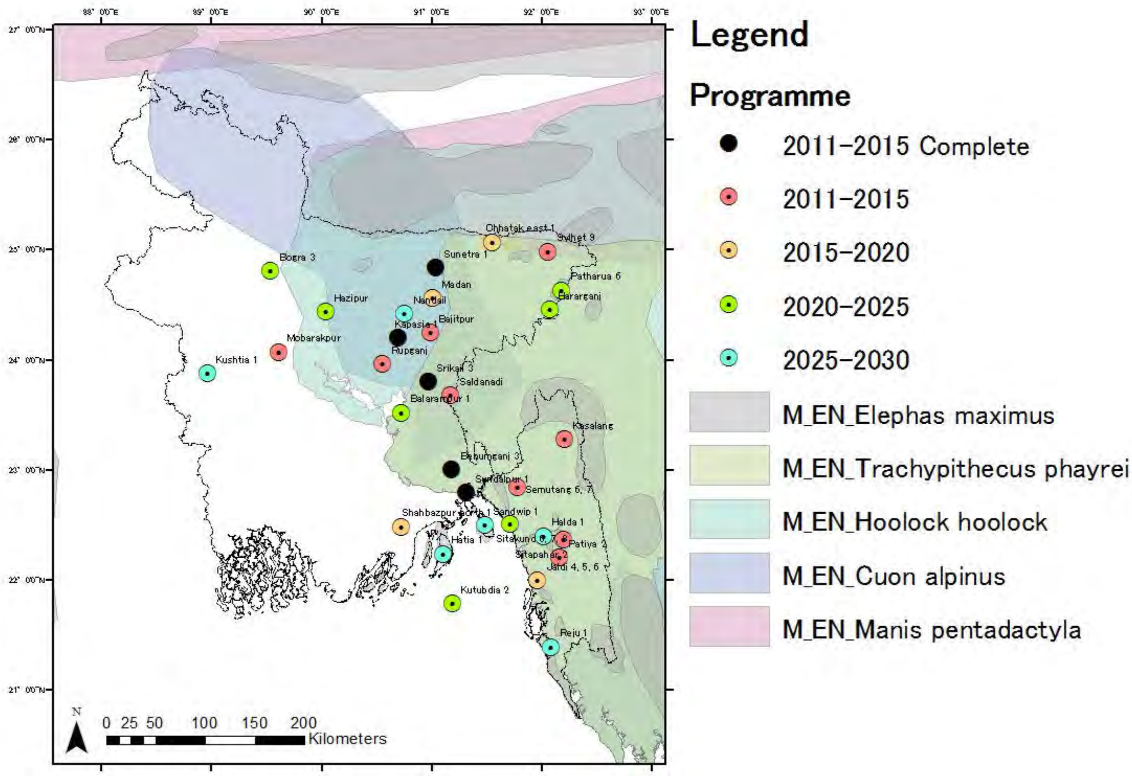
7.7.3 Environmental and social risk of gas development

According to Preparatory Survey on The Natural Gas Efficiency Project in The People's Republic of Bangladesh (2014, JICA), planned gas fields are 24 on shore and 1 off shore. Six locations are in the domestic or international protected areas. 21 fields are in the known distribution areas of five mammals listed in IUCN red list as Endangered (EN) category. No EIA report is confirmed for the planned projects. Kasalang, Hararganj, Hazipur, Hatia 1, Reju 1, Sandwip 1 are located in the National parks or other protected areas. Then the layout should be planned to avoid the impacts on the protected areas (See Table 7-15). Saldanadi, Sylhet 9, Chhatak east 1, and Patharua 6 are located in the habitats of more than three protected species. Then detail biological survey before identifying the location and off-set mitigation planning is recommended. Although 16 fields locate in the agricultural areas, the resettlements will be avoided by carefully site selection (Table 7-16). The most anxious risk is a blowout. In order to lower the risk of blowout, the exploration companies with high technic should be selected.



Source: Preparatory Survey on The Natural Gas Efficiency Project in The People's Republic of Bangladesh (2014, JICA)

Figure 7-20 Protected Areas and Possible Gas Fields



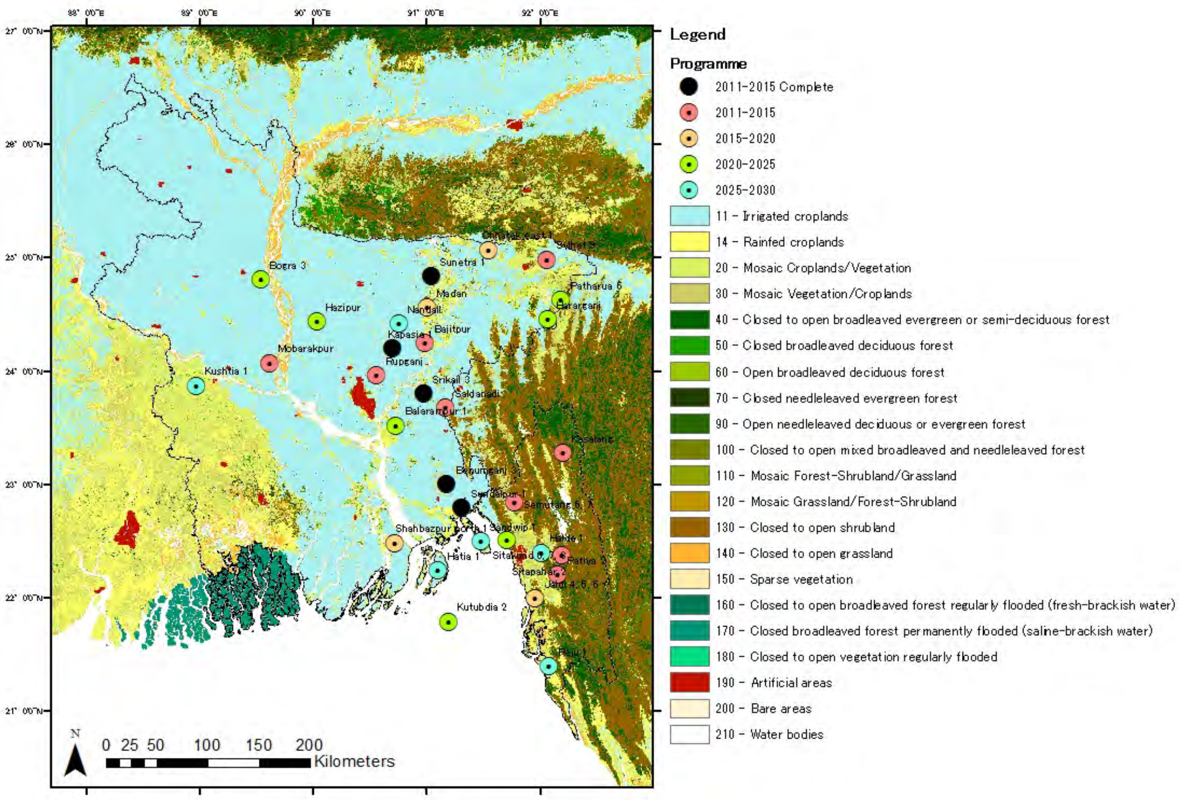
Source: JICA Survey Team

Figure 7-21 Habitat of Protected Mammals and Possible Gas Fields

Table 7-15 Possible Gas Fields and Protected Areas and Protected Mammals

Programme	Name	Protected Area	IUCN Red list species (Mammal, Endangered)				
			Elephas maximus	Trachypithecus phayrei	Hoolock hoolock	Cuon alpinus	Manis pentadactyla
2011-2015	Bajitpur				*	*	
	Kasalang	Reserved Forest		*	*		
	Mobarakpur						
	Patiya 2			*	*		
	Rupganj				*	*	
	Saldanadi			*	*	*	
	Semutang 6, 7			*	*		
	Sitapahar 2			*	*		
	Sylhet 9			*	*		*
2015-2020	Chhatak east 1			*	*		*
	Jaldi 4, 5, 6			*	*		
	Madan				*	*	
	Shahbazpur north 1						
2020-2025	Balarampur 1			*	*		
	Bogra 3						
	Hararganj	Reserved Forest		*	*		
	Hazipur	Reserved Forest			*		
	Kutubdia 2						
	Patharua 6		*	*	*		
	Sitakund 6, 7, 8			*	*		
2025-2030	Halda 1			*	*		
	Hatia 1	KBA, Reserved Forest	*				
	Kushtia 1						
	Nandail				*	*	
	Reju 1	National Park		*	*		
	Sandwip 1	KBA	*				

Source: JICA Survey Team



Source: JICA Survey Team

Figure 7-22 Land Use and Possible Gas Fields

Table 7-16 Possible Gas Fields and Land Use

Programme	Name	Farm land	Forest	Water
2011-2015	Bajitpur	Irrigated croplands		
	Kasalang		Closed to open shrub land	
	Mobarakpur	Irrigated croplands		
	Patiya 2		Closed to open shrub land	
	Rupganj	Irrigated croplands		
	Saldanadi	Mosaic Croplands/Vegetation		
	Semutang 6, 7	Mosaic Vegetation/Croplands		
	Sitapahar 2		Closed to open shrub land	
	Sylhet 9	Mosaic Croplands/Vegetation		
2015-2020	Chhatak east 1	Mosaic Croplands/Vegetation		
	Jaldi 4, 5, 6		Closed to open shrub land	
	Madan	Mosaic Croplands/Vegetation		
	Shahbazpur north 1	Irrigated croplands		
2020-2025	Balarampur 1	Irrigated croplands		
	Bogra 3	Irrigated croplands		
	Hararganj		Closed to open broadleaved evergreen or semi-deciduous forest	
	Hazipur	Irrigated croplands		
	Kutubdia 2			Water bodies
	Patharua 6		Closed to open shrub land	
	Sitakund 6, 7, 8		Closed to open shrub land	
2025-2030	Halda 1		Closed to open shrub land	
	Hatia 1	Irrigated croplands		
	Kushtia 1	Mosaic Vegetation/Croplands		
	Nandail	Irrigated croplands		
	Reju 1		Closed to open shrub land	
	Sandwip 1	Mosaic Vegetation/Croplands		

Source: JICA Survey Team

Chapter 7 Attachment

7-1 Natural Gas Supply Analysis

7-1 Natural Gas Supply Analysis

1. Current Status of Existing Gas fields

Understanding of the current status of the existing gas fields is very important for production forecasts for each gas field. Therefore, a comparison of actual production (average daily production) from each gas field over the years of 2010 to 2014 and the forecasts by PSMP 2010 is shown in Table 1.

Based on the information/data such as the remaining 2P reserves shown in the "Draft Five Year Gas Supply Strategy" and the results of drilling and workover shown in Petrobangla Annual Reports, The current status of the existing gas fields in Bangladesh and the future outlook are summarized in Table 2.

Table 1and Table 2 indicate the following points.

- Only Bibiyana gas field has shown a steady increase in production since 2010 in Bangladesh.
- The Jalalabad gas field also significantly increased production in 2012, but after that production from the field has not increased significantly.
- Production from the Sangu gas field was suspended from October 1, 2013.
- Measures for troubles associated with excessive water production need to be taken
- Successes of new development wells are important to increase production in the future.
- Additions of recoverable reserves by introduction of wellhead gas compressors in mature gas fields resulting in the extension of the field life are expected.

Table 1 Comparison between Actual Average Daily Production and PSMP2010 Forecasts

Unit: mmscfd

Sl. No.	Gas Field	Average Daily Production							
		Actual					PSMP2010 Forecasts		
		2010	2011	2012	2013	2014	2010	2014: Case1	2014: Case 2
1	Titas	404	445	450	490	515	408	578	560
2	Habiganj	235	260	227	225	225	240	260	260
3	Bakhrabad	35	33	32	41	41	36	51	51
4	Kailashtila	91	86	89	84	74	87	97	97
5	Rashidpur	49	49	47	47	61	49	84	85
6	Sylhet/Haripur	3	10	9	9	8	7	30	30
7	Meghna	0	10	10	11	10	0	5	5
8	Narshingdi	33	30	30	28	28	35	25	25
9	Beanibazar	15	9	11	10	10	15	15	15
10	Fenchuganj	25	23	36	37	39	24	65	60
11	Saldanadi	8	18	16	15	12	8	8	8
12	Shahbazpur	6	0	7	7	8	8	10	10
13	Semutang	0	14	8	6	5	0	15	15
14	Sundalpur	0	0	10	10	4	0	60	60
15	Srikail	0	0	0	42	39	0	60	60
16	Sangu	37	14	23	0	0	40	0	0
17	Jalalabad	163	165	232	249	246	130	250	200
18	Moulavi Bazar	58	42	94	77	63	60	160	80
19	Bibiyana	658	753	792	822	1,007	716	900	850
20	Bangura	105	102	86	111	110	120	120	120
21	Begumganj	0	0	0	0	0	0	0	0
22	Kutubdia	0	0	0	0	0	0	0	0
23	Chattak	0	0	0	0	0	0	0	0
24	Kamta	0	0	0	0	0	0	0	0
25	Feni	2	0	0	0	0	2	2	2
Total		**1,926**	**2,062**	**2,210**	**2,323**	**2,435**	**1,995**	**2,765**	**2,563**

Note: A production rate of 60 mmscfd for Sundalpur and Srikal by the PSMP2010 forecasts means that the sum of production from Sundalpur and Srikail should be equal to 60 mmscfd in this case.

Source: Prepared based on Petrobangla Annual Reports 2010 to 2014 and PSMP2010 report (JICA, 2011)

Table 2 Evaluation of Current Status of Existing Gas Fields

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014: Forecasts by PSMP2010 (MMscfd) Case 1	Case 2	Production Capacity (MMscfd)	Actual Production (MMscfd)	Recoverable 2P Reserves as of the end of 2014 (BCF)	Remaining 2P Reserves as of Jan. 2015 (BCF)	Evaluation of Production Status
1	Titas	21	578	560	518	515.2	6,367.0	2,515.67	• The actual daily production rate was lower than that predicted by PSMP2010 study because the drilling of new development wells was delayed from initilal schedule. • Production rates for recently drilled development wells Titas-19, 20, 21 and 22 were significantly lower than expected (see Table 1.4-1). • Production from the Titas-21 well has been suspended from late June 2014. • It is expected that an increase in the production capacity depending on the plan and results of future development drilling. • It is possible to add the reserves and extend the field life by installation of the wellhead gas compressors being scheduled around 2016. The installation of the wellhead gas compressors will be limited to a part of the production sites, it is necessary to intstall them in other production sites in future.
2	Habiganj	7	260	260	225	225.1	2,633.0	523.81	• The actual production in 2014 was slightly lower than that predicted by PSMP2010. • A significant increase in production will not be expected because the remaining 2P reserves are only 20% of recoveralbe (2P) reserves, although the size of the remaining recoverable (2P) reserves are evaluated as medium.
3	Bakhrabad	7	51	51	43	41.0	1,231.5	456.37	• The overall field's production has not increased because workover of the existing suspended wells were unsuccessful, although the well Bakharabad-9 resulted in success. • An increase in production is expected by drilling of new development wells in the future.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
4	Kailashtila	4	97	97	80	73.5	2,760.0	2,163.60	• The field's production has not increased. This is due to in part the delay in drilling of new development well Kailashtila-7. • The future production performance will be dependent on whether new development drilling and well workover operations will be sucessful or not. • Prior to preparing the programs for the future development drilling the review of 3D seismic data over the field is required.
5	Rashidpur	5	84	85	64	60.7	2,433.0	1,889.79	• An increase in production is small at present because drilling of new development wells, including the Rashipur-8 well from which production was started in August 2014, has been delayed from the initial schedule. • According to the Petrobangla's five-year plan, drilling of three development wells is planned. • Gas production will not increase to the level such as over 500 MMscfd in the future, which was predicted by PSMP2010.
6	Sylhet/Haripur	2	30	30	11	8.4	318.9	113.64	• Based on recent development activities an increase in production can be expected, depending on the results of future development wells, although a significant increase in production will not be expected from the development plan shown in the Petrobangla's five-year plan. • The installation of wellhead gas compressor scheduled around 2017 makes it possible to add substantial reserves to the current reserves and extend the field life.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
7	Meghna	1	5	5	11	10.0	69.9	16.84	• The field life will be short because the remaining 2P reserves are small. According to the production forecasts by PSMP2015, the field production will continue up to 2022, whereas it will continue only up to 2015 by PSMP2010's forecasts.
8	Narshingdi	2	25	25	30	28.1	276.8	116.40	• Gas production has been continuing as forecasted by PSMP2010 since 2010. • The installation of wellhead gas compressor scheduled around 2017 makes it possible to have substantial quantity of additional reserves and extend the field life.
9	Beanibazar	1	15	15	14	9.6	203.0	115.28	• Average daily production of 9.5 MMscfd in 2014 is significantly lower than that predicted by PSMP2010.
10	Fenchuganj	3	65	60	40	38.7	381.0	256.21	• There is no increase in production because the Fenchuganj-5 well drilled in 2014 resutlted in unsuccessful. • An increase in production will not be expected for some time because any programs of development drilling are not shown in the Perobangla's five-year plan.
11	Saldanadi	1	8	8	20	12.0	279.0	197.44	• The reserves are small. Therefore the field's production will not increase significantly in the future, although this may be dependent on the results of new development wells. However, the size of the remaining 2P reserves indicates that the field can produce gas at a rate of about 20 MMscfd, about twice as much as the average daily production as of December 2014, in the near future. • According to the Petrobangla's five-year plan, development well Saldanadi-4 are to be drilled and then completed in May 2015.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
12	Shahbazpur	2	10	10	30	7.9	390.0	379.50	• Daily production in 2014 is almost the same as that predicted by PSMP2010. • Development wells Shahbazpur-3 and 4 were completed in September 2014 and November 2014, respectively, and a flow rate of about 19 MMscfd of gas from well no. 3 and about 32 MMscfd of gas from well no. 4 were confirmed by the flow tests, respectively. But gas production from both wells have not started yet. • According to the Petrobangla's five-year plan, any new development wells are not planned. However, from the viewpoin of the size of recoverable reserves, drlling of new development wells for increasing production is expected in the near future
13	Semutang	2	15	15	12	4.6	317.7	308.03	• Gas production in 2014 was significantly lower than that predicted by PSMP2010. This is because the field development may have not progressed as planned. • Regarding the actual production as of December 2014, an average daily production rate of 4.7 MMscfd from 2 wells is very low. • The future production will depend on the results of the planned two development wells shown in the Petrobangla's five-year plan.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014: Forecasts by PSMP2010 (MMscfd) Case 1	Case 2	Production Capacity (MMscfd)	Actual Production (MMscfd)	Recoverable 2P Reserves as of the end of 2014 (BCF)	Remaining 2P Reserves as of Jan. 2015 (BCF)	Evaluation of Production Status
14	Sundalpur Shahzadpur	1	60	60	10	3.6	35.1	27.10	• According to the production forecasts by PSMP2010, this field is considered to be one of newly discovered gas fields, and an average daily production is estimated to be 60 MMscfd including production from other new fields in 2014. • From the viewpoint of the size of the remaining reserves, a significant increase in production is not expected. • According to the Petrobangla's five-year plan, drilling of one development wells is planned.
15	Srikail	2	60	60	44	38.7	161.0	135.57	• Gas production from the field started in March 2013. • According to the production forecasts by PSMP2010, this field is considered to be one of newly discovered gas fields, and an average daily production is estimated to be 60 MMscfd including production from other new fields in 2014. • According to the Petrobangla's five-year plan, drilling of one development wells is planned and production from the well is expected to start 2016..
16	Sangu	0	0	0	0	0.0	577.8	89.85	• Gas production from the field has been suspended from 1 October 2013. The production facilities have been handed over to Petrobangla as per contract. However, whether Petrobangla resume production from this field is unknown. • According to the forecasts by PSMP2010, production was not expected after 2014. • According to the forecasts by PSMP2015, production is also not expected over the years from 2015 through 2041.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014				Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production			
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
17	Jalalabad	4	250	200	246	246.2	1,184.0	281.15	• The results of case 1 in the production forecasts by PSMP2010 shows that the production rate of 250 MMscfd in 2014 is almost the same as that of actual production. • Even in case 2 by PSMP2010, in which the field life is longer life compared to case 2, production will continue only to 2022. On the other hand, PSMP2015 forecasts that the field production will be sustained up to 2027. • The field life can be extended by, for example, introduction of wellhead gas compressors.
18	Moulavi Bazar	6	160	80	60	62.6	428.0	160.51	• Cases 1 and 2 in the production forecasts by PSMP2010 were 160 MMscfd and 80 MMscfd, respectively, whereas gas was produced at a rate of 60 MMscfd in 2014. • An increase in production could not be expected in the future from recent decrease in production. The field's production was less than 40 MMscfd in late February 2015.
19	Bibiyana	18	900	850	960	1,006.7	5,754.0	3,873.19	• Actual production rate in 2014 was significantly higher than those of both cases 1 and 2 by PSMP2010. • Production increased in November 2014 and February 2015, respectively. • A peak daily production rate of 1,200 MMscfd, following the production rate shown in the Petrobangla's five-year plan, is expected to be maintained over the period of 2015 to 2019 in the long-term production forecasts. Based on the information of the processing capacity of 1,200 MMscfd in the current production facilities, an average daily production rate of 1,200 MMscfd will continue at least until 2019.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014: Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production	Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
20	Bangura	4	120	120	100	110.0	522.0	241.00	• According to the production forecasts by PSMP2010, the average production rate of 120 MMscfd in 2014 in both of cases 1 and 2. However, gas was produced actually at a rate of 109 MMscfd which was slightly lower than the expected. • Accoding to the production forecasts by PSMP2010, the field' production was expected to continue up to 2023. However, the production is expected to further continue because gas has been produced constantly at a rate of about 110 MMscfd since early 2014.
21	Begumganj	0	0	0	0	0.0	70.0	70.00	• According to the production forecasts by PSMP2010, the field's production will start in 2017. On the other hand, according to the Petrobangla's five-year plan, the production will start soon (from the Begumganj-3 well). • According to the Petrobangla's five-year plan, drilling of one development well is planned and production from the well is expected to start in 2017.
22	Kutubdia	0	0	0	0	0.0	45.5	45.50	• According to the forecasts by PSMP2010, the field's production is expected to be from Block 16, and the start-up of production is scheduled to be 2017. However, from the information available at present it is difficult to start production. • No production from the field is expected in the long-term production forecasts in this survey.
23	Chhatak	0	0	0	0	0.0	474.0	447.54	• According to the forecasts by PSMP2010, any gas production is not expected. • According to the Petrobangla's five-year plan, drilling of two development wells is planned at Chhatak West, and production from the field is expected to start in 2016.

Table 2 Evaluation of Current Status of Existing Gas Fields (continued)

as of February 2015

Sl. No.	Gas Field	No. of Producing Wells as of Dec. 2014	Average Daily Production in 2014: Forecasts by PSMP2010 (MMscfd)		Production Capacity	Actual Production	Recoverable 2P Reserves as of the end of 2014	Remaining 2P Reserves as of Jan. 2015	Evaluation of Production Status
			Case 1	Case 2	(MMscfd)	(MMscfd)	(BCF)	(BCF)	
24	Kamta	0	0	0	0	0.0	50.3	29.20	• Production was not estimated by the PSMP2010. Production is also not estimated in the Petrobangla's five-year plan. • Based on the above situation, the field's production is not expected in this survey..
25	Feni	0	2	2	0	0.0	125.0	62.60	• There was no production from the field in 2014, whereas according to the production forecasts by PSMP2010, gas was produced at a rate of 2 MMscfd. • According to the Petrobangla's five-year plan, drilling of two development wells is planned and production from the field is expected to resume in 2016.

Note: 1) Remaining 2P reserves = Recoverable 2P reserves - Cumulative production
2) The rcoverable 2P reserves as of the end of 2014 and remaining 2P reserves are based on the Draft Five Year Gas Supply Strategy prepared by Petrobangla.

Source: Prepared based on PSMP2010 report (JICA, 2011), Petrobangla Anuual Reports 2010 to 2014 and Petrobangla's "Draft Five Year Gas Supply Strategy" (2015)

2. Production forecast for existing gas fields 2015-2019

Production forecasts for the existing gas fields for the next five years are necessary for long-term production forecasts. In this survey production forecasts for the period of 2015 to 2019 are conducted based on the production forecasts shown in the Petrobangla's five-year plan
The production rates are overestimated as a whole in the production forecasts for the period of 2015-2019 shown in the Petrobangla's five-year plan. Therefore, as described below, the production rates estimated by Petrobangla were corrected, if necessary, based on the comparison of between expected and actual for the times of well completion and production rates.

(1) Evaluation of Times of Well Completion and Production Rates Shown in the Petrobangla's Five-Year Plan

Evaluation of times of well completion and production rates shown in the Petrobangla's five-year plan is carried out based on a comparison between expected and actual for times of well completion and production rates for the wells shown in the "Gas Evacuation Plan 2010-2015" prepared in 2010. The comparison is shown in Table 3 It is noted that the wells whose actual data were not available are excluded from the table. As a result, the data evaluation was made only on the development and exploratory wells.

Table 3 indicates that the times of completion for newly drilled wells were more than one year behind schedule except for exploratory well Sundalpur-1. Regarding daily production rates it is evaluated as about 70% of the initial estimates, although the actual values ranges from 52 to 167% of the initial estimates. Averaged value of the ratio of actual/expected for daily production rate shows 0.78 for all wells (12 wells) listed in Table 3 and 0.69 for development wells (10 wells), respectively. Production forecasting is focused on development wells in the existing gas fields. Therefore a value of 0.69 was chosen because the evaluation is to be performed on the development wells, and then 0.69 rounded off to one decimal place is 0.7.

Based on these results the times of well completion and production rates shown in the Petrobangla's five-year plan are evaluated as follows,

- Times of well completion: At least one year behind schedule
- Production rates: About 70% of initial estimates

(2) Revision of Production Forecasts by Petrobangla for Existing Gas Field

Based on the comparison described above, correction factors for times of well completion and production rates shown in the Petrobangla's five-year plan are basically assumed as follows.

The risk of the delay in the time of well completion is expressed as decrease in production rate. Based on the idea that if one-year delay occurs in a five-year period, production decreases by 20% of the initial estimate, the production rates shown in the Petrobangla's five-year plan were corrected. The values of production rates are corrected by multiplying 0.8 for the wells to be completed in and after 2016.

- Times of well completion: 80% of the initial estimate
- Production rates: 70% of the initial estimates

Thus, the corrected production rates for the wells shown in the Petrobangla's five-year plan are listed in Table 4.

(3) Production Forecasts for 2015-2019

The production forecasts for the period of 2015-2019 were conducted by party modifying those shown in the "Draft Five Year Gas Supply Strategy" by Petrobangla, if necessary, based on the comparison of between expected and actual for the times of well completion and production rates as described above. Thus, the modified production forecasts are shown in Table 5.

- Patterns of production profiles are basically the same as those shown in the Petrobangla's five-year plan.
- According to the Petrobangla's five-year plan, an increase in production by 5 mmscfed from the Shahbazpur gas field since 2018 is planned. However, this increase in production was not taken into consideration in this survey because any development plans are not presented in the plan.
- The grand total shows a peak production rate of 2,811 mmscfd at the period of July-December in 2016 (Table 5). On the other hand, the production forecasts shown in the Petrobangla's five-year plan also shows a peak production rate of 2,916 mmscfd at the same period as shown above. As a result, the production rate estimated by the survey team is lower than that by Petrobangla by about 100 mmscfd.

Table 3 Times of Well Completion and Production Rate for Wells Shown in Gas Evacuation Plan 2010-2015: Expected vs Actual

As of February 2015

Well Name	Owner/ Operator	Time of Well Completion			Daily Production Rate			Remarks
		Excpected	Actual	Difference (Delay) (month)	Excpected	Actual	Ratio of Actual/Expected	
Development Wells								
Fenchuganj-4	BAPEX	Oct 2010	Feb 2012	16	20	20	1	
Saldanadi-3	BAPEX	Nov 2010	Jan 2012	13	15	15	1	
Saldanadi-4	BAPEX	Mar 2011	—	47+	15	0	0	During drilling
Titas-17	BGFCL	Jun 2011	Mar 2013	21	25	15	0.60	
Fenchuganj-5	BAPEX	Aug 2011	Apr 2014	32	20	0	0	Dry
Titas-18	BGFCL	Nov 2011	Aug 2013	21	25	16	0.64	
Bakhrabad-9	BGFCL	Apr 2012	Aug 2013	16	20	16	0.80	
Titas-19	BGFCL	Jun 2012	May 2014	23	100	15	0.52	
Titas-20	BGFCL		Oct 2013	?		10		
Titas-21	BGFCL		Dec 2013	?		15		Suspended in July 2014 due to production of exccesive amount of water
Titas-22	BGFCL		Mar 2014	?		12		
Rashidpur-8	SGFL	Jun 2012	Aug 2014	26	20	15	0.75	
Exploratory Wells								
Sundalpur-1	BAPEX	Oct 2010	Sep 2011	11	15	12	0.80	Production started in March 2012
Srikail-2	BAPEX	Feb 2011	Jun 2012	16	15	25	1.67	Production started in March 2013
Kapasia-1	BAPEX	Mar 2011	Apr 2012	13	15	0	0	Dry
Mubarakpur-1	BAPEX	Sep 2011	—	41+	15	0	0	During drilling

Source: Prepared based on Petrobangla's "Gas Evacuation Plan (2010-2015)" (2010), Petrobangla Annual Reports, etc.

Table 4 Data Used for Correction of Production Rate in Production Forecast for Existing Gas Fields by Petrobangla

As of February 2015

Gas Field	Development Drilling/Workover		Estimates of Production Rate			Reasons for Correction of Production Rate	Production Outlook
	Well Name	Type of Operations	Estimates by Petrobangla (MMscfd)	Correction Factor	Production Rate after Correction (MMscfd)		
Titas	No. 23	Dev. Drlg	20	0.7	14	• Production rates estimated based on the actual productio rates in recently drilled development wells • Correction: Production rates only	• It is expected that an increase in the production capacity depending on the plan and results of future development drilling. • It is possible to add the reserves and extend the field life by installation of the wellhead gas compressors being scheduled around 2016. The installation of the wellhead gas compressors will be limited to a part of the production sites, it is necessary to intstall them in other production sites in future.
	No. 24	Dev. Drlg	20	0.7	14		
	No. 25	Dev. Drlg	20	0.7	14		
	No. 26	Dev. Drlg	20	0.7	14		
Bakhrabad	No. 10	Dev. Drlg	10	0.8	8	• Correction: Time of production start-up only	• An increase in production is expected by drilling of new development wells in the future.
Kailashtila	No. 7	Dev. Drlg	15	0.56	8	• Workover operational risk is relatively high • Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• The future production performance will be dependent on whether new development drilling and well workover operations will be sucessful or not.
	No. 1&5	Workover	15	0.56	8		
	No. 9	Dev. Drlg	25	0.56	14		
Rashidpur	No. 9	Dev. Drlg	10	0.56	6	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• An increase in production is small at present because drilling of new development wells, including the Rashipur-8 well from which production was started in August 2014, has been delayed from the initial schedule. • According to the Petrobangla's five-year plan, drilling of three development wells is planned.
	No. 10	Dev. Drlg	20	0.56	11		
	No. 11	Dev. Drlg	20	0.56	11		
Sylhet/Haripur	No. 9	Dev. Drlg	10	0.56	6	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• Based on recent development activities an increase in production can be expected, depending on the results of future development wells, although a significant increase in production will not be expected from the development plan shown in the Petrobangla's five-year plan.

Table 4 Data Used for Correction of Production Rate in Production Forecast for Existing Gas Fields by Petrobangla (continued)

As of February 2015

Gas Field	Development Drilling/Workover		Estimates of Production Rate			Reasons for Correction of Production Rate	Production Outlook
	Well Name	Type of Operations	Estimates by Petrobangla (MMscfd)	Correction Factor	Production Rate after Correction (MMscfd)		
Saldanadi	No. 4	Dev. Drlg	10	1	10	• Evaluated based on the production performance of well No. 1	• The reserves are small. Therefore the field's production will not increase significantly in the future, although this may be dependent on the results of new development wells. However, the size of the remaining 2P reserves indicates that the field can produce gas at a rate of about 20 MMscfd, about twice as much as the average daily production as of December 2014, in the near future. • According to the Petrobangla's five-year plan, development well Saldanadi-4 are to be drilled and then completed in May 2015.
Shahbajpur	No. 4	Dev. Drlg	25	—	19	• Production rate is estimated based on the well test results conducted after completion of drilling	
Semutang	No. 7	Dev. Drlg	8	0.56	4	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• The future production will depend on the results of the planned two development wells shown in the Petrobangla's five-year plan.
	No. 8	Dev. Drlg	8	0.56	4		
Sundupur Shahzadpur	No. 2	Dev. Drlg	8	0.56	4	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• From the viewpoint of the size of the remaining reserves, a significant increase in production is not expected. • According to the Petrobangla's five-year plan, drilling of one development wells is planned.
Srikail	No. 4	Dev. Drlg	20	0.56	11	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the Petrobangla's five-year plan, drilling of one development wells is planned and production from the well is expected to start 2016..

Table 4 Data Used for Correction of Production Rate in Production Forecast for Existing Gas Fields by Petrobangla (continued)

As of February 2015

Gas Field	Development Drilling/Workover		Estimates of Production Rate			Reasons for Correction of Production Rate	Production Outlook
	Well Name	Type of Operations	Estimates by Petrobangla (MMscfd)	Correction Factor	Production Rate after Correction (MMscfd)		
Bibiyana	Specific well names or numbers are not disclosed	Dev. Drlg	150	1	150	• Conrrenction for production rates was not made because the field's average daily production rate was increased to about 980 MMscfd in November 2014 and then will be increased to about 1,200 MMscfd soon.	• A peak daily production rate of 1,200 MMscfd, following the production rate shown in the Petrobangla's five-year plan, is expected to be maintained over the period of 2015 to 2019 in the long-term production forecasts. Based on the information of the processing capacity of 1,200 MMscfd in the current production facilities, an average daily production rate of 1,200 MMscfd will continue at least until 2019.
Begumganj	No. 3	Dev. Drlg	12	0.7	8	• Drilling of well No. 3 has already been completed. • Correction for well No. 3: 0.7 for production rate only • Correction for well No. 4: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the production forecasts by PSMP2010, the field's production will start in 2017. On the other hand, according to the Petrobangla's five-year plan, the production will start soon (from the Begumganj-3 well). • According to the Petrobangla's five-year plan, drilling of one development well is planned and production from the well is expected to start in 2017.
	No. 4	Dev. Drlg	15	0.56	8		
Chattak	No. 3	Dev. Drlg	20	0.56	11	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the Petrobangla's five-year plan, drilling of two development wells is planned at Chhatak West, and production from the field is expected to start in 2016.
	No. 4	Dev. Drlg	20	0.56	11		
Feni	No. 6	Dev. Drlg	10	0.56	6	• Correction: 0.7 for production rate × 0.8 for time of production start-up (= 0.56)	• According to the Petrobangla's five-year plan, drilling of two development wells is planned and production from the field is expected to resume in 2016.
	No. 7	Dev. Drlg	10	0.56	6		

Table 5 Daily Gas Production Forecast for 2015-2019

Unit: mmscfd

Company	Field	2015		2016		2017		2018		2019		Remarks
		Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	
1. BGFCL	Titas	525	520	520	510+56	556	546	489	489	441	441	Production start-up: Jul-Dec 2016—Well nos. 23, 24, 25 and 26
	Bakrabad	40	38	36	34	30	26	23	23	30	30	
	Habiganj	224	224	224	224	220	218	215	215	200	200	
	Narsingdi	28	28	28	28	26	25	24	24	23	23	
	Meghna	10	10	10	10	10	10	9	9	9	9	
	Sub-total	**827**	**820**	**818**	**862**	**842**	**825**	**760**	**760**	**703**	**703**	
2. SGFL	Sylhet	8	8	7	7+6	12	11	11	10	10	9	Production start-up:Jul-Dec 2016—Well no. 9
	Kailashtila	72	70+8	78+14	92+8	100	96	96	92	92	88	Production start-up: Jul-Dec 2015—Well no. 1&5, Jan-Jun 2016—Well no. 9, Jul-Dec 2016—Well no. 7
	Rashidpur	60	59	58	57	56	61	72	70	67	67	Production start-up: Jul-Dec 2017--Well no. 9, Jan-Jun 2018--Well nos. 10 & 11
	Beani Bazar	9	9	9	9	8	8	8	8	8	8	
	Sub-total	**149**	**154**	**166**	**179**	**176**	**176**	**187**	**180**	**177**	**172**	
3. BAPEX	Saldanadi	10	6+10	16	13	12	11	10	10	10	10	Prpduction start-up: Jul-Dec 2015—Well no. 4
	Fenchuganj	35	34	32	30	30	29	28	28	28	28	
	Shahbazpur	10	10+9	29	29	29	29	29	29	29	29	Production start-up: Jul-Dec 2015—Well no. 4
	Semutang	4	3	2	2	2+4	6+4	10	10	10	10	Production start-up: Jan-Jun 2017—Well no. 7, Jul-Dec 2017—Well no. 8
	Sundalpur	3	3	2	0+4	4	4	4	4	4	4	Production start-up: Jul-Dec 2016—Well no.2
	Srikail	38	36	35+11	46	41	41	41	41	36	36	Production start-up: Jan-Jun 2016—Well no. 4
	Rupganj	0	8	8	8	8	8	7	7	7	7	
	Begumganj	4	4+8	12	12	10	10+8	16	16	12	9	Jan-Jun 2015: Actual production, Production start-up: Jul-Dec 2015—Well no. 3, Jul-Dec 2017—Well no. 4
	Sub-total	**104**	**141**	**147**	**144**	**140**	**150**	**145**	**145**	**136**	**133**	
	Sub-total (1+2+3)	**1,080**	**1,115**	**1,131**	**1,185**	**1,158**	**1,151**	**1,092**	**1,085**	**1,016**	**1,008**	
4. Chevron	Jalalabad	250	250	250	250	220	220	220	220	220	220	
	Maulavibazar	50	50	50	50	45	45	45	45	45	45	Jan-Jun 2015: Actual production
	Bibiyana	1,100	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,200	Jan-Jun 2015: Actual production
5. Tullow	Bangora	110	110	109	109	81	81	69	69	58	58	Jan-Jun 2015: Actual production
	Sub-total (4+5)	**1,510**	**1,610**	**1,609**	**1,609**	**1,546**	**1,546**	**1,534**	**1,534**	**1,523**	**1,523**	
6.	Feni				6	6+6	12	12	11	9	8	Resumption of production: Jul-Dec 2016—Well no. 6, Jan-Jun 2017—Well no. 7
7.	Chhatak				11	11+11	22	22	19	19	16	Resumption of production: Jul-Dec 2016—Well no. 3, Jan-Jun 2017—Well no. 4
Ground Total (1+2+3+4+5+6+7)		**2,590**	**2,725**	**2,740**	**2,811**	**2,738**	**2,731**	**2,660**	**2,649**	**2,567**	**2,555**	

Note: 1) Production rates in yellow cells were modified from those shown in the Petrobangala's five-year plan based on the actual production data or corrected production rates shown in Table 1.4-2.
2) The expression such as "510+56" means a daily production rate without additional production plus an additional daily production rate.

Source: Petrobangla's "Draft Five Year Gas Supply Strategy" (2015) and JICA Survey Team

Chapter 7 Attachment

7-2 Cost Estimation for Natural Gas Exploration and Development

7-2 Cost Estimation for Natural Gas Exploration and Development

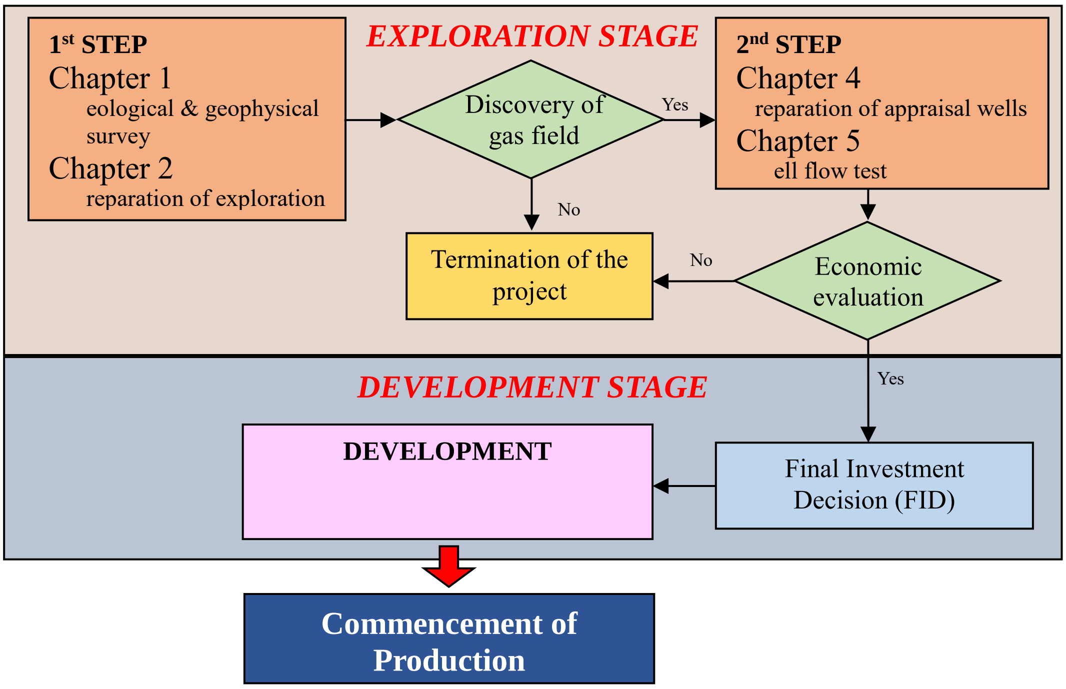
1. Introduction

(1) General

In order to grasp the approximate future gas development costs, the investment costs required for the exploration, drilling, and construction of the gas production facility till 2027 were estimated. The construction costs for the construction of the new gas production facility – intended to increase the nation's gas production - were estimated based on Bangladesh's gas field development plan as scheduled at present.

(2) Cost Estimation Objects

Generally, a flow of natural gas development is divided into "Exploration stage" and "Development stage", and the related activities proceed as shown in Figure 1.



Source: JICA Survey Team

Figure 1 Flow Chart of Gas Field Development

In the exploration stage, the potential of the gas field is mainly ensured and the risk of gas development is reduced by measures including 3D seismic surveys. The gas reservoir is evaluated on a commercial basis and if there are no problems here, the gas field is able to move to the development stage. At this point the final investment decision on the gas field development is made by the company.

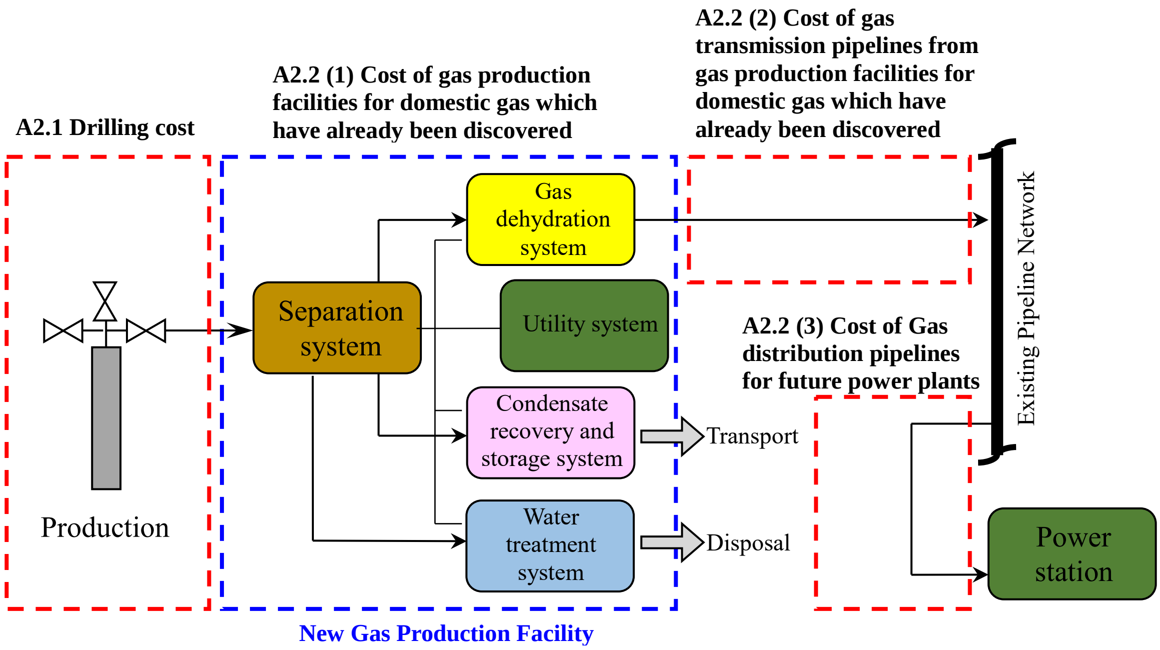
In the development stage, the gas production wells are completed with drilling works. Following this, the gas production and related facilities with appropriate plant capacity are constructed to start production.

Accordingly, the investment costs are estimated separately and divided into the two stages mentioned above. The facility construction costs are also separately estimated into around four categories including gas production facilities and pipelines. Furthermore, to properly meet the country's expected future rising gas demand, imports of LNG from overseas as well as domestic gas development is planned by the government. Therefore, the overall investment costs are divided into domestic gas development costs and import gas development costs.

The objectives (and their content) for these cost estimations are listed below, and the scope of these estimations are shown in Figure 2

A. Domestic Gas Development Costs
A.1 Field Exploration Costs
A.1.1.Seismic Survey Cost
A.1.2.Well Drilling Cost

A.2 Field Development Costs
A.2.1 Drilling Costs
A.2.2 Facility Construction Costs
(1) Gas production facilities for alredy-discovered domestic natural gas
(2) Gas transmission pipelines for alredy-discovered domestic natural gas
(3) Gas distribution pipelines for future power plants



Source: JICA Survey Team

Figure 2 Scope of Cost Estimations

B. Import Gas Development Costs
B1. Facility Construction Costs
(1) LNG receiving terminal
(2) LNG transmission pipeline

(3) Cost Estimation Procedure

Prior to conducting the cost estimation, a facility development concept of the future gas field and/or the existing gas field to be enhanced is examined based on the data and information provided by Petrobangla. Following this, a typical gas treatment process – including a separation system, a gas dehydration system, a condensate recovery and storage system, and a water treatment system – is examined through consideration of matters such as fluid property and characteristics.

As the result of the above examinations, the facility construction costs are estimated based on appropriate conditions and assumptions. These costs are estimated using the worldwide industry standard Siemens' Oil and Gas Manager (OGM) software project design tool. OGM is a suite of computer programs for performing field development planning, feasibility studies and cost estimates for oil and gas field development. OGM is used to specify the particular case to be modeled by defining the various production facilities, and then filling in forms to specify the flow connections between each facility, with the estimation results being summarized in a comprehensive database.

One of OGM's major advantages is that the facility design process (including process calculations, utility consumption calculations, conceptual facility design, selection of equipment, cost estimations) can all be processed at the same time through inputting the appropriate data. Accordingly, when compared to the facility design work time, OGM enables effective cost estimation with sufficient accuracy in a short time. Although OGM is widely used internationally in the oil and gas industry, as at February 2015 Japan Oil Engineering Co., Ltd. is the only user in Japan.

The OGM cost estimation procedure using OGM is described below:

Step 1:

In this step the type of the facility necessary for successful gas treatment is specified. Based on the data and information collected in various surveys, the OGM can establish the configurations for the of gas production facility, including for the gas/liquid separation system, the gas dehydration system, the condensate recovery and storage system, and the water separation system.

Step 2:

Input data for the facility configuration established in step 1 is prepared for modeling before running the OGM program. Based on this data, the cost estimation is then carried out utilizing OGM.

The main input data is described below and other data is listed in the Table 6.

- Project construction site information
  Depending on the particular project location, localized data, such as wage levels, are formulated and adjusted by OGM.

- Required facilities (such as the separator, the gas dehydrator, the condensate storage, and the water treatment facilities)
  Facility configuration is entered to model a fluid treatment process. The main equipment in each facility is selected by the OGM database in consideration of the facility specifications and requirements.

- Process conditions
  Process conditions such as flow rate, pressure, temperature and fluid composition are entered so that OGM database may select the proper equipment.

- Gas handling capacity
  By entering a flow rate, simplified sizing for equipment is operated, and the equipment capacity is examined in the software.

- Gas dehydration requirement
  The scale of the gas dehydration facility is examined based on the gas dehydration level specified.

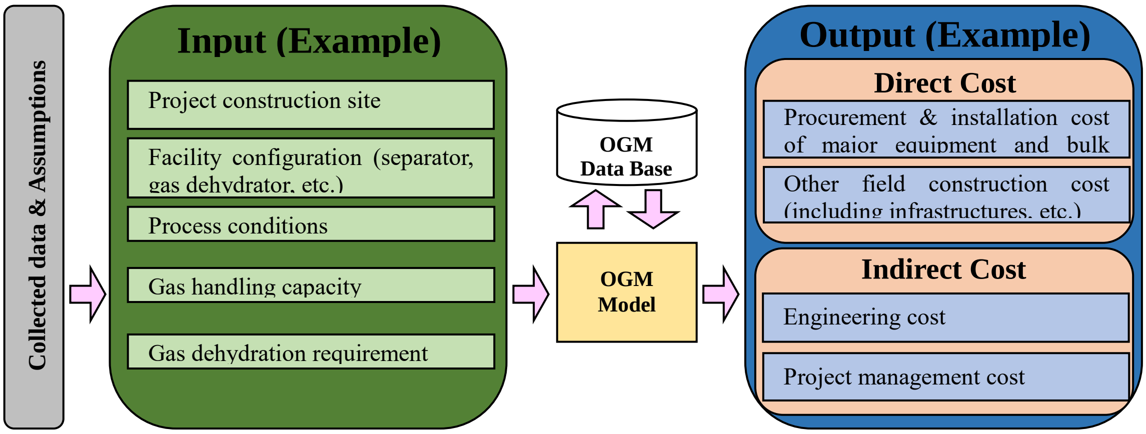
Step 3:

The direct and indirect costs of the total construction costs estimated are analyzed based on the OGM output. The costs breakdown from OGM are as follows:

- Direct costs
  - Procurement and installation costs of main equipment and bulk materials
  - Other field construction costs (including for infrastructure)
- Indirect costs
  - Engineering costs
  - Project management costs

Step 4:
The accuracy and validity of the OGM cost estimation results is checked in line with data from the previous construction of similar scale gas production facilitiese.

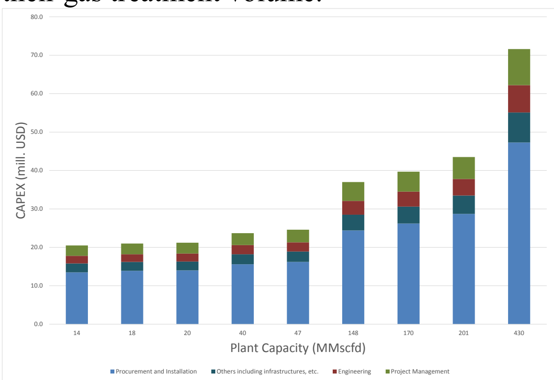
The cost estimation image by OGM is shown in Figure 3.



Source: JICA Survey Team

Figure 3 OGM Output Image

A more detailed cost estimation procedure for a gas production facility modeled using OGM is described below.

	Procedure	Description
Step 1	Preparation of input data	Southeast Asia was designated as the construction site. In relation to the configuration of the gas production facility, five facilities, such as the separation system, the dehydration system, the condensate recovery and storage system, and the water treatment facility, were specified for proper gas treatment. The following were also prepared as the input data: the gas treatment volume, the process conditions (gas composition, pressure, and temperature), the plant capacity, the level of gas dehydration, the number of facility trains, and the equipment required.
Step 2	Modeling the gas production facility and execution of OGM	In modeling the gas production facility, approximately five cases were set at the gas treatment volume within the range of 20 MMscfd to 400 MMscfd in order to cover all the cases at any gas treatment volume established in this study. OGM was used for each of these cases based on the above input data.
Step 3	Review of the OGM output	The OGM output is reviewed as the cost estimation results. In this review, the direct and indirect costs were analyzed separately, and the total construction costs were checked for their gas treatment volume. 
Step 4	Check of the cost estimation results	The accuracy and validity of the OGM output data was checked through comparing it with past construction cost data.

Source: JICA Survey Team

Figure 4 Cost Estimation Image from OGM

(4) Import Gas Development Plan

(a) Construction of a LNG Receiving Terminal

2 x 200,000 kl LNG tanks at south Chittagon is assumed as an initial stage.

(b) Construction of a LNG transmission pipeline

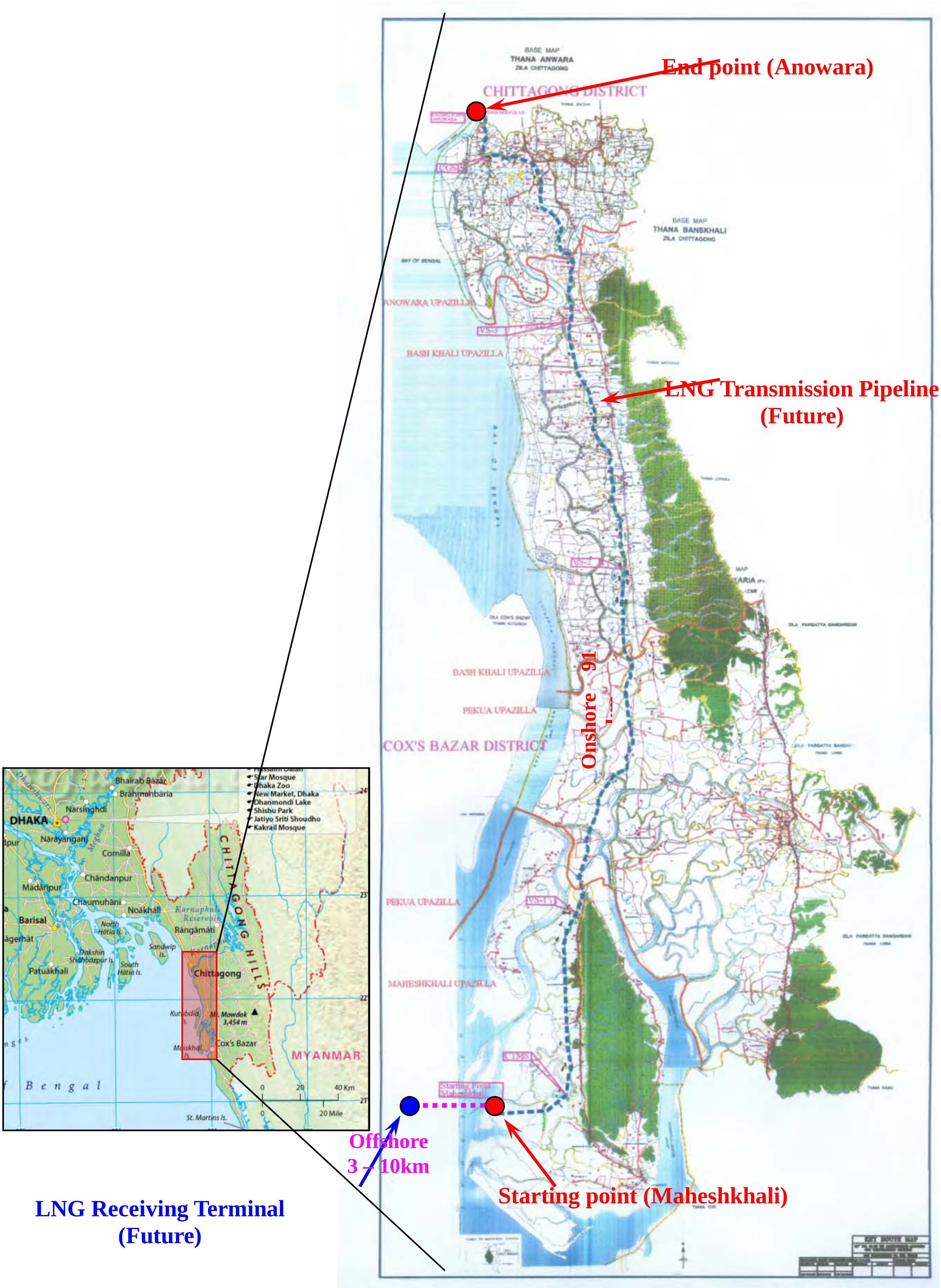
A proposed LNG transmission pipeline is to be constructed as part of a future program to transfer regasified gas of 500 MMscfd from the afore-mentioned proposed offshore LNG receiving terminal to the Chittagong RingMain (Anowara) via Moheshkhali. In this construction project, a 100 km (length) x 30 inch (width) transmission pipeline is to be installed; the pipeline shall be divided into an offshore portion of between 3 km to 10 km and a 91 km onshore portion. Please refer to Figure 5.

The operating conditions for the pipeline have been planned as indicated in Table 1.

Table 1 Operating Condition in LNG Transmission Pipeline

	Location	Flow rate [MMscfd]	Pressure [psig]
Starting point	Moheshkhali	500	1000
End point	Anowara		300

Source: information provided by Petrobangla



Source: information provided by Petrobangla

Figure 5 Pipeline Route Map of LNG Transmission Pipeline

2. Estimation Bases and Assumptions for Exploration Stage

As a part of cost estimation of natural gas development, seismic survey and well drilling costs were roughly estimated based on the information available from the websites of Petrobangla and its subsidiaries and news media.

Oil and gas exploration involves significant cost, time, and also high risk. It is important first step to gather geophysical data to narrow down the target area in the potential gas or oil field prior to start further exploratory activities.

For the last two-three decade, drilling technology has advanced significantly and exploration approach has also changed drastically. Recovery rate of oil and gas has improved due to the technological advancement. Key technological advancements are:

1) 3D seismic survey and 3D modeling technology
2) Directional and horizontal drilling technologies

Oil and gas exploration in Bangladesh started in mid 1950s. Majority of existing wells were designed and installed before 1990, and there may be some room for technological improvement to the existing facilities and also for new potential areas.

(1) Geophysical Survey:

Geophysical survey in the area of oil and gas exploration refers to a gravity survey, a magnetic survey, and a seismic survey. Gravity survey and magnetic survey are called air borne survey and used to identify size and depth of sedimentary basin as a whole and assist in modeling of subsurface structure.

Seismic survey provides more information about subsurface structures and indicates potential of subsurface deposits of crude oil and natural gas in the area. Seismic survey uses artificial seismic energy generated on land by vibrator mounted on specialized trucks if the area is accessible by trucks, otherwise use of explosives in the shallow borehole to generate shock wave. In offshore, air gun is used to generate highly compressed air bubbles which go into the water and transmit seismic wave energy into the subsurface layers.

Seismic waves reflect and refract off subsurface rock formations and travel back to acoustic receivers called geophones (on land) or hydrophones (in water). Based on the travel time data of the returned seismic energy, and also integrated with the existing strata information, feature of subsurface formation will be estimated, such as rock type, relative depth of folding, faulting, depositional environment, and nature of the fluid. This information facilitates to decide the location of prospective drilling targets.

Cost Indication for these activates will be as follows:

Type of Survey	Location	Survey Items	Cost Indication	Major Cost Element
Air Borne Survey	Onshore and Offshore	Gravity	not expensive	Airplane Lease Cost Equipment Lease cost
		Magnetic	not expensive	Airplane Lease Cost Equipment Lease cost
Seismic Survey	Onshore	2D	not expensive	Vibrator Truck Lease Cost Geophone Lease Cost
		3D	not so expensive	Vibrator Truck Lease Cost Geophone Lease Cost
	Offshore	2D	expensive	Survey Ship Day-rate
		3D	very expensive	Survey Ship Day-rate

(2) Drilling Works:

Drilling work for oil and gas exploration is carried out by specialized drilling rigs and experienced personals. These rigs are equipped with all necessary facilities to circulate the drilling fluid, hoist and turn the pipe, control down-hole, remove cuttings from the drilling fluid, safety facilities to prevent blowout events, and generate on-site power for these operations.

Size of the drilling hole in general is 40-36 inch initially and down to 5 inch. Soon after the hole is drilled as per the design, sections of steel pipe called casing, slightly smaller in diameter than the borehole, are placed in the hole. Cement will be placed between the outside of the casing and the borehole (annulus). The casing provides structural integrity to the newly drilled wellbore, in addition to isolating potentially dangerous high pressure zones from each other and from the surface.

Drilling fluid called "Mud" is used to pumped down the inside of the drill pipe and exits at the drill bit for the purpose of cooling the bit, lifting rock cuttings to the surface, preventing destabilization of the rock in the wellbore walls, and overcoming the pressure of fluids inside the rock so that these fluids do not enter the wellbore.
The principal components of drilling fluid are usually water and bentonite and also contain a complex mixture of solids and chemicals that must be carefully tailored to provide the correct physical and chemical characteristics required to safely drill the well. Mud logging is carried out to study the lithology of the formation and monitoring the characteristics of the formation.

Drilling is carried out with following purposes,

1) Exploratory drilling is carried out to gather information about the subsurface around the area of drilling through mud logging analysis.
2) Appraisal well is used to evaluate characteristics (flow rate etc.) of a proven hydrocarbon accumulation.
3) Production well is for production of oil and gas, once the evaluation of the well is completed and commercial production is proven.

Drilling cost is mostly affected by equipment lease cost and also depending on the depth/length (case of directional drilling), field location, and factors. Offshore is more expensive than onshore. General cost element for drilling work is as follows:

1) Hiring cost for geoscientists, geologists, mud loggers, engineers
2) Contractors for logistics and casing /cementing
3) Drilling rig lease cost with operation personals

(3) Drilling Cost

1) Onshore Drilling Cost:

Typical cost for onshore drilling in US is in the range of USD 0.5 million to 15 million per well and lease day rate for drilling rig capable of drilling most exploratory wells will be USD 10,000-15,000/day.

Unit drilling cost in Bangladesh is considered in the range of USD 10-20 million per well as shown in the Annural Reports by Petrobangla. Recent driling cost based on a competitive bidding using Best Practice is USD 15 million, and this figure can be used as a benchmrk cost for futre cost estimate.

2) Offshore Drilling cost:

High performance jack up rig lease rate in 2015 is USD 177,000/day in accordance with

Rigzone. With the use of similar facility, operating cost in the duration of 100 days can cost USD 30 million, including mobilization and demobilization, but varies to the local factors and location.

3. Construction Cost Estimate

The following assumptions were used for making cost estimate.

(1) Gas Production and Processing Facilities in the Existing Gas Fields

At present there are no new gas fields which are at the development stage. However, in order to increase future domestic gas supply, Petrobangla has a natural gas enhancement program for several of its existing gas fields. These programs run from 2014 to 2017 and are shown in Table 2.

Table 2 Gas Production Enhancement Program (Petrobangla)

Production Enhancement Program (Nov. 2014 – June 2015)

Sl. No.	Gas Fields & Wells	Well type	Flow (MMcfd)	Completion Date
1	Shahbazpur # 4	Development	25	November 2014
2	Bibiyana (sevem wells)	Development	220	Drilling completed, awaiting completion production facilities, will be in production within June 2015 in phases.

Production Enhancement Program (July 2015 - June 2016)

Sl. No.	Gas Fields & Wells	Well type	Flow (MMcfd)	Completion Date
	Titas # 25	Development	20	December 2015
	Kailashtila # 9	Development	25	December 2015
	Kailashtila 1& 5	W/O	15	June 2016
	Titas # 23	Development	20	June 2016
	Begumganj # 4	Development	15	June 2016
	Srikail # 4	Development	20	June 2016
	Titas # 26	Development	20	March 2016
	Salda # 4	Development	15	June 2016

Production Enhancement Program (July 2016 - June 2017)

Sl. No.	Gas Fields & Wells	Well type	Flow (MMcfd)	Completion Date
	Titas # 24	Development	20	September 2016
	Sundalpur # 2	Development	8	December 2016
	Semutang #7	Development	8	December 2016
	Semutang # 8	Development	8	June 2017
	Rashidpur # 9	Development	10	June 2017
	Sylhet # 9	Development	10	December 2016
	Rashidpur # 10, 11	Development	20	December 2017

Source: information provided by Petrobangla (Petrobangla reply to JICA survey team questionnaire).

The production enhancement programs are planned at 17 gas fields, as well as new installations and workovers are being conducted at 25 production wells. In these programs, 23 gas production wells are being newly installed at the existing gas fields, and the workovers of two existing wells being carried out at the Kailashtila gas field in order to improve the present declining gas production rate.

The program outline is shown in Table 3.

Table 3 Production Enhancement Program for the Existing Gas Fields

As at December 2014

Serial No.	Gas Field	Well #	Development Type & Number of Wells		Production Increment [MMscfd]	Completion Date (*2)	Necessity of New Gas Production Facility (*3)
1	Titas	23	Development x 1		20	June 2016	○
		24	Development x 1		20	September 2016	○
		25	Development x 1		20	December 2015	○
		26	Development x 1		20	March 2016	○
4	Kailashtila	1, 15		Workover x 2	15	June 2016	X
		9	Development x 1		25	December 2015	X
5	Rashidpur	9	Development x 1		10	June 2017	X
		10, 11	Development x 2		20	December 2017	X
6	Sylhet	9	Development x 1		10	December 2016	X
12	Shahbazpur	4	Development x 1		25	November 2014	X
13	Semutang	7	Development x 1		8	December 2016	X
		8	Development x 1		8	June 2017	X
17	Bibiyana (*1)	-	Development x 7		220	June 2015	X
19	Sundalpur	2	Development x 1		8	December 2016	X
20	Srikail	4	Development x 1		20	June 2016	X
21	Begumganj	4	Development x 1		15	June 2016	X
Other 1	Salda	4	Development x 1		15	June 2016	X
TOTAL		-	23	2	479	-	-
			25				

Source: Information based on Table 2 Gas Production Enhancement Program (Petrobangla)

NOTE:

*1: In Bibiyana Gas Field, gas of total 220 MMscfd will be additionally produced from seven wells.

*2: "Completion Date" means that construction or workover of the gas production well will be completed at that time.

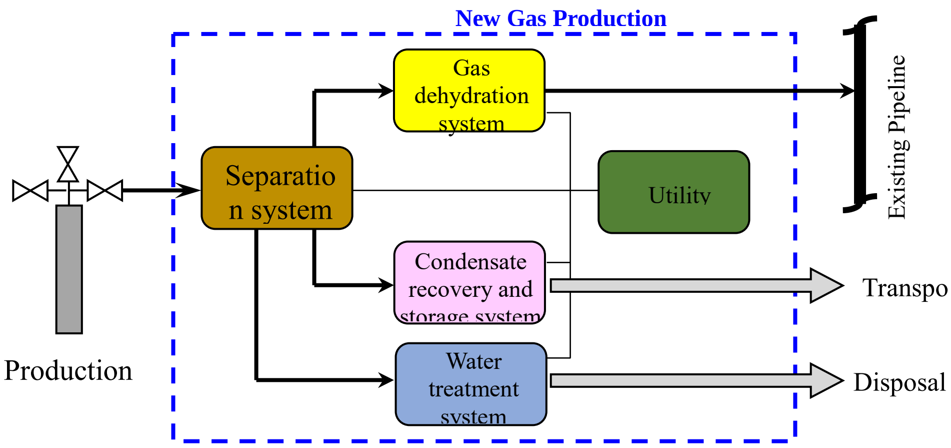
*3: The information regarding the necessity of a new gas production facility was obtained at the time of the meeting with Petrobangla

As shown in Table 3, the production enhancement program scheduled until 2017 has been planned, and the gas production wells are expected to be newly completed by and the workover of the existing wells should be carried out up to the date indicated in the table. The gas produced from these wells, except for that from the Titas Gas Field, is expected to be treatable within the plant capacity of the existing gas treatment facility. Accordingly, the construction of a new gas treatment facility should not be required for those production increments.

Regarding the four wells (23, 24, 25, and 26) in the Titas Gas Field – which should increase production to a total of 80 MMscfd – all the gas produced at these wells is planned to be collected at a site through gathering pipelines and treated in a newly-constructed gas production facility. The construction of this facility will be financed under an ADB project.

To treat produced gas properly, new gas production facility is to be composed of the following five main systems. The typical treatment process is shown in Figure 6 and Table 4.

- ✓ Separation system
- ✓ Gas dehydration system
- ✓ Condensate recovery and storage system
- ✓ Water treatment system
- ✓ Utility system



Source: JICA Survey Team

Figure 6 Typical Gas Treatment Process

Table 4 Function of Gas Treatment System

FACILITY	FUNCTION	PICTURE
Separation system	➢ Separation of gas, liquid and water ➢ Removal of foreign substances in well fluid	
Gas dehydration system	➢ Removes water vapour from the separated gas stream	
Condensate recovery and storage system	➢ Storage and unloading of condensate separated in the separation system	
Water treatment system	➢ Recovery of oil content in produced water using a CPI separator and a flotation unit ➢ Disposal of produced water	
Utility system	➢ Supply of fuel gas, instrument air, cooling water, utility air and water for maintenance, and electrical power.	 （The above picture shows instrument air compressor.）

Source: JICA Survey Team

(2) Parameter for OGM Software of Cost Estimation

(a) Trains at the gas production facility
There shall be no standby train at the proposed new gas production facility.

(b) Equipment standby philosophy
None of the main equipment in the gas production facility will have a standby unit.

(c) Wellhead fluid composition
The gas composition of the Titas Gas Field – Bangladesh's largest gas field – was applied to all cases in this study. This gas composition is shown in Table 5.

Table 5 Typical Wellhead Fluid Composition

Component	mol%
Nitrogen	0.37
Carbon Dioxide	0.31
Methane	96.76
Ethane	1.80
Propane	0.36
i-Butane	0.09
n-Butane	0.05
i-Pentane	0.02
n-Pentane	0.02
n-Hexane	0.04
n-Heptane	0.02
n-Octane	0.01
n-Nonane	0.00
n-Decane+	0.04
H2O	0.11
Total	100.00

Source: Information prepared based on Petrobangla data

Based on the standard gas sales contract in Bangladesh, as allowable water content in treated gas is restricted to below 7 lb/MMscf, this water content value has been applied to the planning of the gas dehydration facility.

(d) Operating conditions at the wellhead
- ✓ Pressure: 1,700 psig
- ✓ Temperature: 142 deg.F

(e) Cost estimation software (OGM) input data
The estimation of the costs for the gas production facility using OGM, was carried out with the input items and the input methods described in Table 6

Table 6 OGM Input Data

No.	Input Item	Input Method
1.	Project Construction Site Information	
1-1	Project Construction Site	The project construction site is specified from major oil/gas production areas worldwide such as the Arabian Gulf, Gulf of Mexico, North Sea, West Africa, Brazil, Venezuela, Southeast Asia, Northeast Asia and Malaysia. In this case, Southeast Asia was specified due to the proximity of Bangladesh. The appropriate wage rate for the specified project construction site was then applied – the same data is inputted for to all the cases regardless of the gas handling capacity.
2.	Required Facilities (Separator, Gas Dehydrator, Condensate Storage, Water Treatment Facilities)	
2-1	Main Facilities	The required main facilities (separator, gas dehydrator, condensate storage tank, and water treatment facility) for gas production are specified. Here, as there are no sour components (H2S) in the gas the general facility configuration for normal gas production was selected. As the facility configuration is the same for all the cases, the same data was inputted regardless of the gas handling capacity.
3.	Process Conditions	
3-1	Gas Production Rate	The gas production rate is specified. In this case, gas handling capacities were specified to cover the wide range of gas production rates in Bangladesh. The facilities required to handle the specified gas production rate are designed in connection with gas handling capacity, and then the costs are estimated.
3-2	Composition Basis	The gas composition is specified and the gas/liquid separation calculation is conducted based on the inputted composition. The facilities required to handle the separated gas and liquid are designed, and then the costs are estimated. The typical gas composition in Bangladesh is inputted in all cases regardless of the gas handling capacity. In case that the toxic substances such as sour component (H2S) and mercury are included in the produced gas, requisite removal facilities will be required. However, as the gas produced in Bangladesh is classified in sweet gas, the installation of such facilities is not

No.	Input Item	Input Method
		necessary.
4.	Separation System	
4-1	Flowing Wellhead Pressure	The wellhead pressure is specified. The pressure level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical wellhead pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.
4-2	Flowing Wellhead Temperature	The wellhead temperature is specified. Temperature level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted temperature, after which the costs are estimated. The typical wellhead temperature in Bangladesh was inputted in all the cases regardless of the gas handling capacity.
4-3	Production Manifold Design Pressure	The manifold design pressure is specified. The pressure level at the manifold is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure was inputted in all the cases regardless of the gas handling capacity.
4-4	Production Separator Design Pressure	The separator design pressure is specified. The pressure level of the separator is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure was inputted in all the cases regardless of the gas handling capacity.
4-5	Production Separator Operating Pressure	The separator operating pressure is specified. The gas/liquid separation calculation is conducted based on the inputted pressure, then the separator size and wall thickness required to handle the separated gas and liquid are designed, after which the costs are estimated. The typical separator operating pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.
4-6	Test Separator	The necessity of the test separator is specified. The test separator is normally required to monitor the production rate of one well and to manage the gas reservoir. “Allocated” was selected for all the cases regardless of the gas handling capacity.

No.	Input Item	Input Method
4-7	Residence Time	The oil/condensate residence time in a separator that is required to segregate water droplets from oil/condensate phase was inputted. The As the separator is designed based on the residence time, the typical residence time is inputted in all the cases regardless of the gas handling capacity.
4-8	Separator per Stage	The number of separators per stage is inputted. Normally, vessels such as separators do not have any spares. Also, as the facility configuration without any spares is a design premise in the study, the number of train was inputted as one for all the cases regardless of the gas handling capacity.
4-9	Percent Flow per Separator	In relation to the "separator per stage", the percentage of the handling flow rate per train in the total flow rate was inputted. As the facility configuration without any spares is a design premise in the study, the percent flow per separator is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
4-10	Water Separation Option	The necessity of water separation in a separator is specified. The produced water is normally removed from the oil/condensate and gas. "Allocated" was selected for all the cases regardless of the gas handling capacity.
5.	Gas Dehydration System	
5-1	Gas Dehydration Medium	The gas dehydration medium is specified. "Glycol" is specified as a typical medium (chemical) used in gas dehydration process for all the cases regardless of the gas handling capacity.
5-2	Number of Gas Dehydration Trains	The number of gas dehydration trains is inputted. Vessels such as gas dehydration facility normally do not have any spares, and facility configuration without any spare is a design premise in the study, therefore number of train is inputted as one for all the cases regardless of gas handling capacity.
5-3	Percent Flow per Dehydration Train	In relation to the "number of gas dehydration trains", the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spares is a design premise in the study, the percent flow per gas dehydration train is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
5-4	Outlet Water Dew Point Temperature	The outlet water dew point temperature for the gas dehydration is inputted. The water dew point temperature of 32 F corresponding to 7 lb water in 1 MMscf gas, as regulated in the standard sales gas contract in Bangladesh, is inputted for all

No.	Input Item	Input Method
		the cases regardless of the gas handling capacity.
5-5	Dehydrator Column Design Pressure	The gas dehydrator column design pressure is specified. The pressure level of the dehydrator column is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical design pressure is inputtedfor all the cases regardless of the gas handling capacity.
6.	Condensate Recovery and Storage System	
6-1	Oil/Condensate Tank Capacity	The oil/condensate tank capacity is specified. The required oil/condensate storage facilities are designed for the inputted tank capacity, then the costs are estimated.
6-2	Oil Pump Outlet Pressure	The oil pump outlet pressure required for shipping is specified. The Pressure level of the pump is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure is inputted for all the cases regardless of the gas handling capacity.
6-3	Number of Pumps	The number of pumps is inputted. As the facility configuration without any spares is a design premise in the study, the number of trains is inputted as one for all the cases regardless of the gas handling capacity.
6-4	Percent Flow per Pump	In relation to “number of pumps”, the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spare is a design premise in the study, thepercent flow per pump is inputted in common as one hundred (100%) for all the cases regardless of the gas handling capacity.
7.	Water Treatment System	
7-1	Produced Water Design Rate	The produced water design rate is specified. The facilities required to handle the specified water rate are designed in connection with the produced water design rate, then the costs are estimated.
7-2	Sour Water Stripping Option	The necessity of a sour (H_2S) component stripping facility as one the of water treatment systems is specified. As gas produced from Bangladesh is classified as sweet gas a without sour (H_2S) component, the installation of such a facility is not required. “Not allocated” was selected for all the cases regardless of the gas handling capacity.

No.	Input Item	Input Method
7-3	CPI Unit	The necessity of a CPI unit as the first stage of water treatment is specified. A CPI unit is normally used in the water treatment. “Allocated” was selected for all the cases regardless of the gas handling capacity.
7-4	Floatation/Hydrocyclone Unit	The necessity of a floatation/hydrocyclone unit as the second stage of water treatment is specified. A floatation/hydrocyclone unit is normally used in the water treatment. “Allocated” was selected for all the cases regardless of the gas handling capacity.
8.	Utility System	
8-1	Type of Main Power Generator	The type of main power generator driver is specified. “Turbine” was specified as the typical most proven type of driver for all the cases regardless of the gas handling capacity.
8-2	Number of Main Power Generators	The number of main power generators is inputted. As the facility configuration without any spares is a design premise in the study, thethe number of trains was inputted as one for all the cases regardless of the gas handling capacity.
8-3	Percent of Main Power Load	In relation to the “number of main power generators”, the percentage of power generation per train in the total power generation is inputted. As the facility configuration without any spares is a design premise in the study, the percent of the main power load was inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
8-4	Power Generator Selection	The manufacturer’s model of the main power generator is specified. In this case, the required power for all the facilities was internally calculated in the software by specifying “internally determined” for all the cases regardless of the gas handling capacity. Also, the type of main power generator was automatically selected to cover the power demand required.
9.	Other Related Facilities	
9-1	Number of People in Operation Camp	The number of people to be accommodated in the operation camp is inputted. Based on three shift of eight hours , the number of people – including operators, supervisors, maintenance workers, administrators, and guests – are assumed for the required accommodation, then the costs are estimated.
9-2	Number of People in Construction Camp	The number of people to be accommodated in construction camp is inputted. The number of people is assumed for the required accommodation, then the costs are estimated.

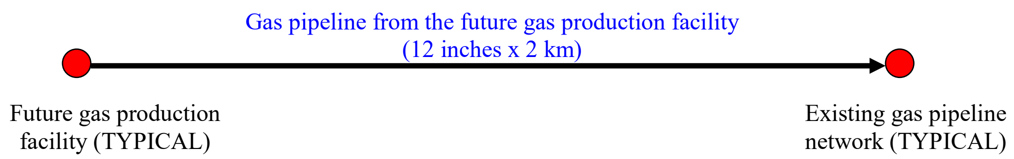
Source: JICA Survey Team

(3) Gas Transmission Pipelines for Already-discovered Domestic Natural Gas

For the costs estimation, the following conditions were uniformly applied for all the gas pipelines to be newly laid between the future gas production facility and the existing pipeline network.

- Pipe material: API5L Gr.X60 with 3LPE coating
- Nominal pipe size: 12 inches
- Wall thickness: 0.312 inches
- Pipeline length: 2 km (per each pipeline)
- Concrete coating: Not required
- Construction cost: 0.5 million USD/km

The overall view of the pipeline is as follows.

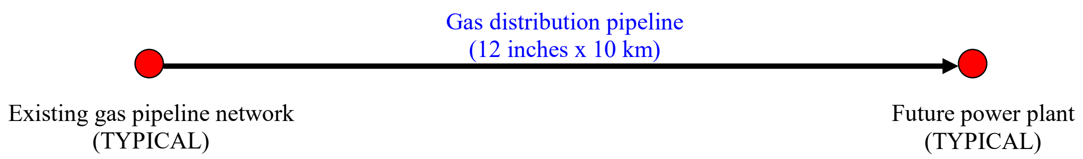


(4) Gas distribution pipelines for future power plants

For the costs estimation, the following conditions were uniformly applied for all the gas distribution pipelines to be newly laid for future power plants which will be constructed for the power supply increment.

- Pipe material: API5L Gr.X60 with 3LPE coating
- Nominal pipe size: 12 inches
- Wall thickness: 0.312 inches
- Pipeline length: 10 km (per each pipeline)
- Concrete coating: Not required
- Construction cost: 0.5 million USD/km

The overall view of the pipeline is as follows.



(5) Import Gas Development Cost

(a) LNG Receiving Terminal

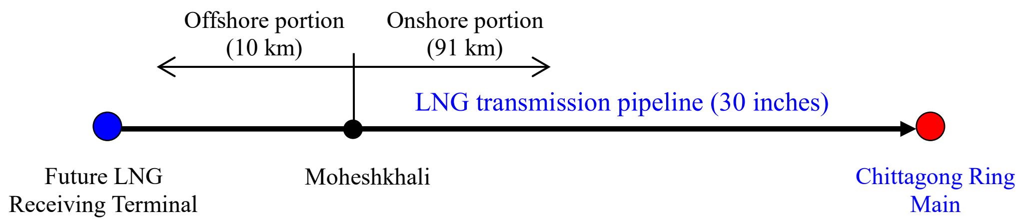
Cost for LNG Receiving terminal inclusive of Jetty and Loading facilities, 2 x 200,000 kl tanks and re-gasification facilities are estimated USD 500 million.

(b) LNG Transmission Pipeline

For the costs estimation, the following conditions were applied for the LNG transmission pipeline to be newly laid between the LNG receiving terminal to the Chittagong ring main.

- Pipe material: API5L Gr.X60 with 3LPE coating
- Nominal pipe size: 30 inches
- Wall thickness: 0.562 inches
- Pipeline length: 10/91 km (Offshore/Onshore)
- Concrete coating: Required for the offshore portion
- Construction cost: 1.5 million USD/km (Offshore)
  1.1 million USD//km (Onshore)

Overall view of the pipeline is shown as follows.



4. Results of Cost Estimate

Cost estimate for future gas exploration and production, and also cost for LNG introduction ware carried out based on various assumptions as mentioned in the previous sections.

(1) Exploration and Drilling Cost (Remaining reserves 2P)

Seismic survey and well drilling costs were roughly estimated based on the information available from the websites of Petrobangla and its subsidiaries and news media.

1) Seismic Survey Cost

(a) Seismic Data Acquisition

There are two different types of methods for the data acquisition in seismic surveys: two-dimensional (2D) seismic survey and three-dimensional (3D) seismic survey. A 2D seismic survey is conducted mainly in the exploration phase, and if promising amounts of oil and gas are confirmed by exploration drilling, a 3D seismic survey is conducted for confirming the size and structure of the field in the appraisal and development phases. In addition, a 3D seismic survey may be also conducted for better reservoir management in the field development phase.

The method for the cost estimation of a seismic survey depends on the type of survey: 2D or 3D survey. A total cost of seismic survey can be roughly estimated based on the seismic line length (line-km) for 2D seismic survey and survey area (km2) for 3D seismic survey, respectively. It should be noted that, for example, the specifications can be different depending on the environmental conditions of given area or location, and this makes it difficult to estimate the cost based on a given survey line length or survey area only.

(b) Cost Analysis of Seismic Survey

Regarding the seismic surveys conducted in recent 4 or 5 years in Bangladesh, the available data was organized in order to examine the relationships between the survey costs and the survey line length for a given 2D seismic survey and a survey area for a 3D seismic survey, respectively (Table 7). In addition, based on the collected data, rough estimates of the costs per line-km for 2D and per sq. km for 3D seismic surveys were also carried out, respectively (Table 7).

The data such as name of field/area, survey line length (2D seismic survey) and area (3D seismic survey), survey period and total survey cost is shown in Table 7.

In addition, as shown in the table, the surveys for which necessary data for cost analysis were available are three projects only, of which one project was 2D seismic survey and two projects were 3D seismic surveys. From the viewpoint of analysis of seismic survey cost, the data is considered to be insufficient for 2D seismic survey.

The results of the cost analysis of seismic surveys are summarized below, as also shown in Table 7:

- 2D seismic survey: US$5.1 thousand/line-km
- 3D seismic survey: US$12.0 to 18.5 thousand/km^2

Table 7 Analysis of Seismic Survey Costs

As of October 2015

Field/Area	Length	Area	Survey Period	Estimated Survey Cost		Cost Analysis		Remarks
						Cost per line-km	Cost per sq km	
	(line-km)	(sq km)		M BDT	M USD	K USD	K USD	
Dhaka, Manikganj, Shariatpur, Faridpur, Gopalganj, Madaripur, Khulna, Netrokona, Kishoreganj, Sunamganj, Habiganj, Sylhet, Maulavibazar and Bhola	1,800	—	Dec. 2012 (?) - (Underway)	711.3	9.15	5.1	—	
Titas	—	335	2010 - 2012 (Details unknown)	784.5 (for 2 fields)	10.09 (for 2 fields)	—	18.5	• Appraisal of Gas Field (3D Seismic) (Titas, Bakhrabad, Sylhet, Kailashtila and Rashidpur) Project (Revised)
Bakhrabad	—	210						
Rashidpur	—	325		859.5 (for 3 fields)	11.05 (for 3 fields)	—	15.7	
Kailashtila	—	190						
Sylhet	—	190						
Sunetra	—	260	May 2013 (?) - (Underway)	1,825.0 (for 6 fields/area, 1,950 sq km in total)	23.47 (for 6 fields/area, 1,950 sq km in total)	—	12.0	
Shahbazpur	—	600						
Sundalpur-Begumganj	—	440						
Srikail	—	150						
Narshingdi	—	250?						
Habiganj	—	250?						

Note: The BDT to USD exchange rate on January 1, 2015 (1 BDT = US$ 0.01286) is used.

Source: Prepared based on Petrobangla Annual Report 2012 and BAPEX Annual Reports 2013 and 2014

2) Well Drilling Cost

(a) Well Type

Two types of wells, exploration (or exploratory) and appraisal wells, are drilled in the exploration phase. An exploration or exploratory well is usually drilled in an area where any oil or gas has not been discovered yet. However, if a well is targeted for new oil or gas pool, for example, in a deeper horizon in the existing oil or gas field, the well is also called as exploration well. If promising oil and/or gas are discovered by exploration drilling, then an appraisal well will be drilled for confirming the size of the discovered oil and/or gas reservoir(s) in the next phase. Most of the wells to be drilled in the development phase are defined as development well.

(b) Factors Affecting Well Drilling Cost

The cost of a well depends mainly on the daily rate of the drilling rig and a well operation period in days, and a well drilling cost is basically determined by multiplying the rig day rate by duration of drilling operations in days. In the viewpoint of the estimation of a well drilling cost, the difference in

types of wells shown above are not significant.
There are various factors affecting the duration of the well operations, and in general, for example, the factors are as follows:

However, the information on the factors except for well depth is not available or insufficient, those factors are not examined in this survey.

- Drilling depth
- Subsurface geological conditions
- Subsurface pressure and temperature conditions
- Well type (vertical, directional, horizontal)
- Duration of well test

However, the information on the factors except for well depth is not available or insufficient, those factors are not examined in this survey.

3) Well Drilling Cost Analysis

Based on the description in the above section, the cost analysis was performed on the wells which show the data of relatively high reliability listed below.

- Estimated cost per well
- Well depth (total depth)
- Well type (vertical or directional)
- Duration of drilling operations

Regarding the wells whose cost analysis was conducted, the data such as well name, well type, well drilling cost, well depth (drilling depth) and duration of drilling operations are shown in Table 8. The number of the wells whose cost analyses have been done to date is only 10. These wells consist of nine vertical wells (including wells whose types have not been confirmed yet) and one directional well. The relationship between well drilling cost and well depth for these wells are shown in Figure 7 in which the well types are classified. Proposed well depths should be used as well depths in this type of plot because the estimated well drilling costs are only available. However, regarding the wells where the actual well depths are not available, the actual well depths were used instead of the proposed well depths in the plot.

In general, it is empirically known that a well drilling cost can be described as an exponential function of depth. Therefore, if a well depth is given, the corresponding well drilling cost can be roughly estimated. However, unfortunately such a relationship is not apparent in Figure 7. This is due to the following reasons:

- A small amount of data set
- Relatively narrow range of well depths (about 2,900 to 3,700 m)

In addition, it should be noted that the estimated well drilling cost varies largely depending on different drilling contractors in Bangladesh. Recently, Gazprom, a Russian company, was involved in the drilling of the wells in Bangladesh. The costs of the wells drilled by Gazprom are at least twice as high as compared with those of the wells drilled by BAPEX. For example, as shown in Table 8, Well Rashidpur-8, where the drilling operations were undertaken by Gazprom, was drilled to a proposed total depth of 2,902 m at an estimated cost of US$ 22.0 million. On the other hand, Well Fenchuganj-5, where drilling operations were undertaken by BAPEX, was drilled to a proposed total depth of 3,100 m at an estimated cost of US$ 9.8 million.

4) Estimates of Well Drilling Cost for Model Wells

Based on the results shown in the section (3), the estimated well drilling costs are tentatively proposed for two model cases having the well depths of 3,000 m and 4,500 m, respectively. The model well with a total depth of 3,000 m can be used as one of the model wells for estimating a well drilling cost in Bangladesh, taking into account the range of the well depths. The other model well with a total depth of 4,500 m is proposed based on the fact that the exploration well Mubarakpur-1 currently being drilled has a proposed total depth of 4,500 (+) m, indicating that the well is to be drilled at least to a total depth of 4,500 m, and the proposed total depth of the exploration well Sunetra-1 was also 4,500 m (actual total depth of 4,683 m).

- Model well with a total depth of 3,000 m:
  The cost of the model well having a total depth of 3,000 m is about US$ 9.5 million by calculation using the estimated cost of Well Fenchuganj-5 shown in Table 8.
- Model well with a total depth of 4,500 m:
  The cost of the model well having a total depth of 4,500 m is about US$ 10.9 million by averaging the estimated costs of both wells Mubarakpur-1 and Sunetra-1 shown in Table 8,

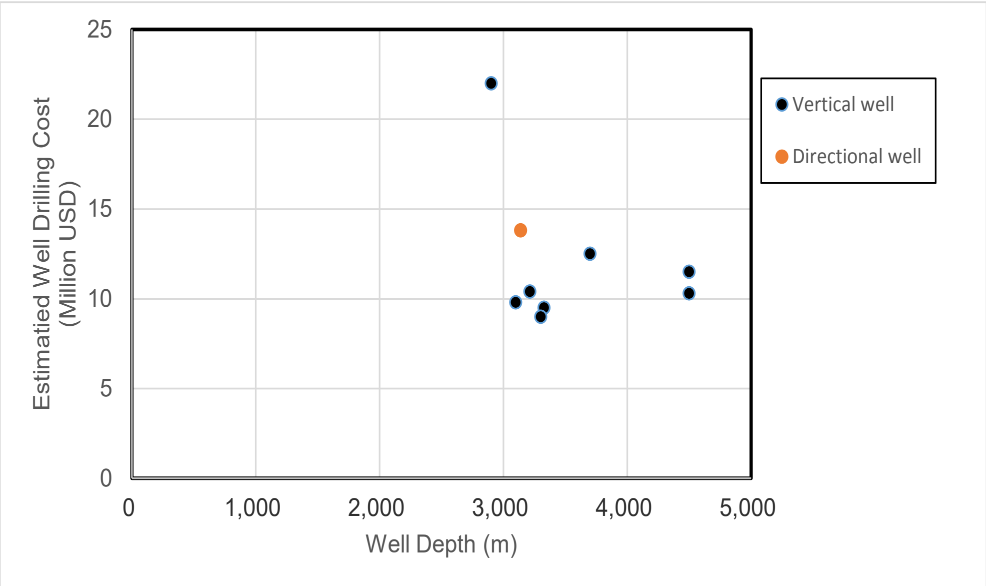
In this study, 4 development wells are assumed and converted to production wells at the later stage.Recent case shows that total cost of drilling of 4 wells in Bangladesh is assumed USD 60 million.

Table 8 Analysis of Well Drilling Costs

As of October 2015

Well Name	Expl./ Appr./ Dev.	Well Type	Well Depth (m)		Operation Period	Estimated Well Drilling Cost		Remarks
			Proposed	Actual		M BDT	M USD	
Titas-27	Dev.	Directional	(N/A)	3,138	Nov. 19, 2013 - Apr. 11, 2014	1,070.0	13.8	
Mubarakpur-1	Expl.	Vertical?	4,500 (+)	(Underway)	Aug. 22, 2014 - (Underway)	892.6	11.5	• Mubarakpur Oil/Gas Exploration Well Drilling Project
Sundalpur-1	Expl.	Vertical?	(N/A)	3,327	Dec. 21, 2010 - Mar. 11, 2011	736.5	9.5	• Discovery well
Kapasia-1	Expl.	Vertical?	(N/A)	3,301	Feb. 6, 2012 - Apr. 13, 2012	701.7	9.0	• Kapasia Oil/Gas Exploration Well Drilling (Revised) • Dry
Srikail-2	Appr.	Vertical?	(N/A)	3,214	May 5, 2012 - June 29, 2012	811.2	10.4	• Srikail Oil/Gas Exploration Well Drilling Project (Well #2) • Discovery well
Fenchuganj-5	Dev.	Vertical	3,100	3,137	Sept. 27, 2013 - (?)	760	9.8	• A part of Salda # 3, 4 & Fenchuganj # 4, 5 Gas Fields Development Project • Dry
Sunetra-1	Expl.	Vetical	4,500	4,683	Aug. 10, 2012 - Mar. 18, 2013	802.5	10.3	• Sunetra Oil/Gas Exploration Well Drilling Project • Dry
Rashidpur-8	Dev.	Vertical	2,902	2,990	(?) - Aug. 27, 2014	1,705.0	21.9	• Drilliing was undertaken by Gazprom.
Rupganj-1	Expl.	Vertical	3,700	3,615	May 19, 2013 - (?)	970.0	12.5	• Discovery well
Sundalpur-2	Dev.	Vertical?	3,250	—	—	754.5	9.7	• Well has not been drilled yet.

Note: The BDT to USD exchange rate on January 1, 2015 (1 BDT = 0.01286 USD) is used.



Source: Prepared based on Petrobangla Annual Reports 2012 and 2013, etc.

Figure 7 Estimated Well Drilling Cost vs. Well Depth Plot

(2) Facility Construction Costs

The facility construction costs necessary for supplying incremental gas in the future was estimated below in items 1) to 3).

(a) Gas Production Facilities

Gas production facilities for already-discovered domestic natural gas described earlier, there are no new gas fields which will move to the development stage in Bangladesh. Also, although several gas field enhancement plans have been scheduled at the existing gas fields, most of them do not require the construction of new gas production facilities because the increased gas should be able to be treated in the existing facilities. In relation to the Titas gas field requiring an additional gas production facility, the production of gas of 80 MMscfd is anticipated to be increased in the near future.

However, at present these plans have been scheduled only up until 2017; there is still no specific gas development plan for after 2018. Accordingly, it is difficult to frame a financial plan for the gas field development based on such a short term plan. Nevertheless, in December 2012 the World Bank published a long term production forecast for each gas field up until 2030 in its report entitled "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development". Thus, a financial plan can be made based on this long term plan.

In this study, as a yearly financial plan is required to properly conduct economic and financial analyses, the construction costs of gas production facility for future gas development were estimated based on the said long term production forecasts.

The future field wise gas production forecast is indicated in Table 9.

Table 9 Field Wise Gas Field Enhancement Plan

Field wise predicted production

Titas

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		450	450	480	600	600	600	600	600	600	500	500	450	400	300	250	250	250	200	200
Yearly Production, tcf		0.1643	0.1643	0.1752	0.219	0.219	0.219	0.219	0.219	0.219	0.1825	0.1825	0.1643	0.146	0.1095	0.0913	0.091	0.091	0.073	0.073
Remaining Reserve, tcf	3.073	2.9088	2.7445	2.5693	2.3503	2.1313	1.9123	1.6933	1.4743	1.2553	1.0728	0.8903	0.7261	0.5801	0.4706	0.3793	0.288	0.197	0.1238	0.051

Habiganj

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		250	250	250	250	200	200	100	100	50	50	50	50	50	50	50	50	50	50	20
Yearly Production, tcf		0.0913	0.0913	0.09125	0.0913	0.073	0.073	0.0365	0.0365	0.01825	0.0183	0.0183	0.0183	0.0183	0.0183	0.0183	0.018	0.018	0.0183	0.007
Remaining Reserve, tcf	0.8363	0.7451	0.6538	0.56255	0.4713	0.3983	0.3253	0.2888	0.2523	0.23405	0.2158	0.1976	0.1793	0.1611	0.1428	0.1246	0.106	0.088	0.0698	0.063

Bakhrabad

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		30	30	30	50	50	80	80	80	80	80	80	80	70	70	50	50	50	50	20
Yearly Production, tcf		0.011	0.011	0.01095	0.0183	0.01825	0.0292	0.0292	0.0292	0.0292	0.0292	0.0292	0.0292	0.0256	0.0256	0.0183	0.018	0.018	0.0183	0.007
Remaining Reserve, tcf	0.514	0.5031	0.4921	0.48115	0.4629	0.44465	0.4155	0.38625	0.3571	0.32785	0.2987	0.2695	0.2403	0.2147	0.1892	0.1709	0.153	0.134	0.1162	0.109

Meghna

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		10	10	10	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0037	0.0037	0.00365	0.0037	0.00365	0.0037	0.00365	0	0	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.0312	0.0276	0.0239	0.02025	0.0166	0.01295	0.0093	0.00565	0.0057	0.00565	0.0057	0.0057	0.0057	0.0057	0.0057	0.0057	0.006	0.006	0.0057	0.006

Narsingdi

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		30	30	30	30	30	30	30	30	20	20	20	20	20	20	15	15	10	0	0
Yearly Production, tcf		0.011	0.011	0.01095	0.011	0.01095	0.011	0.01095	0.011	0.0073	0.0073	0.0073	0.0073	0.0073	0.0073	0.0055	0.005	0.004	0	0
Remaining Reserve, tcf	0.1547	0.1438	0.1328	0.12185	0.1109	0.09995	0.089	0.07805	0.0671	0.0598	0.0525	0.0452	0.0379	0.0306	0.0233	0.0178	0.012	0.009	0.0087	0.009

Sylhet

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		10	10	10	25	25	25	25	25	25	25	20	20	20	20	15	10	10	0	0
Yearly Production, tcf		0.0037	0.0037	0.00365	0.0091	0.009125	0.0091	0.00913	0.0091	0.00913	0.0091	0.0073	0.0073	0.0073	0.0073	0.0055	0.004	0.004	0	0
Remaining Reserve, tcf	0.1255	0.1219	0.1182	0.11455	0.1054	0.0963	0.0872	0.07805	0.0689	0.0598	0.0507	0.0434	0.0361	0.0288	0.0215	0.016	0.012	0.009	0.0087	0.009

Beanibazar

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		14	14	14	14	14	14	14	14	14	14	14	14	10	10	10	0	0	0	0
Yearly Production, tcf		0.0051	0.0051	0.00511	0.0051	0.00511	0.0051	0.00511	0.0051	0.00511	0.0051	0.0051	0.0051	0.0037	0.0037	0.0037	0	0	0	0
Remaining Reserve, tcf	0.136	0.1309	0.1258	0.12067	0.1156	0.11045	0.1053	0.10023	0.0951	0.09001	0.0849	0.0798	0.0747	0.071	0.0674	0.0637	0.064	0.064	0.0637	0.064

Rashidpur

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		50	70	70	100	150	200	200	250	250	250	250	250	250	250	250	200	200	200	200
Yearly Production, tcf		0.0183	0.0256	0.02555	0.0365	0.05475	0.073	0.073	0.0913	0.09125	0.0913	0.0913	0.0913	0.0913	0.0913	0.0913	0.073	0.073	0.073	0.073
Remaining Reserve, tcf	1.949	1.9308	1.9052	1.87965	1.8432	1.7884	1.7154	1.6424	1.5512	1.4599	1.3687	1.2774	1.1862	1.0949	1.00	0.9124	0.839	0.766	0.6934	0.62

Kailashtilla

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		100	100	100	150	150	200	200	250	250	250	250	250	250	250	250	200	200	200	200
Yearly Production, tcf		0.0365	0.0365	0.0365	0.0548	0.05475	0.073	0.073	0.0913	0.09125	0.0913	0.0913	0.0913	0.0913	0.0913	0.0913	0.073	0.073	0.073	0.073
Remaining Reserve, tcf	2.2229	2.1864	2.1499	2.1134	2.0587	2.0039	1.9309	1.8579	1.7667	1.6754	1.5842	1.4929	1.4017	1.3104	1.22	1.1279	1.055	0.982	0.9089	0.836

Field wise predicted production

Saldanadi

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		20	25	20	18	15	14	10	9	7	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0073	0.0091	0.0073	0.0066	0.005475	0.0051	0.00365	0.0033	0.00256	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.2149	0.2076	0.1985	0.19118	0.1846	0.17913	0.174	0.17037	0.1671	0.16453	0.1645	0.1645	0.1645	0.1645	0.16	0.1645	0.165	0.165	0.1645	0.165

Fenchuganj

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		35	50	60	60	55	50	45	40	40	35	35	25	20	0	0	0	0	0	0
Yearly Production, tcf		0.0128	0.0183	0.0219	0.0219	0.020075	0.0183	0.01643	0.0146	0.0146	0.0128	0.0128	0.0091	0.0073	0	0	0	0	0	0
Remaining Reserve, tcf	0.30	0.2902	0.272	0.25008	0.2282	0.2081	0.1899	0.17343	0.1588	0.14423	0.1315	0.1187	0.1096	0.1023	0.10	0.1023	0.102	0.102	0.1023	0.102

Shahbazpur

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		8	50	50	60	60	60	70	70	70	60	55	50	40	30	0	0	0	0	0
Yearly Production, tcf		0.0029	0.0183	0.01825	0.0219	0.0219	0.0219	0.02555	0.0256	0.02555	0.0219	0.0201	0.0183	0.0146	0.011	0	0	0	0	0
Remaining Reserve, tcf	0.27	0.2671	0.2488	0.23058	0.2087	0.18678	0.1649	0.13933	0.1138	0.08823	0.0663	0.0463	0.028	0.0134	0.002	0.002	0.002	0.002	0.0025	0.002

Semutang

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		12	10	20	25	25	25	30	30	30	25	25	20	15	15	12	12	10	10	10
Yearly Production, tcf		0.0044	0.0037	0.0073	0.0091	0.009125	0.0091	0.01095	0.011	0.01095	0.0091	0.0091	0.0073	0.0055	0.0055	0.0044	0.004	0.004	0.0037	0.004
Remaining Reserve, tcf	0.3173	0.3129	0.3093	0.30197	0.2928	0.28372	0.2746	0.26365	0.2527	0.24175	0.2326	0.2235	0.2162	0.2107	0.205	0.201	0.196	0.193	0.1892	0.186

Jalalabad

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		180	180	230	230	200	200	100	0	0	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0657	0.0657	0.08395	0.084	0.073	0.073	0.0365	0	0	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.565	0.4993	0.4336	0.34965	0.2657	0.1927	0.1197	0.0832	0.0832	0.0832	0.0832	0.0832	0.0832	0.0832	0.083	0.083	0.083	0.083	0.0832	0.083

Maulavibazar

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	0	0	0
Yearly Production, tcf		0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.015	0	0	0
Remaining Reserve, tcf	0.249	0.2344	0.2198	0.2052	0.1906	0.176	0.1614	0.1468	0.1322	0.1176	0.103	0.0884	0.0738	0.0592	0.045	0.030	0.015	0.015	0.0154	0.015

Bibiana

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		760	760	1000	1000	1000	1200	1200	1200	1200	1200	800	600	400	200	150	100	100	100	50
Yearly Production, tcf		0.2774	0.2774	0.365	0.365	0.365	0.438	0.438	0.438	0.438	0.438	0.292	0.219	0.146	0.073	0.0548	0.037	0.037	0.0365	0.018
Remaining Reserve, tcf	4.8998	4.6224	4.345	3.98	3.615	3.25	2.812	2.374	1.936	1.498	1.06	0.768	0.549	0.403	0.330	0.275	0.239	0.202	0.1657	0.147

Sangu

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		9	8	8	8	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0
Yearly Production, tcf		0.0033	0.0029	0.00292	0.0029	0.00292	0.0029	0.00292	0.0029	0	0	0	0	0	0	0	0	0	0	0
Remaining Reserve, tcf	0.1	0.0967	0.0938	0.09088	0.088	0.085035	0.0821	0.0792	0.0763	0.07628	0.0763	0.0763	0.0763	0.0763	0.076	0.076	0.076	0.076	0.0763	0.076

Bangura

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Daily Production, mmcfd		103	100	100	100	100	100	100	70	50	40	30	20	10	10	0	0	0	0	0
Yearly Production, tcf		0.0376	0.0365	0.0365	0.0365	0.0365	0.0365	0.0365	0.0256	0.01825	0.0146	0.011	0.0073	0.0037	0.0037	0	0	0	0	0
Remaining Reserve, tcf	0.364	0.3264	0.2899	0.25341	0.2169	0.180405	0.1439	0.10741	0.0819	0.06361	0.049	0.0381	0.0308	0.0271	0.023	0.023	0.023	0.023	0.0235	0.023

Source: Annexure 3, FINAL REPORT "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development」 (prepared in December 2012)

In Table 10, the production enhancement plan for the existing gas fields is comparatively recent information that was reported in December 2012; the contents of the plan were approved by Petrobangla with certain corrections. Hence the investment costs were estimated on the assumption that the existing gas production facilities would be expanded in accordance with the plan.

In Annexure 3 of the said World Bank report, the field wise daily production rate and timing of the field expansion has been predicted up until 2030. Thus "the peak production rate (a)" and the peak production year may be for each gas field. Data for the field wise "current plant capacity (b)" is available in the Petrobangla Annual Report 2012. (Please refer to Appendix 3 for this.)

The value of (a) and (b) are listed in Table 10.

Table 10 Predicted Peak Production Rate versus Current Plant Capacity

Serial No.	Gas Field	Operating Company	Predicted Peak Production Rate (a) [MMscfd]	Current Plant Capacity (b) [MMscfd]	Additional Capacity Required (a – b) [MMscfd]	Peak Production Year [MMscfd] (See Note *2)
1	Titas	BGFCL	600	452	148	2015
2	Habiganj	Ditto	250	240	0 (See Note *1)	2012
3	Bakhrabad	Ditto	80	33	47	2017
4	Kailashtila	Ditto	250	80	170	2019
5	Rashidpur	Ditto	250	49	201	2019
6	Sylhet	SGFL	25	11	14	2015
7	Meghna	Ditto	10	11	0 (See Note *1)	2012
8	Narshingdi	Ditto	30	30	0	2012
9	Beanibazar	Ditto	14	14	0	2012
10	Fenchuganj	Ditto	60	40	20	2014
11	Saldanadi	BAPEX	25	20	0 (See Note *1)	2013
12	Shahbazpur	Ditto	70	30	40	2018
13	Semutang	Ditto	30	12	18	2018
14	Sangu	SANTOS	9	9	0	2012
15	Jalalabad	CHEVRON	230	230	0	2014
16	Moulavibazar	Ditto	40	60	0	2012
17	Bibiyana	Ditto	1200	770	430	2017
18	Bangura	TULLOW	103	100	0 (See Note *1)	2012

Source: information based on Petrobangla Annual Report 2012 and FINAL REPORT "Consulting Services for Preparation of Implementation and Financing Plan for Gas Sector Development" reported in December 2012

Note:

*1: Since the predicted peak production rate (a) is almost same as the current plant capacity (b), further investment for the gas field is not be considered.

*2: The peak production year in each gas field is scheduled as in 2012.

As shown in Table 10, if gas at “predicted peak production rate (a)” is produced in future in excess of the “current plant capacity (b)”, the construction of new facility will be required to treat the excess volume of gas. Since the new facility must be able to treat the “additional capacity required (a minus b)” in the above table, this costs estimation is carried out based on the additional capacity required for the respective nine gas fields – Titas, Bakhrabad, Sylhet, Kailashtila, Rashidpur, Fenchuganj, Shahbazpur, Semutang, and Bibiyana). As for other gas fields, since the “predicted peak production rate (a)” is smaller than the “current plant capacity (b)” or almost same as (b), further investment for the gas field is not be considered.

For the Titas gas field, a new production facility having a capacity of 80 MMscfd will be constructed in the near future as mentioned in Paragraph 2.1.2 (1). It can be considered that the 148 MMscfd of “additional capacity required (a minus b)” in Table 10 includes the planned capacity of 80 MMscfd because the “predicted peak production rate (a)” of 600 MMscfd was forecasted before 2012. Accordingly, his means that the gas development plan for producing a part of the 148 MMscfd has now moved to its implementation stage as a construction project. Therefore, the construction costs of the new facility in the Titas gas field were estimated at 148 MMscfd.

Construction cost of the future gas production facilities which will be installed in each gas field is estimated as described below.

In Table 11, there is great variation in the “additional capacity required (a minus b)” between minimum 14 MMscfd and maximum 430 MMscfd. Typically, in plant construction the “six-tenths factor rule”, as a simplified calculation method, is often utilized for estimating approximate construction costs. In term of the rule, there is an empirical relationship between the cost and the size of a manufacturing facility; as the size increases, cost the increases by an exponent of six-tenths, that is cost1/cost2 = (size1/size2) 0.6.

However, in this study, a typical gas production facility with specific plant capacity of 20, 40, 150, 200 and 400 MMscfd was estimated using OGM and in-house cost data Also, the construction costs of the future gas production facilities stated above were estimated based on the costs estimation results for a typical gas production facility.

At first, construction cost of the plant capacity; 20, 40, 150, 200 and 400 MMscfd, was estimated using OGM. In the case of applying the input data in Table 21 (as attached on the last page of this chapter) the construction costs were estimated as listed in Table 11.

Table 11 OGM Output for Construction Costs of Gas Production Facility (20, 40, 150, 200 and 400 MMscfd)

Cost Item	Plant Capacity (MMscfd)				
	20	40	150	200	400
Procurement & Fabrication, Installation	**14,003.2**	**15,769.4**	**24,244.8**	**27,872.2**	**45,424.6**
Separation System	1,221.3	1,639.0	4,349.5	6,181.9	12,935.2
Production Manifold	464.3	738.3	1,505.1	2,268.7	5,143.8
Separation	757.0	900.7	2,844.4	3,913.2	7,791.4
Gas Dehydration System	1,655.1	2,506.3	5,989.6	6,982.3	13,717.5
GasDehydration1	1,655.1	2,506.3	5,989.6	6,982.3	13,717.5
Condensate Recovery & Storage System	3,256.3	3,488.5	4,504.9	4,881.8	6,300.2
Crude Metering & Export	137.6	132.2	123.3	123.3	121.5
Tankage	3,118.7	3,356.3	4,381.6	4,758.5	6,178.7
Water Treatment System	550.1	581.6	784.0	857.0	1,158.4
Produced Water	151.1	155.0	190.5	195.3	286.7
Drain Effluent Water	399.0	426.6	593.5	661.7	871.7
Utility & Support Systems, Others	7,320.4	7,554.0	8,616.8	8,969.2	11,313.3
GasCompression1	356.2	376.4	387.0	391.7	410.2
Relief	217.3	261.3	577.8	649.2	709.3
Flare	160.0	175.9	263.1	302.8	461.4
Power Generation	1,100.8	1,100.8	1,100.8	1,100.8	1,100.8
Power Distribution	1,273.3	1,330.2	1,283.7	1,303.4	1,383.4
Heating Medium	0.0	0.0	196.3	205.0	309.4
Instrument Air	295.8	298.3	312.2	330.6	363.8
Utility Air	70.4	73.3	89.2	95.0	109.6
Fuel Gas	97.8	99.8	128.0	131.8	141.5
Diesel Fuel	213.9	217.0	233.3	239.2	254.2
Fire Protection	729.9	741.7	841.0	884.8	982.5
Control Center	1,472.5	1,472.5	1,472.5	1,472.5	2,667.8
Buildings	576.6	583.6	583.0	584.3	602.3
Site Preparation	100.0	107.7	154.7	173.5	227.4
Site Mgt	655.9	715.5	994.2	1,104.6	1,589.7
Infrastructure & Other Cost	**2,735.5**	**2,762.0**	**4,389.2**	**4,443.6**	**7,206.8**
Infrastructure	2,500.0	2,500.0	4,000.0	4,000.0	6,500.0
Construction Camp	1,000.0	1,000.0	2,000.0	2,000.0	4,000.0
Operations Camp	1,500.0	1,500.0	2,000.0	2,000.0	2,500.0
Other Cost	235.5	262.0	389.2	443.6	706.8
Certification	70.0	78.8	121.2	139.4	227.1
Insurance	140.0	157.7	242.5	278.7	454.2
Land	25.5	25.5	25.5	25.5	25.5
Engineering & Project Management	**4,901.1**	**5,519.2**	**8,485.7**	**9,755.3**	**15,898.6**
Engineering	2,100.5	2,365.4	3,636.7	4,180.8	6,813.7
Project Management	2,800.6	3,153.8	4,849.0	5,574.5	9,084.9
CAPEX	**21,639.8**	**24,050.6**	**37,119.7**	**42,071.1**	**68,530.0**

Source: JICA Survey Team

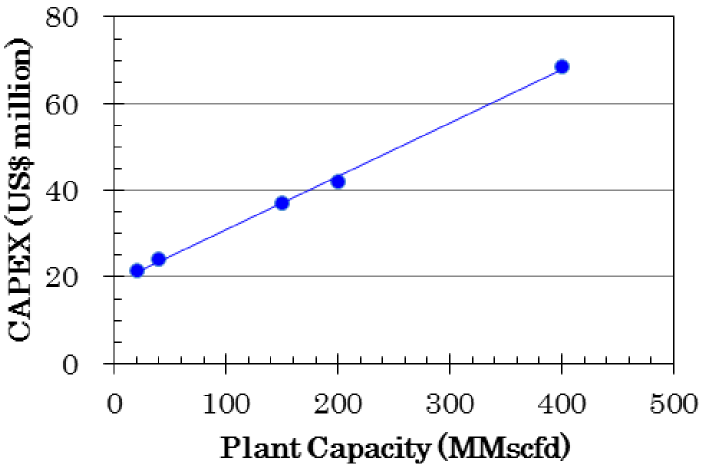
The OGM output in Table 11 may also be arranged by the principal cost items as listed in Table 12.

Table 12 Construction Costs of Gas Production Facility (20, 40, 150, 200 and 400 MMscfd)

Plant Capacity (MMscfd)	Total Construction Cost (million USD)	Cost Breakdown (mill. USD)			
		Direct Cost		Indirect Cost	
		Procurement and installation	Other field construction including infrastructures	Engineering	Project management
20	21.6	14.0	2.7	2.1	2.8
40	24.1	15.8	2.8	2.4	3.1
150	37.1	24.2	4.4	3.6	4.9
200	42.1	27.9	4.4	4.2	5.6
400	68.5	45.4	7.2	6.8	9.1

Source: JICA Survey Team

According to Table 12, the OGM costs estimation results for the typical gas production facilities can be plotted as shown in Figure 8.



Source: JICA Survey Team

Figure 8 Construction Cost of Gas Production Facility (20, 40, 150, 200 and 400 MMscfd)

As shown in Figure 8, it can be said that as the plant capacity increases CAPEX is also likely to increase by a certain percentage. As stated above, construction costs of the future gas production facilities can be predicted. The cost of the nine gas production facilities with the “additional capacity required (a minus b)” in Table 13 may be estimated.

Table 13 Construction Costs of the Gas Production Facility for Already-Discovered Domestic Natural Gas (Predicted Cost based on OGM output)

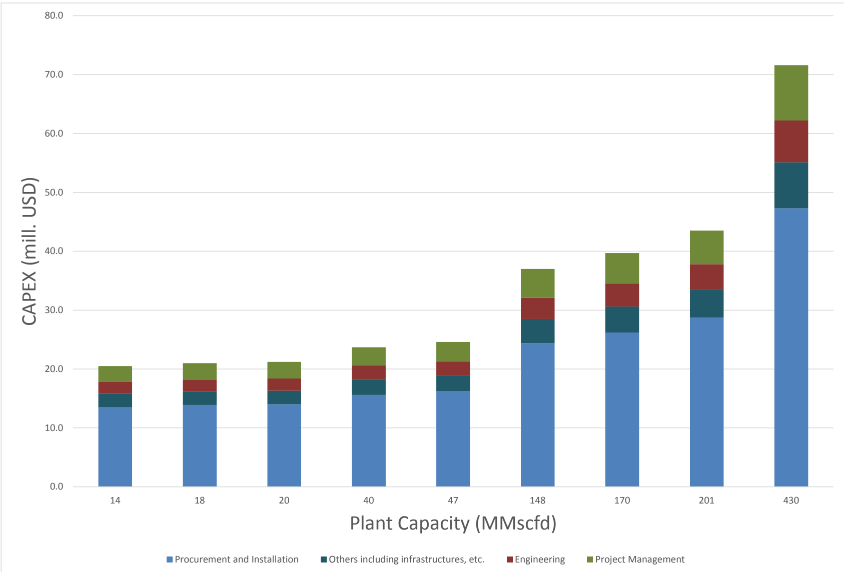
Field Name	Sylhet	Semutung	Fenchuganj	Shahbazpur	Bakhrabad	Titas	Kailashtila	Rashidpur	Bibiyana
Gas Production Rate (MMscfd)	**14**	**18**	**20**	**40**	**47**	**148**	**170**	**201**	**430**
Procurement & Fabrication, Installation	**13,533.4**	**13,857.6**	**14,019.7**	**15,640.7**	**16,208.0**	**24,393.9**	**26,176.9**	**28,689.4**	**47,249.4**
Separation System	1,180.3	1,208.6	1,222.7	1,625.6	1,684.5	4,376.2	4,696.1	6,363.2	13,454.9
Production Manifold	448.7	459.4	464.8	732.2	758.8	1,514.4	1,625.1	2,335.2	5,350.5
Separation	731.6	749.2	757.9	893.4	925.8	2,861.9	3,071.1	4,028.0	8,104.4
Gas Dehydration System	1,599.6	1,637.9	1,657.1	2,485.8	2,576.0	6,026.4	6,466.9	7,187.0	14,268.6
GasDehydration1	1,599.6	1,637.9	1,657.1	2,485.8	2,576.0	6,026.4	6,466.9	7,187.0	14,268.6
Condensate Recovery & Storage System	3,147.0	3,222.4	3,260.1	3,460.0	3,585.5	4,532.6	4,863.9	5,024.9	6,553.3
Crude Metering & Export	132.9	136.1	137.7	131.1	135.9	124.0	133.1	126.9	126.4
Tankage	3,014.1	3,086.3	3,122.4	3,328.9	3,449.6	4,408.6	4,730.8	4,898.0	6,426.9
Water Treatment System	531.6	544.4	550.7	576.8	597.8	788.8	846.5	882.1	1,205.0
Produced Water	146.0	149.5	151.3	153.7	159.3	191.6	205.6	201.0	298.3
Drain Effluent Water	385.6	394.8	399.4	423.1	438.4	597.2	640.9	681.1	906.7
Utility & Support Systems, Others	7,074.9	7,244.3	7,329.1	7,492.4	7,764.2	8,669.8	9,303.5	9,232.2	11,767.7
GasCompression1	344.3	352.5	356.7	373.3	386.9	389.3	417.8	403.2	426.7
Relief	210.0	215.1	217.6	259.2	268.6	581.3	623.8	668.2	737.8
Flare	154.6	158.3	160.2	174.4	180.8	264.7	284.1	311.6	479.9
Power Generation	1,063.9	1,089.4	1,102.1	1,091.8	1,131.4	1,107.6	1,188.5	1,133.1	1,145.0
Power Distribution	1,230.6	1,260.1	1,274.8	1,319.4	1,367.3	1,291.7	1,386.1	1,341.7	1,439.0
Heating Medium	0.0	0.0	0.0	0.0	0.0	197.5	211.9	211.0	321.8
Instrument Air	285.8	292.7	296.1	295.9	306.6	314.1	337.0	340.3	378.4
Utility Air	68.0	69.6	70.4	72.7	75.4	89.8	96.3	97.7	114.0
Fuel Gas	94.5	96.7	97.9	98.9	102.5	128.7	138.1	135.6	147.2
Diesel Fuel	206.8	211.7	214.2	215.2	223.0	234.7	251.9	246.2	264.4
Fire Protection	705.4	722.3	730.7	735.7	762.3	846.2	908.0	910.7	1,021.9
Control Center	1,423.2	1,457.3	1,474.4	1,460.6	1,513.6	1,481.7	1,590.0	1,515.8	2,775.1
Buildings	557.2	570.6	577.3	578.8	599.8	586.6	629.5	601.4	626.4
Site Preparation	96.6	99.0	100.1	106.8	110.7	155.7	167.0	178.6	236.5
Site Mgt	633.9	649.1	656.7	709.7	735.4	1,000.3	1,073.4	1,137.1	1,653.6
Infrastructure & Other Cost	**2,255.6**	**2,309.6**	**2,336.6**	**2,606.8**	**2,701.3**	**4,065.6**	**4,362.8**	**4,781.6**	**7,874.9**
Infrastructure	2,061.4	2,110.7	2,135.4	2,359.5	2,445.1	3,705.2	3,976.0	4,304.2	7,102.5
Construction Camp	824.5	844.3	854.2	943.8	978.0	1,852.6	1,988.0	2,152.1	4,370.8
Operations Camp	1,236.8	1,266.4	1,281.3	1,415.7	1,467.0	1,852.6	1,988.0	2,152.1	2,731.7
Other Cost	194.2	198.9	201.2	247.3	256.3	360.5	386.8	477.3	772.4
Certification	57.7	59.1	59.8	74.4	77.1	112.3	120.5	150.0	248.2
Insurance	115.5	118.2	119.6	148.8	154.2	224.6	241.0	299.9	496.4
Land	21.0	21.5	21.8	24.1	24.9	23.6	25.3	27.4	27.9
Engineering & Project Management	**4,716.2**	**4,829.2**	**4,885.7**	**5,450.5**	**5,648.2**	**8,500.9**	**9,122.3**	**9,997.8**	**16,465.7**
Engineering	2,021.2	2,069.6	2,093.9	2,335.9	2,420.7	3,643.2	3,909.5	4,284.8	7,056.7
Project Management	2,695.0	2,759.5	2,791.8	3,114.6	3,227.6	4,857.7	5,212.7	5,713.0	9,409.0
CAPEX	**20,505.2**	**20,996.4**	**21,242.0**	**23,698.0**	**24,557.6**	**36,960.4**	**39,662.0**	**43,468.8**	**71,590.0**

Then, the predicted costs in Table 13 can be arranged by the principal cost items as shown in Table 14.

Table 14 Construction Costs of the Gas Production Facility for Already-Discovered Domestic Natural Gas

Serial No.	Gas Field	Additional Capacity Required (MMscfd)	Total Construction Cost (mill. USD)	Cost Breakdown (mill. USD)			
				Direct Cost		Indirect Cost	
				Procurement and installation	Other field construction including infrastructures	Engineering	Project management
1	Titas	148	37.0	24.4	4.1	3.6	4.9
3	Bakhrabad	47	24.6	16.2	2.7	2.4	3.3
4	Kailashtila	170	39.7	26.2	4.4	3.9	5.2
5	Rashidpur	201	43.5	28.7	4.8	4.3	5.7
6	Sylhet	14	20.5	13.5	2.3	2.0	2.7
10	Fenchuganj	20	21.2	14.0	2.3	2.1	2.8
12	Shahbazpur	40	23.7	15.6	2.6	2.4	3.1
13	Semutang	18	21.0	13.9	2.3	2.0	2.8
17	Bibiyana	430	71.6	47.3	7.8	7.1	9.4
Total		1088	302.8	199.8	33.3	29.8	39.9

Source: JICA Survey Team



Source: JICA Survey Team

Figure 9 Construction Costs Breakdown of the Gas Production Facility for Already-Discovered Domestic Natural Gas

As shown in Figure 9, the construction cost of gas production facility varies according to the plant capacity. Even if the plant capacity is small, facility configuration required for the proposed gas treatment is same, and only the scale of the facility is reduced in connection with gas treatment volume. Therefore, approximately minimum 20 million USD is necessary even for Sylhet gas field case, which has the smallest facility scale (14 MMscfd) of the nine gas fields. The plant capacity of 14 MMscfd is classified in the minimum plant scale in regular gas development projects, and it is considered that the approximately 20 million USD is “base cost” of gas production facilities that are planned to be constructed in each gas field. Accordingly, the facility construction cost in each gas field may be estimated by adding this “base cost” and facility costs escalated by the increase of plant capacity.

The construction cost estimated in Table 14 includes not only the five main systems stated earlier, but also the related facilities such as: power generation and distribution systems, fuel gas systems, tankage systems, drain/effluent water systems, relief/flare systems, fire protection systems, instrument air systems, and buildings.

For the above costs estimation, the validity of the finally estimated costs for the future gas production facilities in Table 14 was checked below in comparison with past construction data. As stated above, since all the costs in these nine gas fields were predicted based on CAPEX increasing (indicated in Figure 8, the validity was checked in relation to the original costs shown in in Figure 8.

According to the past construction data, the total construction costs of gas production facilities having 45 MMscfd capacity was estimated at approximately 22.1 million USD whne applying the current exchange rate (1 USD = 117 YEN). In response, CAPEX of the facility with the same plant capacity can be considered at around 24.3 million USD in Figure 8. Thus it can be said that CAPEX in Figure 8 is almost same as that of the past construction experience, and that CAPEX in Table 14 also has sufficient validity in terms of its accuracy.

(b) Gas transmission pipelines from the gas production facilities for already-discovered domestic natural gas

It is proposed that nine gas pipelines shall be constructed to transfer gas treated in the future gas production facilities that are to be built in the gas fields shown in Table 15, and that this gas will be sent to the existing pipeline network for future incremental gas supply. Each pipeline will be tied-in to the nearest valve station and/or city gate station on the existing pipeline network.

Based on the pipeline data described in the paragraph 3(3), the unit costs of 0.5 million USD/km are applied, the total construction costs for the above pipelines is estimated at approximately 9 million USD. Please refer to Table 15.

Table 15 Construction Cost of the Gas Transmission Pipelines from the Gas Production Facilities for Domestic Natural Gas which has Already Been Discovered

Serial No.	Starting point	Length (km)	Unit cost (mill. USD/km)	Total cost (mill. USD)
1	Titas gas field	2	0.5	1.0
3	Bakhrabad gas field	2	0.5	1.0
4	Kailashtila gas field	2	0.5	1.0
5	Rashidpur gas field	2	0.5	1.0
6	Sylhet gas field	2	0.5	1.0
10	Fenchuganj gas field	2	0.5	1.0
12	Shahbazpur gas field	2	0.5	1.0
13	Semutang gas field	2	0.5	1.0
17	Bibiyana gas field	2	0.5	1.0
	Total	18	-	9.0

Source: JICA Survey Team

(c) Gas distribution pipelines for future power plants

It is proposed that gas distribution pipelines will be constructed to supply gas for future power plants which will be newly required based on an examination of the domestic power balance between supply and demand. Each pipeline it expected to be branched at the nearest valve station and/or city gate station on the existing pipeline network and tied-in to the respective appropriate delivery points in the future power plants.

Based on the pipeline data described in Paragraph 3 (4) if the unit costs of 0.5 million USD/km are applied, the construction costs for the 12 inch x 10 km pipeline is estimated at 5 million. Please refer to Table 16.

Table 16 Construction Cost of Gas Distribution Pipeline

Delivery point	Length (km)	Unit cost (mill. USD/km)	Total cost (mill. USD)
xxx power plant	10	0.5	5.0
Total	10	-	5.0

Source: JICA Survey Team

As a result, the estimated investment costs for the the future gas development is summarized as shown in Table 17.

Table 17 Investment Cost for Gas Field Development

Item			Predicted Peak Production Rate (a) [MMscfd]	Current Plant Capacity (b) [MMscfd]	Additional Capacity Required (a) – (b) [MMscfd]	Completion of New Facility Construction [Year]	Investment Cost											Total [mill. USD]
							Drilling				Facility construction			Pipeline				
							Quantity	Specification	Unit cost [mill. USD/well]	Subtotal [mill. USD]	Quantity [MMscfd]	Specification	Subtotal [mill. USD]	Quantity [km]	Specification	Unit cost [mill. USD/km]	Subtotal [mill. USD]	
Serial No.	1.	**Construction cost of gas production facilities for domestic gas which have already been discovered**																
1		Titas	600	452	148	2015				0	148	Wellhead press./temp.: 1,700psig/142 deg.F	37.0	2	API5L Gr.X60 w/3LPE coating, 12" x 0.312"wt	0.5	1.0	38.0
3		Bakhrabad	80	33	47	2017				0	47	Ditto	24.6	2	Ditto	0.5	1.0	25.6
4		Kailashtila	250	80	170	2019				0	170	Ditto	39.7	2	Ditto	0.5	1.0	40.7
5		Rashidpur	250	49	201	2019				0	201	Ditto	43.5	2	Ditto	0.5	1.0	44.5
6		Sylhet	25	11	14	2015				0	14	Ditto	20.5	2	Ditto	0.5	1.0	21.5
10		Fenchuganj	60	40	20	2014				0	20	Ditto	21.2	2	Ditto	0.5	1.0	22.2
12		Shahbazpur	70	30	40	2018				0	40	Ditto	23.7	2	Ditto	0.5	1.0	24.7
13		Semutung	30	12	18	2018				0	18	Ditto	21.0	2	Ditto	0.5	1.0	22.0
17		Bibiyana	1200	770	430	2017				0	430	Ditto	71.6	2	Ditto	0.5	1.0	72.6
		Subtotal (1)					0.0			0.0	1088	-	302.8	18	-	-	9.0	311.8
	2.	**Construction cost of gas production facilities for domestic gas which have not been discovered**																
			-	-	-					0							0	0
			-	-	-					0							0	0
		Subtotal (2)					0.0			0.0		-	0.0	0	-	-	0.0	0.0
	3.	**Gas distribution pipelines for future power plants**																
			-	-	-		-	-	-		-	-		10	API5L Gr.X60 w/3LPE coating, 12" x 0.312"wt	0.5	5.0	5
			-	-	-		-	-	-		-	-					0	0
		Subtotal (3)					-				-	-		10	-	-	5.0	5.0
		Total					-	-	-	0.0	-	-	302.8	-	-	-	14.0	316.8

Source: JICA Survey Team

Table 18 Investment Plan for Gas Field Development

Item			Predicted Max. Production Rate [MMscfd]	Current Plant Capacity [MMscfd]	Additional Capacity Required [MMscfd]	Completion of New Facility Construction	Investment Cost [mill. USD]																												
							Fisical Year																												
							2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	Total Cost
Serial No.	**1.**	**Gas production facilities for domestic gas which have already been discovered**																																	
1		Titas	600	452	148	2015		38.0																											38.0
3		Bakhrabad	80	33	47	2017				25.6																									25.6
4		Kailashtila	250	80	170	2019						40.7																							40.7
5		Rashidpur	250	49	201	2019						44.5																							44.5
6		Sylhet	25	11	14	2015		21.5																											21.5
10		Fenchuganj	60	40	20	2014	22.2																												22.2
12		Shahbazpur	70	30	40	2018					24.7																								24.7
13		Semutung	30	12	18	2018					22.0																								22.0
17		Bibiyana	1200	770	430	2017				72.6																									72.6
		Subtotal (1)					22.2	59.5	0.0	98.2	46.7	85.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	311.8
	2.	**Gas production facilities for domestic gas which have not been discovered**																																	
			-	-	-																														0.0
			-	-	-																														0.0
		Subtotal (2)					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3.	**Gas distribution pipelines for future power plants**																																	
			-	-	-																														0.0
			-	-	-																														0.0
		Subtotal (3)					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total					22.2	59.5	0.0	98.2	46.7	85.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	311.8

Source: JICA Survey Team

(3) Import Gas Development Cost

(a) LNG Receiving terminal

LNG Receiving Onshore terminal assumes 2x 200,000 M3 LNG tanks at the initial phase, with jetty and re-gasification facilities. Total estimated cost is USD 500 million.

(b) LNG transmission pipeline

Based on the pipeline data described in Paragraph 3 (5), if the onshore unit costs of 1.5 million USD/km and offshore unit costs of 1.1 million USD are applied, the total construction cost for the pipeline is estimated at approximately 115.1 million USD. Refer to Table 19.

Table 19 Construction Cost of LNG Transmission Pipeline

	Length (km)	Unit cost (mill. USD/km)	Total cost (mill. USD)
Offshore portion	10	1.5	15.0
Onshore portion	91	1.1	100.1
Total	101	-	115.1

Source: JICA Survey Team

5. Total Investment Cost

Some area is not covered by the Software and these are assumed based on the following figures:

1) Significant labor works and time/cost will be required to identify oil and gas deposit in the green field in general, and cost for these area will also differ from country to country and also to the local conditions. In case of Bangladesh, it is assumed that potential of gas borne area is identified already, and actual cost information used for particular field is used as a benchmark cost, i.e., 2D Seismic Survey: USD 3 million (80 L Km), 3D Seismic Survey: USD 28 million (400 km2)

2) Drilling cost assumes four development wells and used as a production well at later stage. Based on the recent experience by BGFCL, total of 4 wells cost USD 60 million.

3) Assuming that production rate from future onshore wells is 500 mmscfd, cost for production facilities will be assumed USD 90 million as per SIMENS Cost Estimate Software.

Table 20 Total Investment Costs for Gas Development till 2027

	Item	Cost [mill. USD]
A	**Domestic Gas Development Costs for the Remaining Reserves 2P**	
A1	Field Exploration Costs	*30*
A2	Field Development Costs	
A2.1	Drilling Costs	*60*
A2.2	Facility Construction Costs	
(1)	Facility construction costs for domestic gas which has already been discovered	302.8
(2)	Gas transmission pipelines from gas production facilities for domestic gas which has already been discovered	9.0
(3)	Facility construction costs for domestic gas which has not been discovered	*90*
(4)	Gas distribution pipelines for future power plants	5.0
	Subtotal (A)	*496.8*
B	**Import Gas Development Costs**	
B1	Facility Construction Costs	
(1)	LNG Receiving Terminal	*760*
(2)	LNG transmission pipeline	115.1
	Subtotal (B)	*875.1*
C	**Contingency (= (A+B) x 50%)**	
	Subtotal (C)	*686*
	Total (A+B+C)	***2057.9***

Source: JICA Survey Team

Numbers of assumptions were made to make cost estimate and the result is not necessarily close enough to predict future cost.

(1) Reinforcement cost for Existing Pipeline Infrastructure is not included in the cost estimate.

(2) Impact of LNG introduction to existing gas infrastructure and to gas field processing facilities/wellhead compressors is not included.

(3) All the cost data and assumed infrastructure models used for cost estimate to be reviewed.

Table 21 OGM Input Data for Plant Capacity (20, 40, 150, 200 and 400 MMscfd)

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
1. Project Construction Site								
1-1	Project Construction Site	Southeast Asia	Southeast Asia	Southeast Asia	Southeast Asia	Southeast Asia	Large	The project construction site is specified from major oil/gas production areas worldwide such as the Arabian Gulf, Gulf of Mexico, North Sea, West Africa, Brazil, Venezuela, Southeast Asia, North East Asia and Malaysia. In this case, Southeast Asia was specified due to the proximity of Bangladesh. The appropriate wage rate for the specified project construction site was then applied –the same data is inputted for to all the cases regardless of the gas handling capacity
2. Required Facilities (Separator, Gas Dehydrator, Condensate Storage, Water Treatment Facilities)								
2-1	Main Facilities	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Separator, Gas Dehydrator, Storage, Water Treatment	Large	The required main facilities (separator, gas dehydrator, condensate storage tank, and water treatment facility) for gas production are specified. Here, as there are no sour components (H2S) in the gas the general facility configuration for normal gas production was selected. As the facility configuration is the same for all the cases, the same data was inputted regardless of the gas handling capacity.
3. Process Conditions								
3-1	Gas Production Rate	20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd	Large	The gas production rate is specified. In this case, gas handling capacities is specified to covers the wide range of gas production rates in Bangladesh. The facilities required to handle the specified gas production rate are designed in connection with gas handling capacity,then the costs are estimated.

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
3-2	Composition Basis	Mole %	Mole %	Mole %	Mole %	Mole %	Large	The gas composition is specified and the gas/liquid separation calculation is conducted based on the inputted composition. The facilities required to handle the separated gas and liquid are designed, and then the costs are estimated. The typical gas composition in Bangladesh is inputted in all cases regardless of the gas handling capacity. In case that the toxic substances such as sour component (H2S) and mercury are included in the produced gas, requisite removal facilities will be required. However, as the gas produced in Bangladesh is classified in sweet gas, the installation of such facilities is not necessary.
	Nitrogen (N2)	0.37	0.37	0.37	0.37	0.37		
	Carbon Dioxide (CO2)	0.31	0.31	0.31	0.31	0.31		
	Hydrogen Sulfide (H2S)	0.00	0.00	0.00	0.00	0.00		
	Methane (C1)	96.76	96.76	96.76	96.76	96.76		
	Ethane (C2)	1.80	1.80	1.80	1.80	1.80		
	Propane (C3)	0.36	0.36	0.36	0.36	0.36		
	i-Butane (iC4)	0.09	0.09	0.09	0.09	0.09		
	n-Butane (nC4)	0.05	0.05	0.05	0.05	0.05		
	i-Pentane (iC5)	0.02	0.02	0.02	0.02	0.02		
	n-Pentane (nC5)	0.02	0.02	0.02	0.02	0.02		
	n-Hexane+ (nC5+)	0.22	0.22	0.22	0.22	0.22		Due to the limitations of the software inputs, the heavier components of n-Hexane (and above) were inputted into all the cases as n-Hexane+
4. Separation System								
4-1	Flowing Wellhead Pressure	1,700 psig	1,700 psig	1,700 psig	1,700 psig	1,700 psig	Medium	The wellhead pressure is specified. The pressure level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical wellhead pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.The normal range of wellhead pressure at the gas fields is approximately 500 to 3,000 psig.
4-2	Flowing Wellhead Temperature	142 F	142 F	142 F	142 F	142 F	Small	The wellhead temperature is specified. Temperature level at the highest upstream part of the facilities is defined, then the wall thickness is calculated and designed based on the inputted

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								temperature, after which the costs are estimated. The typical wellhead temperature in Bangladesh was inputted in all the cases regardless of the gas handling capacity. The normal range of the wellhead temperature is approximately 100 to 180 F
4-3	Prod. Manifold Design Pressure	1,100 psig	1,100 psig	1,100 psig	1,100 psig	1,100 psig	Medium	The manifold design pressure is specified. The pressure level at the manifold is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure was inputted in all the cases regardless of the gas handling capacity.The normal range of the manifold design pressure is approximately 500 to 1,500 psig.
4-4	Prod. Separator Design Pressure	1,100 psig	1,100 psig	1,100 psig	1,100 psig	1,100 psig	Medium	The separator operating pressure is specified. The gas/liquid separation calculation is conducted based on the inputted pressure, then the separator size and wall thickness required to handle the separated gas and liquid are designed, after which the costs are estimated. The typical separator operating pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.The normal range of the separator design pressure is approximately 500 to 1,500 psig.

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
4-5	Prod. Separator Operating Pressure	1,000 psig	1,000 psig	1,000 psig	1,000 psig	1,000 psig	Medium	The separator operating pressure is specified. The gas/liquid separation calculation is conducted based on the inputted pressure, then the separator size and wall thickness required to handle the separated gas and liquid are designed, after which the costs are estimated. The typical separator operating pressure in Bangladesh was inputted in all the cases regardless of the gas handling capacity.The normal range of the separator operating pressure is approximately 500 to 1,500 psig.
4-6	Test Separator	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of the test separator is specified. The test separator is normally required to monitor the production rate of one well and to manage the gas reservoir. "Allocated" was selected for all the cases regardless of the gas handling capacity.
4-7	Residence Time	3 min.	3 min.	3 min.	3 min.	3 min.	Small	The oil/condensate residence time in a separator that is required to segregate water droplets from oil/condensate phase was inputted. The As the separator is designed based on the residence time, the typical residence time is inputted in all the cases regardless of the gas handling capacity.The normal value of the oil/condensate residence time is approximately 3 minutes.
4-8	Separator per Stage	1	1	1	1	1	Medium	The number of separators per stage is inputted. Normally, vessels such as separators do not have any spares. Also, as the facility configuration without any spares is a design premise in the study, the number of train was inputted as one for all the cases regardless of the gas handling capacity.
4-9	Percent Flow per Separator	100%	100%	100%	100%	100%	Medium	In relation to the "separator per stage", the percentage of the handling flow rate per train in the total flow rate was inputted. As the facility

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								configuration without any spares is a design premise in the study, the percent flow per separator is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
4-10	Water Separation Option	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of water separation in a separator is specified. The produced water is normally removed from the oil/condensate and gas. "Allocated" was selected for all the cases regardless of the gas handling capacity.
5. Gas Dehydration System								
5-1	Gas Dehydration Medium	Glycol	Glycol	Glycol	Glycol	Glycol	Medium	The gas dehydration medium is specified. "Glycol" is specified as a typical medium (chemical) used in gas dehydration process for all the cases regardless of the gas handling capacity.
5-2	Number of Gas Dehydration Train	1	1	1	1	1	Medium	The number of gas dehydration trains is inputted. Vessels such as gas dehydration facility normally do not have any spares, and facility configuration without any spare is a design premise in the study, therefore number of train is inputted as one for all the cases regardless of gas handling capacity.
5-3	Percent Flow per Dehydration Train	100%	100%	100%	100%	100%	Medium	In relation to the "number of gas dehydration trains", the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spares is a design premise in the study, the percent flow per gas dehydration train is inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
5-4	Outlet Water Dew Point Temperature	32 deg.F	32 deg.F	32 deg.F	32 deg.F	32 deg.F	Medium	The outlet water dew point temperature for the gas dehydration is inputted. The water dew point temperature of 32 F corresponding to 7 lb water in 1 MMscf gas, as regulated in the standard sales gas contract in Bangladesh, is inputted for all the cases regardless of the gas handling capacity.
5-5	Dehydrator Column Design Pressure	1,100 psig	1,100 psig	1,100 psig	1,100 psig	1,100 psig	Medium	The gas dehydrator column design pressure is specified. The pressure level of the dehydrator column is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the the costs are estimated. The typical design pressure is inputtedfor all the cases regardless of the gas handling capacity.The normal range of the dehydrator column design pressure is approximately 500 to 1,500 psig.
6. Condensate Recovery and Storage System								
6-1	Oil/Condensate Tank Capacity	15 kbbl	20 kbbl	40 kbbl	50 kbbl	100 kbbl	Large	The oil/condensate tank capacity is specified. The tank capacities for above 150 MMscfd cases were determined and inputted in proportion to the actual gas field development/construction record (25 kbbl for 90 MMscfd). Regardign the tank capacities for small development cases (20 and 40 MMscfd), appropriate capacities were inputted so as to reduce the shipping frequency of the condensate stored. The required oil/condensate storage facilities are designed for the inputted tank capacity, then the costs are estimated.
6-2	Oil Pump Outlet Pressure	100 psig	100 psig	100 psig	100 psig	100 psig	Medium	The oil pump outlet pressure required for shipping is specified. The Pressure level of the pump is defined, then the wall thickness is calculated and designed based on the inputted pressure, after which the costs are estimated. The typical design pressure is inputted for all the cases regardless of

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								the gas handling capacity.
6-3	Number of Pumps	1	1	1	1	1	Medium	The number of pumps is inputted. As the facility configuration without any spares is a design premise in the study, the number of trains is inputted as one for all the cases regardless of the gas handling capacity.
6-4	Percent Flow per Pump	100%	100%	100%	100%	100%	Medium	In relation to “number of pumps”, the percentage of the handling flow rate per train in the total flow rate is inputted. As the facility configuration without any spare is a design premise in the study, thepercent flow per pump is inputted in common as one hundred (100%) for all the cases regardless of the gas handling capacity.
7. Water Treatment System								
7-1	Produced Water Design Rate	0.2 kbpd	0.4 kbpd	1.5 kbpd	2 kbpd	4 kbpd	Large	The produced water design rate is specified. The facilities required to handle the specified water rate are designed in connection with the produced water design rate, then the costs are estimated. 10 bbl of water was assumed to be produced with 1 MMscf gas.
7-2	Sour Water Stripping Option	Not Allocated	Not Allocated	Not Allocated	Not Allocated	Not Allocated	Medium	The necessity of a sour (H2S) component stripping facility as one the of water treatment systems is specified. As gas produced from Bangladesh is classified as sweet gas a without sour (H2S) component, the installation of such a facility is not required. “Not allocated” was selected for all the cases regardless of the gas handling capacity.
7-3	CPI Unit	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of a CPI unit as the first stage of water treatment is specified. A CPI unit is normally used in the water treatment. “Allocated”

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								was selected for all the cases regardless of the gas handling capacity.
7-4	Floatation/Hydrocyclone Unit	Allocated	Allocated	Allocated	Allocated	Allocated	Medium	The necessity of a floatation/hydrocyclone unit as the second stage of water treatment is specified. A floatation/hydrocyclone unit is normally used in the water treatment. "Allocated" was selected for all the cases regardless of the gas handling capacity.
8. Utility System								
8-1	Type of Main Power Generator	Turbine	Turbine	Turbine	Turbine	Turbine	Small	The type of main power generator driver is specified. "Turbine" was specified as the typical most proven type of driver for all the cases regardless of the gas handling capacity.
8-2	Number of Main Power Generators	1	1	1	1	1	Medium	The number of main power generators is inputted. As the facility configuration without any spares is a design premise in the study, the number of trains was inputted as one for all the cases regardless of the gas handling capacity.
8-3	Percent of Main Power Load	100%	100%	100%	100%	100%	Medium	In relation to the "number of main power generators", the percentage of power generation per train in the total power generation is inputted. As the facility configuration without any spares is a design premise in the study, the percent of the main power load was inputted as one hundred (100%) for all the cases regardless of the gas handling capacity.
8-4	Power Generator Selection	Internally Determined	Internally Determined	Internally Determined	Internally Determined	Internally Determined	Medium	The manufacturer's model of the main power generator is specified. In this case, the required power for all the facilities was internally calculated in the software by specifying "internally determined" for all the cases

No.	Input Data	Gas Handling Capacity					Cost Impact	Note
		20 MMscfd	40 MMscfd	150 MMscfd	200 MMscfd	400 MMscfd		
								regardless of the gas handling capacity. Also, the type of main power generator was automatically selected to cover the power demand required.
9. Other Related Facilities								
9-1	Number of People in Operation Camp	30	30	40	40	50	Medium	The number of people to be accommodated in the operation camp is inputted. Based on three shift of eight hours , the number of people – including operators, supervisors, maintenance workers, administrators, and guests – are assumed for the required accommodation, then the costs are estimated.
9-2	Number of People in Construction Camp	50	50	100	100	200	Medium	The number of people to be accommodated in construction camp is inputted. The number of people is assumed for the required accommodation, then the costs are estimated.

Source: JICA Survey Team

Chapter 8 Liquefied Natural Gas Supply

8.1 Background of LNG Import in Bangladesh

According to the natural gas supply and demand balance forecast study from 2009 to 2030 in Bangladesh by PSMP2010, the tremendous shortage data of natural gas supply from the domestic gas well in 2015 onward was shown to us.

In the present study, as one of the solutions to compensate the huge gap between natural gas supply and demand, onshore LNG receiving terminal will be studied and the technical challenges at the earliest stage will be shown.

In the process of the study, the main objective is to pursue the stable natural gas supply to bulk users like power station and fertilizer nearby and we will find the technical challenges to have an economic and energy effective LNG receiving terminal, while looking at the design, construction, and O&M procedure of LNG receiving terminal in Japan and studying the gas tie-in condition with the local gas pipeline.

Source: Osaka Gas Brochure

Figure 8-1 Overview of LNG Receiving Terminal Owned by Osaka Gas

8.2 Overview of LNG Terminal Development Plans

Until 2041, approximately 5,900mmscfd gas will be required, out of which 4,000mmscfd will be supplied from newly constructed LNG terminals (refer to the below Table). In addition to the terminals, 125mmscfd (up to 250 mmscfd) will be supplied mainly in Khulna, through an international gas pipeline to be connected to a newly constructed FSRU in West Bengal (further details can be referred in section 8.7 .).

Table 8-1 LNG Terminal Development Plans

FY	Type of Terminal	Capacity (mmcfd)	Remarks
2018	*FSRU*	*500*	*On-going project by Petrobangla*
2023	FSRU	500	To be planned
2027	Onshore	500	Moheshkhali and/or Payra
2029	Onshore	500	Moheshkhali and/or Payra
2036	Onshore	500	Moheshkhali and/or Payra
2039	Onshore	500	Moheshkhali and/or Payra
2040	Onshore	500	To be planned
2041	Onshore	500	To be planned
Total Capacity		4,000	

Source: JICA Survey Team

The FSRU project by Petrobangla makes the first move and three other LNG projects follow.

Table 8-2 Four Immediate Future LNG Import Projects

Project	Location	Capacity (mmscfd)	Leading Agency	Operating Entity	Status and/or Commercial Operation	Project Operation
FSRU	Moheshkhali	500	Petrobangla	Excelerate Energy Bangladesh	2018	BOOT
Land Based LNG	Moheshkhali	LNG for 3,000 MW of IPPs	Power Cell	SPV of BPDB/ ICF Infra Venture/	Expression of Interest (EoI) for FS released.	BOO
Land Based LNG	Moheshkhali	1000	Petrobangla	Petrobangla companies	EoI for FS released. Await for anouncement for Request for Proposal (RfP)	not finalized yet
Land Based LNG	Payra	1000				

Source: JICA Survey Team based on the publically available information

From the next section, these four projects will be described.

8.3 Status of FSRU Planning in Bangladesh

The Bangladeshi Government has focused on the LNG supply technology of FSRU to recover quickly the natural gas supply and demand gap and agreed the charter party of one unit of FSRU in 2014.

DHAKA, BANGLADESH – Excelerate Energy and Petrobangla have reached agreement on terms for the development and operation of Bangladesh's first LNG import terminal. The agreement includes the provision of one of Excelerate's existing floating storage and regasification units (FSRU) under a 15-year long-term charter, as well as the design and construction of the facility. Located offshore near Moheshkhali Island in the Bay of Bengal, the terminal will provide much needed natural gas to the southeastern Chittagong region of Bangladesh.

The facility will include the installation of a subsea buoy system anchored offshore. The buoy system will act as both the mooring mechanism for the FSRU and as the conduit through which natural gas is delivered to shore through a subsea pipeline. The FSRU will have 138,000 cubic meters of LNG storage capacity and a base regasification capacity of 500 million standard cubic feet per day.

Source: Höegh LNG Holdings Ltd.

Figure 8-2 FSUR Image

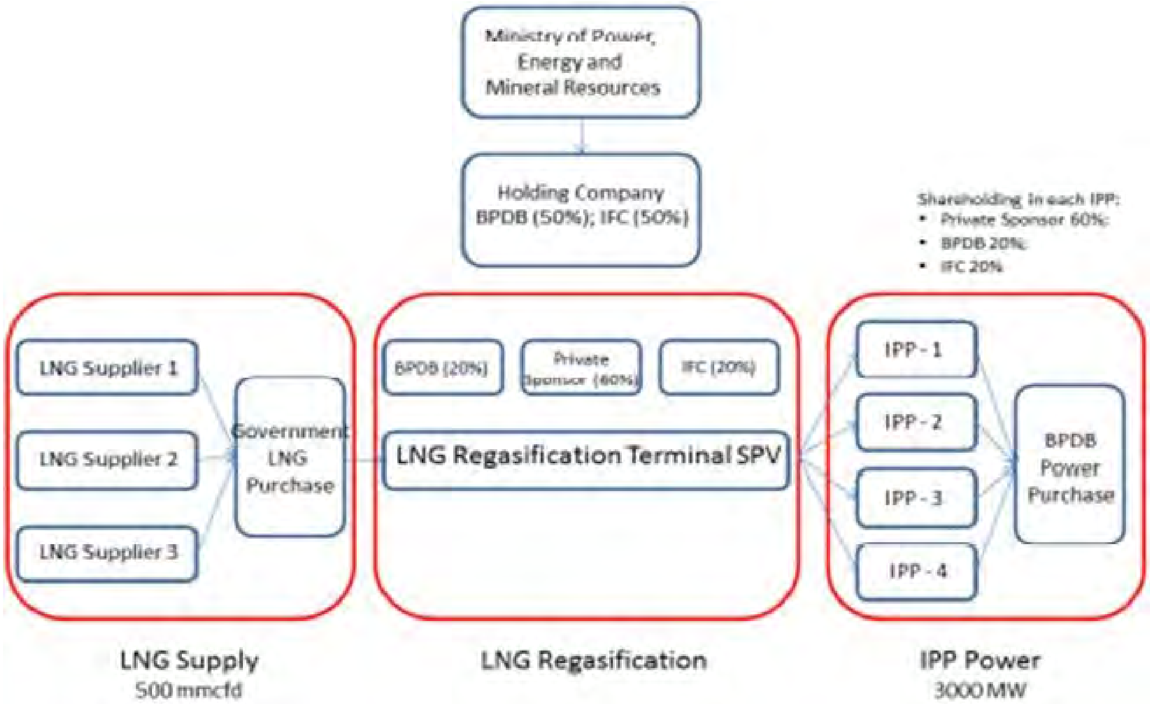
FSRU has some advantages over onshore LNG receiving terminal, in terms of up-front construction cost, construction period, easiness of dismantling, etc. (for further detail of economic cost comparison, refer to the following section). But on the other hand, FSRU operation is largely influenced by weather and sea phenomena condition. This is because onshore LNG receiving terminal is needed to utilize LNG for a long time and supply stably natural gas to the customer. Thus the technical challenges for the basic plan and main specification of LNG receiving terminal will be shown here.

8.4 Status of Land-based LNG terminal Planning

In parallel with the introduction of FSRU, the Government is also processing on-shore (land based) LNG terminal project. Currently two GoB agencies, namely Power Cell and Petrobangla have their own land-based LNG plans.

8.4.1 Power Cell Project

This "Land Based LNG Terminal Project" is expected to import 5MMTPA (approx.710 mmscfd) to supply to newly built or existing 3,000MW gas-fired power plants (IPPs expected). The project will be operated on BOO (build-own-operate) basis, operated by LNG consortium mainly sponsored by private finance, and LNG itself will be procured by the Government (see the below figure).



Source: Power Cell

Figure 8-3 Structure of On-shore LNG Terminal and IPPs

The candidate site of this land-based LNG terminal is Matarbari/Moheshkhali area, which is adjacent to the JCA-supported Matarbari Ultra Super Critical coal power plant. Power Cell is the executing agency of this on-shore LNG terminal project, BPDB is the off-taker of LNG and power, and International Financial Corporation (IFC) is an advisor as part of their power sector private sector investment promotion.

The four contractors have been short-listed including one Japanese firm[1]. The employment process of the feasibility study consultant has been in progress since 2015. Design and construction schedule of the LNG will be determined in the feasibility study.

As described above, this Power Cell driving LNG terminal plan is expected to serve for power generation plants. To meet the growing national gas demand including non-power sector (e.g. Transport), more comprehensive LNG plan (e.g. LNG master plan) would be required.

8.4.2 Petrobangla Project

In January 2016, Petrobangla floated the consultant EoI for the feasibility study consultant of LNG projects. According to the EoI document, Petrobangla, similarly to Power Cell, is planning to develop two land-based LNG terminals, one 1,000 mmscfd in Moheshkhali, and/or the other 1,000 mmscfd in Payra. As of June 2016, no further detail is yet available and the plan seems to be still at an early stage.

8.5 Economic Comparison between FSRU and Land-based LNG Receiving Terminal

This Section is primarily intended to make comparison of the two different LNG Import infrastructure, FSRU and Land LNG terminal, in terms of economics. However, it should be understood that each method has its own features and advantages. Therefore this Section also covers all the design factors to be considered for the introduction and construction of LNG infrastructures.

8.5.1 Overview

At the moment (as of May 2016) negotiation on the introduction of FSRU (Floating Storage and Re-gasifying Unit) is underway between Petrobangla and Excelerate Energy from US. According to press report (Bangladesh Energy and Power News) general description of the FSRU Project is as follows:

Location	:	Moheshkhali
Storage Capacity	:	138,000 M3
Re-Gasification Capacity	:	500 mmcfd
Start of Commercial Operation	:	2018
Contract Term	:	15 years, on BOOT base
Service Charge	:	USD 0.49 per mcf

The facility will include FSRU (Floating Storage and Re-gasifying Unit) and Single Point Mooring Buoy system anchored to the sea bottom. Gas produced from LNG is delivered through a conduit of the Buoy system and submarine pipeline and tied into the onshore pipeline system. LNG loading to FSRU will be carried out by Ship to Ship transfer. In order to supply 500mmcfd of gas, more than 60 shipments will be required in a year. Capacity of the shuttle tanker will be the same or smaller than that of FSRU. Construction of FSRU is almost the same as that of LNG tanker. Retired LNG tankers can be remodeled as FSRU to save construction cost. Operation of FSRU in general is vulnerable to weather condition and emergency evacuations plan must be in place if it is operating in the cyclone prone area.

Land LNG Terminal requires larger space near shore, capable of accommodating more than 10 tanks. This is to minimize investment to the infrastructure and also to secure freedom to construct additional tanks to meet the incremental demand. Initial tank numbers are assumed to be two to match with the performance of FSRU under negotiation, and to be expanded with the increase of demand.

[1] According to Power Cell, these four companies are: Mitsui & Co. Ltd., Japan, Royal Dutch Shell (Netherland), China Huanqui Contracting & Engineering Corp. (HQC) (China) and PetroNet LNG Limited (India).

Tank size has been designed larger to meet the increasing size of LNG tankers. Recent trend of tank size constructed in Asia (Korea) is 180,000 kl and larger to accommodate Q-Flex size. Berth size is designed for Q-Max (265,000 kl) size.

8.5.2 Land-based LNG terminal specifications and construction cost

Land LNG Terminal Specification and Construction Cost Estimate to be used for cost comparison with FSRU is as follows:

(1) Specification for land –based LNG terminal

Objectives of Land LNG Terminal may differ from case to case and sometimes designed for specific power plant only. But in Asia in general, LNG is constructed by taking emergency factor into consideration and therefore some allowance in the storage capacity is included.
In general, annual tank rotation is 12 times as an operational Index. However, Bangladesh is gas producing country and significant amount of gas is supplied domestically, and therefore storage allowance can be trimmed off in case of Bangladesh. In the economic comparison, 20 times of rotation is used. This 20 times is considered low enough in comparison with the case of FSRU with 60 times and more to supply 500 mmcfd of gas

Following are assumed terminal specification.

Terminal Size	:	90 ha
Tank Size	:	180,000 kl
Initial tank Numbers and gas supply	:	3 (500 mmcfd)
Final tank Numbers and gas supply	:	14 (3,000 mmcfd max.)
Jetty	:	Initially 1
Berth Number and capacity	:	1(Q-Max-127,000ton/265,000M3)
Berth will be expanded to suit.		

Note that Re-Export capability and loading arms may be added to allow LNG trading in future, Break water may be required to allow stable off loading.

Tank Utilization	:	18/Year/tank
Capacity	:	1.8 Million ton/yr/tank

(2) Initial land LNG –based terminal construction cost

Assuming that Initially 2 tanks are constructed to commence commercial operation and supply 500 mmcfd of gas. Initial EPC cost inclusive of 3 tanks, re-gasification, Jetty, Loading Arms, operation rooms are USD 550 Million. 90ha of Land acquisition cost capable of constructing 14 tanks in total is assumed USD 200 million, and project development cost of USD 10 million. Initial Project Cost is assumed to be 760 million. Numbers of tanks will be increased with the increase of gas demand. Final construction cost after completion of 14 tanks will be USD 2,260, and gas supply capacity will be 3,000 mmcfd as maximum.

8.5.3 Operation cost comparison

FSRU appears to be constructed as a private enterprise project. To make fair comparison, operation charge of land LNG terminal, inclusive of tugboat operation is circulated based on the economic factors of 10% of IRR, 20% of Corporate Tax, and 20 years of Depreciation.
Economic data of FSRU is given in the News Press “Bangladesh Energy and Power News”. According to the press, Operation Charge of tugboat (Port Operation Cost) is excluded and need to be covered by Petrobangla.

Table 8-3 Operation Cost Comparison between FSUR and Land-based LNG Terminal

		FSRU (See Note 1)	Land LNG (See Note2)	
			Initial 3 Tanks	Expanded to 14 Tanks
Tank Capacity	M3	138,000	3X180,000	14x180,000
Annual LNG Delivery	Times/Year	59	40	186
Re-Gasification Capacity	MMscfd	500	500	3,000
Construction Cost	MM USD		760	2,260
Operation Charge	USD/Mcf	0.49	0.64 (See Note3)	0.33 (See Note 3)

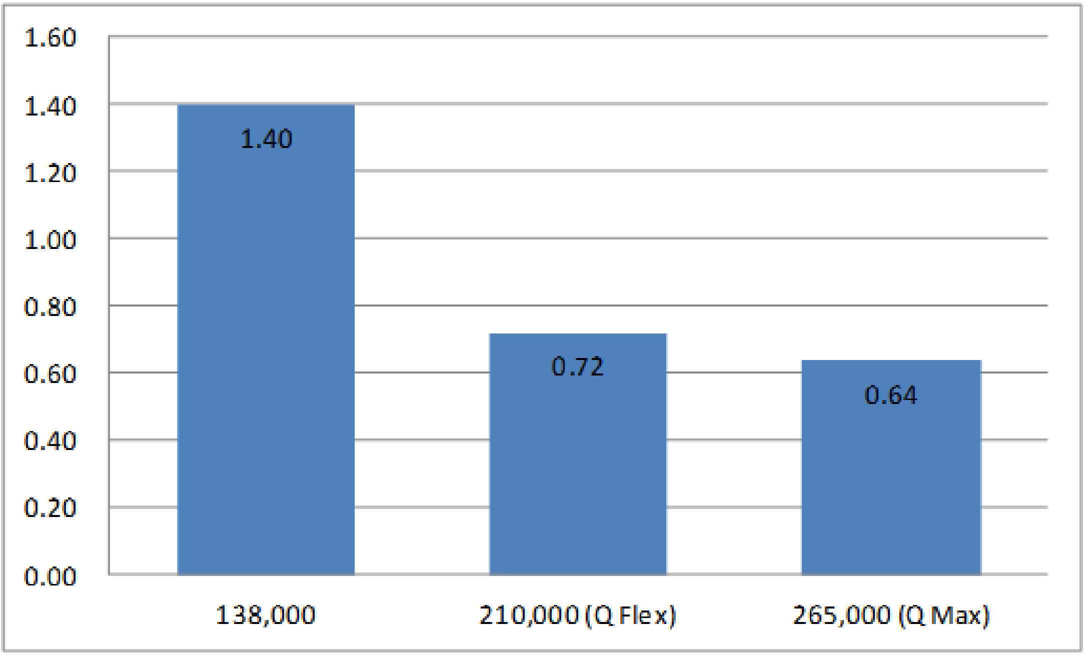
Note:
1: Data from Bangladesh Energy and Power News
2: Land Acquisition Cost for Terminal assumed USD 200 million
3: Tax Rate 20% and IRR 10% assumed, Including Port Operation Cost

Source: JICA Survey Team

8.5.4 Freight cost comparison

Freight cost of LNG differs to the size of LNG tankers. To reduce the unit freight cost, size of the tanker has become larger. In this report LNG freight cost from Middle East (Ras Laffan) to Chittagong is assumed based on the data from Middle East to Korea/Japan.

Storage capacity of FSRU is 138,000m3. To supply LNG to FSRU, the same and/or smaller sized shuttle tankers will be used. For Land LNG Terminal, freight of Q-Flex is used for this economics comparison. Following is a comparison of unit freight cost:

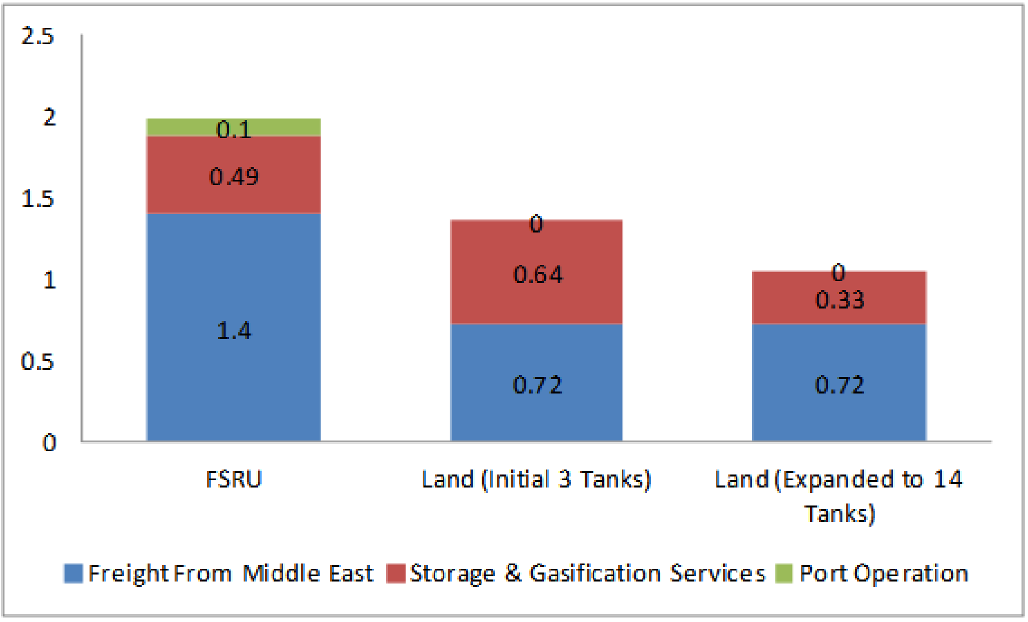


Source: Base data from Freight Study by KOGAS in 2011
Note that NM (Nautical Mile) is adjusted to the Port of Chittagong (from NM 6156 to NM 3833)

Figure 8-4 Transport Cost (USD/MMTBU) by Tanker Size

8.5.5 Operation cost comparison

Assuming that LNG is shipped out from port of Middle East at the same FOB price, cost structure of the gas at the terminal outlet in Moheshkhali is as follows:



Source: JICA Survey Team

Figure 8-5 Operation Cost Comparison (USD/MMBTU) between FSRU and Land LNG Terminal

In view of the comparison of overall cost from the port of origin to gas delivery point, Land LNG terminal has a potential to minimize the cost associated with LNG introduction.

FSRU uses small shuttle tanker to deliver LNG and therefore cost of the transportation is higher. Operation Charge (Storage/re-gasification and port operation) of Land LNG terminal is higher at the initial stage of the operation due to a heavier investment cost for land acquisition and associated infrastructure construction. However, Operation Charge will be lower with the increase of handling volume. Note that Port Operation Charge is included in the Land LNG terminal operation, but not in FRSU case.

8.5.6 Construction time schedule

Majority of construction work of FSRU is carried out at a shipyard and amount of on-site construction work is very small. Project schedule from EIA (Environmental Impact Assessment) to the commencement of operation is short and takes less than 3 years.

Source: JICA Survey Team

Figure 8-6 Time Schedule for FSRU Construction

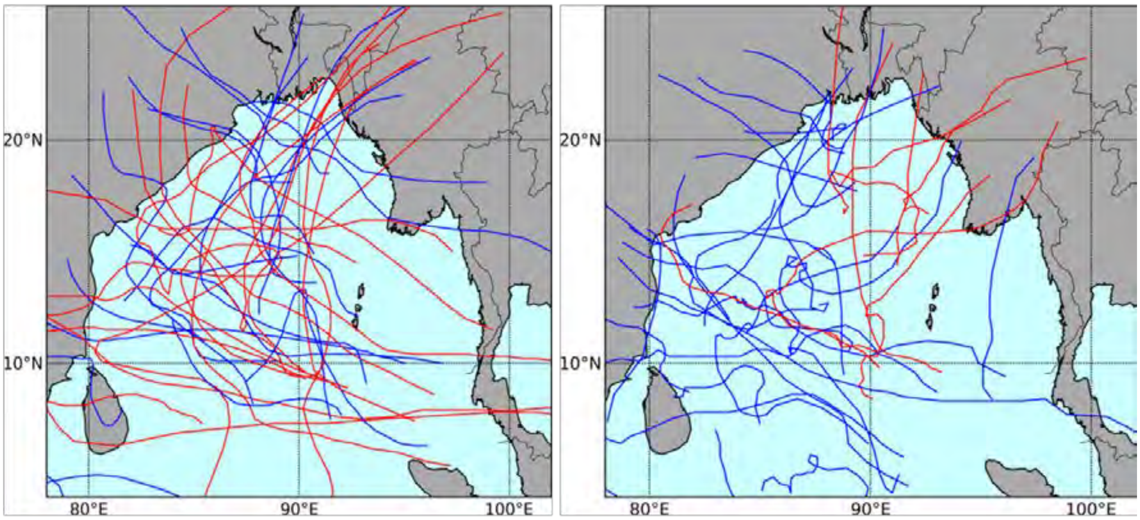
Project schedule for land LNG terminal is longer than that of FSRU. Significant time and effort to be injected to EIA including agreement with the local people and re-settlement plan associated with land acquisition. Large scale land preparation work and infrastructure construction such as breakwater if necessary, will be carried out. Construction of tank foundation to avoid uneven settlement is also time consuming work. Overall project schedule from EIA to commencement of operation will be 8-10 years.

Source: JICA Survey Team

Figure 8-7 Time Schedule for Land-based LNG Terminal Construction

8.5.7 Cyclone risks for FSRU

Operation of FSRU is vulnerable to weather condition. Bay of Bengal is known as Cyclone. Frequency of Cyclone landing at Moheshkhali area is not many in comparison with other areas, but influences every year. Scale of Cyclone is reported to be increasingly larger than before. Operational risk of FSRU should be investigated.



1991～2000年

2001～2010年

Note
Red : Larger than 32 m/sec
Blue: Smaller than 32 m/sec

Source: Nippon Koei Research Institute

Figure 8-8 Cyclone Outbreak in Bay of Bengal

8.5.8 LNG Master Plan

Prior to introducing LNG, several issues such as construction of LNG infrastructures, operation of gas distribution systems, impact to existing infrastructures and strategy for LNG procurement should be investigated further and need to be strategically prepared as a Master Plan.

Nature of gas is changing from domestic to LNG. It is understood that the change of process parameter requires thorough investigation based on the procedures so called “Management of Change”, i.e., how the change of gas composition, the dryer circumstance, the change of pressure balance impact to the existing facilities to be investigated.

Through the Master Plan, capacity building and human resource development also should be considered.

8.6 LNG Trade Contract

8.6.1 Background of LNG pricing

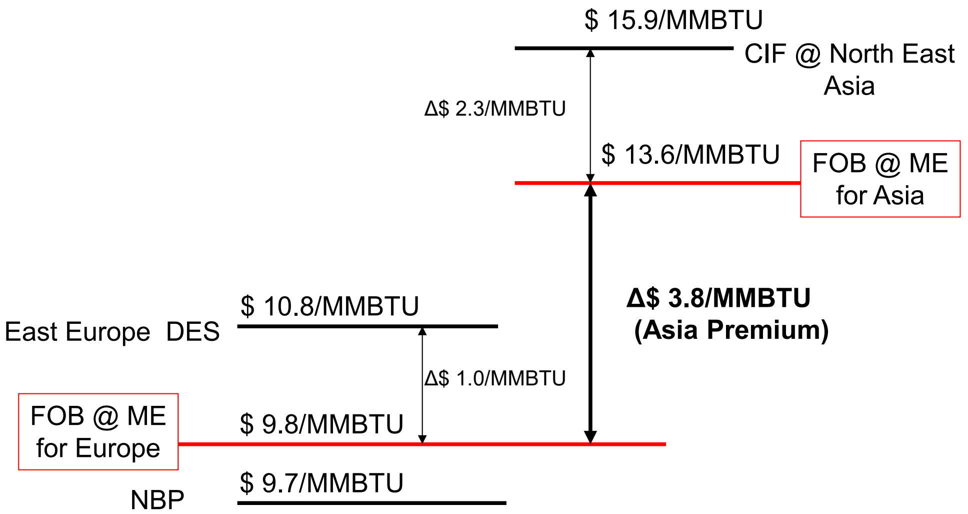
In the 1960s, natural gas in general has been used locally in the city gas distribution outreach area. Gas demand has increased due primarily to an advancement of gas turbine technology for power generation and also increasing demand for chemical uses. To meet the increasing demand, LNG and long distance pipeline was developed to deliver the gas from remote areas.

In Asia, the first LNG was delivered in Japan in 1969 from LNG project in Alaska. Since then, demand for LNG has increased significantly. New LNG projects in Malaysia, Burney and Indonesia, etc. has also been developed and supply gas energy to Japan.

LNG purchase and sale Contract between LNG supplier and buyer has been made based on bilateral Take or Pay Contract. It was designed to share the project risk between the parties, i.e., Price risk borne by Supplier and Quantity risk borne by Buyer. The price was pegged at Low Sulfur Crude Oil, a major clean fuel for power generation in 70's.

Liberalization of Electric Power and Gas Sectors took place in USA and UK/Europe in the 90's. LNG supply contracts have also been affected by this move. In addition to a long term Take or Pay Contract, Spot Market was also created. Suppliers are required to supply LNG to a competitive market directly.

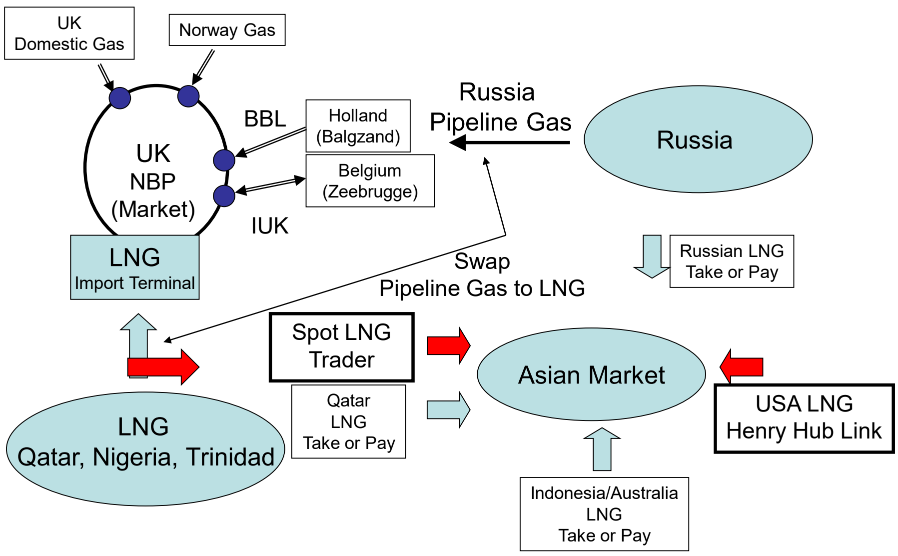
In Asia, long term Take or Pay Contract has long been used predominantly. This has created "Asia Premium", price differential between liberated market in UK and non-liberated region of Asia. Asian end-users have suffered from higher LNG price than market value.



Source: Argus LNG Daily

Figure 8-9 Asia Premium April 2012-Mar 2013

Asia has been lagged behind from US and Europe, however, Asian utility companies has also started to be aware of the risk of long term contract. New LNG traders, such as Gazprom Exports and Vitol, have started to supply destination free cargos on a spot basis, through swapping operation or purchasing from spot market. LNG market in Asia is showing more fluidity and market linked LNG cargos are also available in Asia.



Source: Argus LNG Daily

Figure 8-10 Fluidization of LNG Market

8.6.2 LNG market

Competitive gas market was created in UK. The market price is called National Balancing Point or NBP, and provides benchmark for gas pricing among pipeline gases and LNGs. The resulting gas price is totally independent from oil price, achieving "de-coupling" from crude oil.

In Asia, Singapore LNG is aiming to create LNG market through LNG trading using spare capacity of its own LNG storage tanks. At this stage, their affordable tank capacity is not necessarily large enough to create LNG Market and expansion of the capacity is awaited. PTT of Thailand owns and operates LNG terminal in Maphtapuht, Rayon, Thailand. PTT is buying part of LNG through auction to reduce market risk in long term contract. PTT is planning to re-export LNG for other demanding market in Asia. These terminals in Singapore and Thailand are expected to supply LNG produced in Middle East at market price in Asia.

Significant deposits of shale gas and coal bed methane are discovered in US. Production of these gases has brought the price lower than ever before. Under the circumstances, several gas export projects have started in Gulf area, Oregon, and pacific coast of Canada. LNG pricing formula is different from the conventional crude oil linked pricing system, but based on Henry Hub market pricing. Gas Price Formula for LNG from US to Asia (CIF) is shown as follows:

Table 8-4 CIF at Asia for LNG from US

Cost B/D	USD/MMBTU
Market Price	Henry Hub Priced
Pipeline Tariff	0.6
Liquefaction	3.0
Freight/Insurance	3.0
CIF	Henry Hub Price +6.6

Source: KOGAS and others

CIF Asia will be Henry Hub price plus USD 6.6/MMBTU. Assuming that Henry hub Price is USD 4 /MMBTU, CIF Asia will be USD 10.6/MMBTU. Note that freight cost is based on Panama Size Vessel. There are still rooms to reduce the price if larger vessel is used from Gulf, via Cape to Bangladesh.

8.6.3 New LNG procurement strategy

Japan and Korea import 60 % of world LNG supply in total. Liberalization of the utility industries in these countries will impact context of LNG purchase and sale contract, because long term take or pay can be a risk under liberalized market. Accordingly, Spot or short term contract will play an important role in the contracting strategy and old take or pay contract needs to be more flexible accompanied by appropriate option contracts.

Key LNG Procurement Strategy for Terminal Operators in Asia will be as follows.

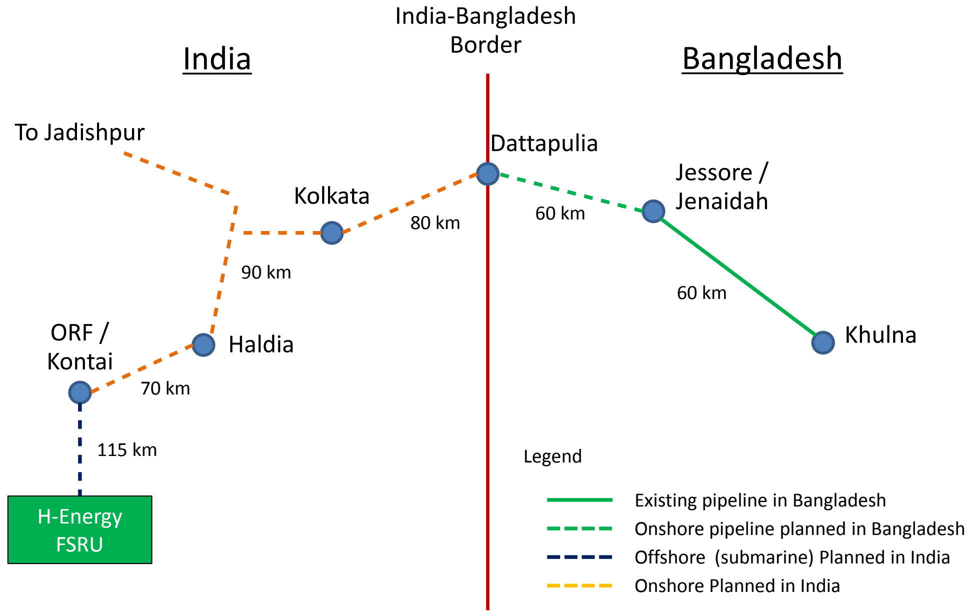
(1) Combination of Long Term Contract and Short (Spot) term Contract
(2) Short Term Contract:
  1) Introduce Auction System
  2) Use futures for risk management
(3) Long Term Contract
  1) Option Contract with quantity increase and decrease Claus
  2) Destination free

The above points should be incorporated into a future LNG MOU as well.

8.7 Cross-border LNG Trade

8.7.1 Project overall

The project is to import LNG 125 mmscfd (up to 250 mmscfd) and to develop cross-border gas transmission pipeline from a FSRU in the state of West Bengal, India to a to-be-built gas combined cycle power plant in Khulna (400MW *2). As the schematic below shows, total length of the on-shore pipeline from Kontai, India to Khulna, Bangladesh is approximately 360km and submarine pipeline portionis115km. RMS is to be built in Dattapulia, and the pipeline will be further extended and tied into existing system at Jessor, 60 km away from Dattapulia, Imported gas will be transported by using existing 60 km pipeline to Khulna.



Source: NWPGCL

Figure 8-11 Cross-border LNG Schematic Diagram

8.7.2 Executing agency

Indian private company H-Energy is expected to be responsible for all the facilities in India side (e.g. LNG procurement, pipeline development). In Bangladesh side, NWPGCL will be a project owner, while GTCL will be commissioned from NWPGCL, under the authority of Power Division.

8.7.3 Progress status

MOU and term sheet were concluded between H-Energy and NWPGCL. Gas Supply Agreement is not (?) yet concluded.

8.7.4 Schedule

Pipeline operation will start in 2018, and the Khulna 400MW＊2 will start operation in 2019.

8.7.5 Construction cost

Cost of 60 km pipeline between Dattapulia and Jessor is estimated approximately 60 million USD. ADB will provide financial support, including FS for the pipeline and the Khulna 400MW*2 power plant.

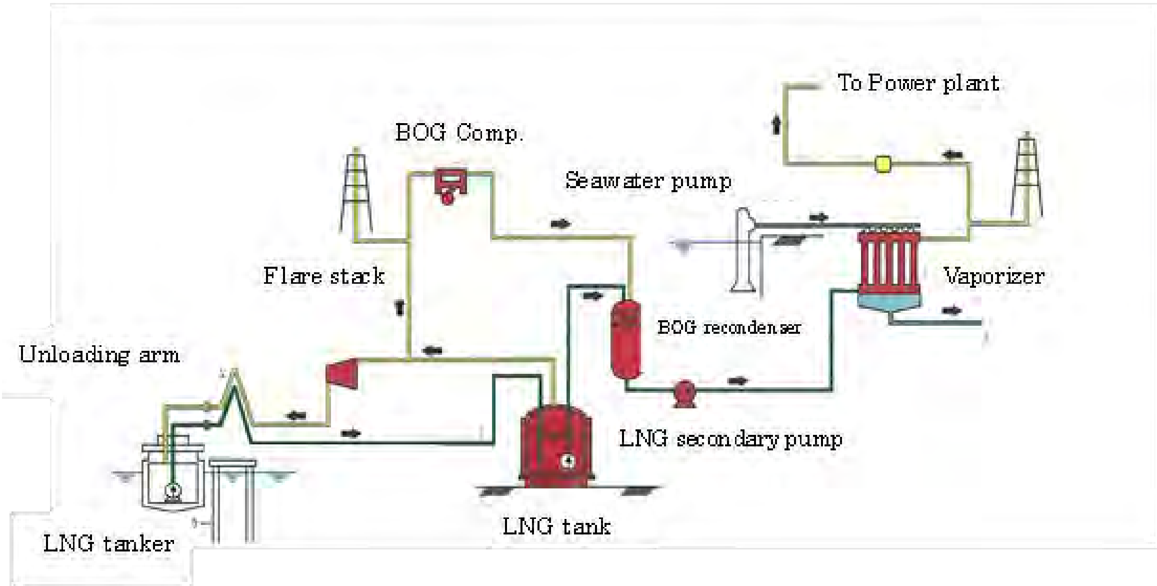
8.8 Land-based LNG Receiving Terminal Planning

8.8.1 General planning

At the first, gas send-out capacity and its related main equipment should be specified.
Key points to specify them are summarized.

(1) Annual LNG operation capacity (fixed by LNG tanker capacity and annual number of docking to LNG jetty)
(2) LNG Tank storage capacity (number of tank revolutions is considered.)
(3) Selection of vaporizer by sea water temperature and quality
(4) Gas send-out pressure (This will specify the LNG secondary pump.)
(5) Necessity of BOG re-liquefaction system
(6) Necessity of heat value adjustment by LPG or air
(7) Necessity of odorization system
(8) Spare unit arrangement of main equipment
(9) Future expansion plan (road map to expansion)

Typical schematic flow diagram of LNG receiving terminal will be shown in the below Figure.



Source: IHI Technical Report Vol.50, No.2 (2010)

Figure 8-12 Flow Diagram of LNG Receiving Terminal

8.8.2 Current planning status

At the second, gas production capacity will be studied and then main equipment specification will be clarified. Now the capacity of LNG receiving terminal is assumed as same as that of FSRU (500mmcfd, 3mm LNG ton per annum) because the same gas amount can be delivered to the customer even if FSRU is removed by the contract. Main equipment specifications and plot plan will be shown in the Tables and Figure below respectively.

Table 8-5 Design Criteria for Terminal Layout and Main Facility

Layout plan	Necessary land space for the final stage (1,500MMCFD) should be secured. Main facility will be expanded in accordance with the demand growth after the first stage completion (500MMCFD).
LNG storage tank specification and code & standard for tank	Bangladesh is an earthquake country, so full containment double dome roof type tank will be recommendable. Code & standard for tank design should be API for inner tank and EN for outer tank, which is applied world widely. Maximum storage capacity per unit can be 180,000 m3. The distance between tanks should be 0.5 times of tank diameter.
Number of LNG storage tank	20 times of 180,000m3 tank capacity will be needed annually. By this, necessary number of LNG storage tank can be set up.
NG send out condition from the terminal and tie-in condition with pipeline	NG send out pressure will be 1,100 psig (76barg). Tie-in point is on the way of new pipeline from Moheshkhali to Anawara.
Assumption of availability of the harbor	It is assumed as 95%. The planned availability of FSRU is 96.2% by Excelerate Energy.
Number of Jetty for terminal expansion	If standard sized LNG vessel (140,000m3) will be mooring 86 times a year, annual LNG receiving amount will come to 5.5 MTPA. Thus one jetty at the first stage and two jetties at the final stage will be needed.
Vaporizer specification	Peak hourly send out ratio during a day can be assumed as 9.5%. By this, capacity of vaporizer can be set up. ORV type vaporizer can be selected.
Other facility	1. BOG treatment facility will be designed. 2. Odorant injection facility will be designed for safety. 3. Metering facility will be designed. 4. Heating value adjustment will be not designed due to the almost equality of LNG and domestic NG. 5. Dual electric power system will be designed in substation. 6. Automatic control system in CCR will be designed. 7. As a preventive disaster system, firefighting and monitoring system will be designed. 8. Cooling water, IA, Nitrogen, and portable water supply system will be designed.
Layout plan	Necessary land space for the final stage (1,500MMCFD) should be secured. Main facility will be expanded in accordance with the demand growth after the first stage completion (500MMCFD).
LNG storage tank specification and code & standard for tank	Bangladesh is an earthquake country, so full containment double dome roof type tank will be recommendable. Code & standard for tank design should be API for inner tank and EN for outer tank, which is applied world widely. Maximum storage capacity per unit can be 180,000 m3. The distance between tanks should be 0.7 times of tank diameter.
Number of LNG storage tank	20 times of 180,000m3 tank capacity will be needed annually. By this, necessary number of LNG storage tank can be set up.
NG send out condition from the terminal and tie-in condition with pipeline	NG send out pressure will be 1,100 psig (76barg). Tie-in point is on the way of new pipeline from Moheshkhali to Anawara.
Assumption of availability of the harbor	It is assumed as 95%. The planned availability of FSRU is 96.2% by Excelerate Energy.

Number of Jetty for terminal expansion	If standard sized LNG vessel (140,000m3) will be mooring 86 times a year, annual LNG receiving amount will come to 5.5 MTPA. Thus one jetty at the first stage and two jetties at the final stage will be needed.
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Source: JICA Survey Team

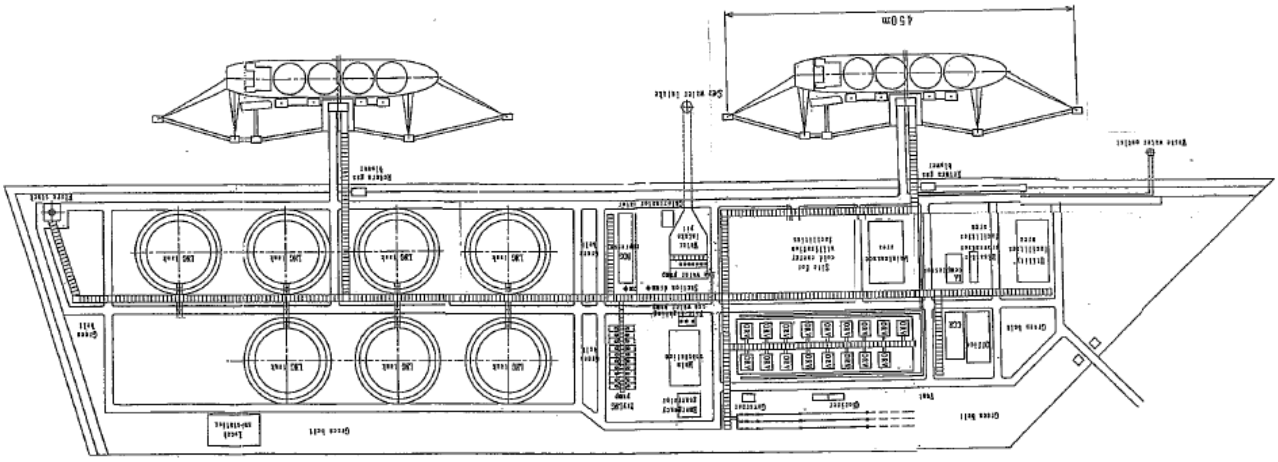
Table 8-6 Main Facility Specifications

	First stage (500MMCFD,3.5MTPA)	Final stage (1,500MMCFD, 10.4MTPA)
LNG storage tank	180,000 m3 X 3 units	180,000 m3 X 7 units
LNG pump	Primary pump; 300 t/h X 6 units + 3 spare units: total 9 units Secondary pump; 150 t/h X 6 units + 2 spare units: total 8 units	Primary pump; 300 t/h X 14 units + 7 spare units: total 21 units Secondary pump; 150 t/h X 18 units + 2 spare units: total 20 units
Jetty	1 jetty	2 jetties
Vaporizer	180 t/h X 5 units + 2 spare units: total 7 units ORV type is recommendable.	180 t/h X 15 units + 2 spare units: total 17 units ORV type is recommendable.
BOG treatment system	BOG compressor: 15 t/h X 4 units + 1 spare units: total 5 units BOG recondensor: 30 t/h X 2 units + 1 spare units: total 3 units Flare stack: 50 t/h X 1 unit (in long term blackout, BOG will be burnt to open air at flare stack.)	No expansion plan
Sea water intake pump	13,000 t/h X 3 units + 2 spare units: total 5 units	13,000 t/h X 9 units + 2 spare units: total 11 units

Source: JICA Survey Team

The logical and economical layout and area study of LNG receiving terminal is a very crucial matter at the basic and detail design stage.It should be done in accordance with the fixed systematic flow diagram. In this sense, the indicative layout plan as shown below is generated on the basis of send-out gas volume and it clarifies the design methodology of unloading facility, storage tank facility, vaporizer facility, and utility facility,etc.

Another attention has to be paid for the economic and functional main piping and cable route design which will connect each facility zone. Moreover future equipment space and piping layout should be studied fully for the future expansion in the terminal.



Source: JICA Survey Team

Figure 8-13 Typical Plot Plan of LNG Receiving Terminal (50ha, 10MTPA)

8.8.3 Impact of the LNG vaporized gas to the existing gas distribution network

Natural Gas produced at the terminal will be transferred to new pipeline (30 inch, 91km, from Moheshkhali to Anawara CGS) through metering station nearby and then delivered to Chittagong division.

In Chittagong division, LNG vaporized gas and domestic gas will be mixed each other but it will not cause a big damage for the end user by the following study.

First, when each heating value is focused on, LNG heating value (HHV) in RasGas, Qatar is around 1,055 BTU/ cft (source: JICA survey) and domestic gas heating value (HHV) is in average 1,042 BTU/cft (source: Petrobangla), which is almost equal. However, if LNG is imported from other countries on a spot basis, the special attention will be needed.

Second, LNG vaporized gas will be sent-out to the transmission line and then 290 MMCFD of it will be consumed in the power plant and fertilizer plant near to Chittagong division and remaining 210 MMCFD will be spread nation widely. However this 210 MMCFD is relatively small when compared to the total gas send-out amount of 2,740 MMCFD supplied from all domestic gas fields.

Table 8-7 Sector Wise Gas Demand and Supply

Unit: MMCFD

Sectors	Customer Category	Demand	Supply
Bulk	Power	1454	1070
	Fertilizer	317	200
	Power	70	68
Non-Bulk	Industry	452	448
	Captive	489	467
	CNG	128	125
	Domestic	332	330
	Commercial and others	33	32
	Total	**3275**	**2740**

Source: Petrobangla

8.8.4 Specification of LNG tanker and harbor conditions

(1) Specification of LNG tanker

LNG taker will be designed larger in capacity year by year but、Q-max class tanker is huge and is limited by the project, so Q-flex class tanker will be applied in Bangladeshi terminal.

Table 8-8 LNG Tanker Size

LNG Tanker		Class (DWT[2])	Length L (m)	Breadth B (m)	Loaded Draft D (m)
LNG Tanker	Q-max	130,000	350	55	13.7
	Q-Flex	110,000	315	50	12.5
	Conventional	80,000	300	50	12.0
Reference: Collier		80,000	220	36	13.0

Source: JICA Survey Team

(2) Performance requirements for waterways and basins

Performance requirements for waterways and basins are defined as follows in Technical Standard and Commentaries for Port and Harbor Facilities in Japan. (http://www.ocdi.or.jp/technical-st.html)

1) Performance criteria of waterways

- Breath of channel：In the channel where ships may meet each other, not less than the breadth over the ship's total length will be needed.
- Water depth of the channel：1.1 times as much as ship's loaded draft will be needed.
- When the channel has an elbow-shaped bend, the angle of intersection of the centerline at the bend of the channel is around less than 30 degree and the radius of curvature is more than about 4 times as long as the length between perpendiculars of the ships.

2) Performance criteria of basins

- Width of basins：in case of turning around by tugboat, a circle space should have a diameter twice longer than the ship length

[2] DWT: Dead Weight Ton

- Water depth of basins：enough water depth more than the loaded draft of the ship (maximum loaded draft plus affordable water depth) should be secured under the standard space by the port authority
- Calmness of basins：calmness which can make more than 97.5% unloading possible through the year should be secured.

Table 8-9 Reference Values of Threshold Wave Height for Cargo Handling Works Not Affected by Swell, or Long Period Waves

Ship type	Threshold Wave height for cargo handling works ($H_{1/3}$)
Small craft	0.3m
Medium/large ship	0.5m
Very large ship	0.7-1.5m

Source: JICA Survey Team

(3) Harbor condition

Specification of LNG Harbor (Waterways & Turning Basin)
Based on Technical Standard and Commentaries for Port and Harbor Facilities in Japan, LNG Harbor will be specified.

Table 8-10 Specification of LNG Harbor for Receiving Q-Flex Class LNG Tanker

Vessel		Class (DWT)	Waterways(Channel)			Turning Basin	
			Width 1L (m)	Length 5L(m)	Depth 1.1d(m)	Diameter 2L (m)	Depth 1.1d (m)
LNG Tanker	Q-Flex	110,000	315	-	14.0	630	14.0
Reference: Collier		80,000	250	1200	15.0	600	15.0

Source: JICA Survey Team

(4) Port entrance and leaving condition of LNG tanker, Unloading condition at LNG jetty

With reference to Technical Standard and Commentaries for Port and Harbor Facilities in Japan and Japanese port entrance and leaving condition of LNG tanker and unloading condition at LNG jetty, maximum wave height (H1/3) for pier docking and undocking in the terminal can be defined as 1.5 meter.
In case of LNG tanker, due to the small specific gravity of LNG, above water surface area is large, so ship operation and unloading work is likely to be influenced by the wind power. In the technical Standard and Commentaries for Port and Harbor Facilities in Japan", there is no limitation of pier docking and undocking under the windy condition but the maximum allowable wind speed is set up to 8 to 15m/sec in almost Japanese LNG receiving terminal. Thus it will be also set up to 15m/sec here in Bangladesh. Calmness should be more than 95 %

Table 8-11 Calmness Condition in the Channel and Basins

		Threshold Wave Height $H_{1/3}$ (m)	Threshold Wind Speed (m/sec)
LNG Tanker	Entrance of Channel	1.5	15
	Berth	1.5	15
Reference: Collier	Entrance of Channel	1.5	-
	Berth	1.0	-

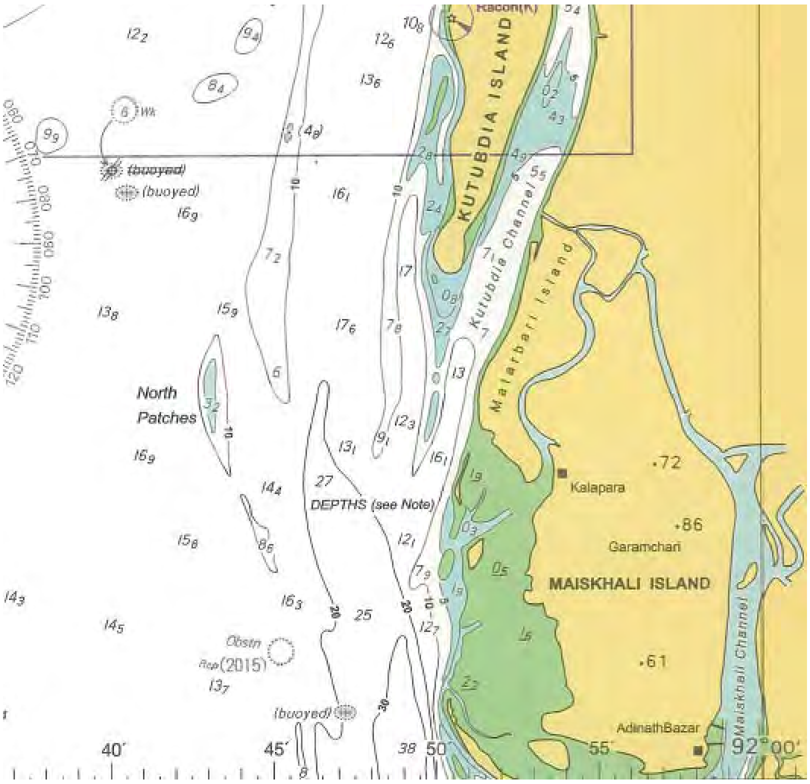
Source: JICA Survey Team

(5) Study of geographical and marine phenomenon condition near to the candidate site of LNG receiving terminal

1) Sea water depth

The chart of the candidate site of LNG receiving terminal will be shown in below Figure. The candidate site is located in the north of Bay of Bengal. Partially some reefs and shoals can be found but they are not barriers for the entrance of LNG tanker.

Marshy areas are spread along with the coast where the range of the tide will influence largely. The criteria of LNG receiving terminal construction are to avoid the marshy area, to set up LNG berth at offshore, and to dredge and cut the channel. When dredging and cut is applied for the channel, long term maintenance of dredge area should be studied.

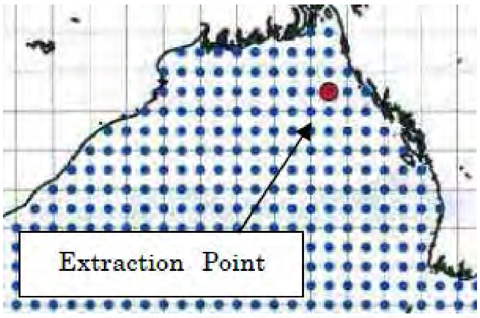


Source: JICA Survey Team

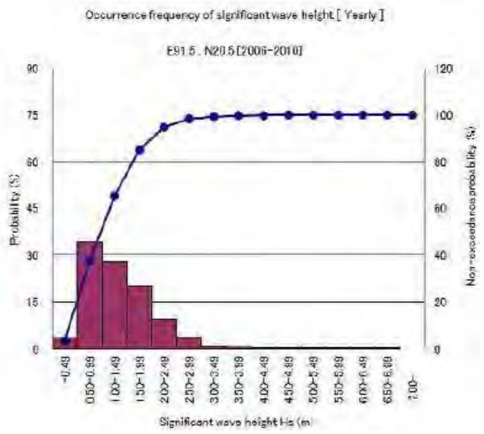
Figure 8-14 Chart of Candidate Site

2) Deep water waves data

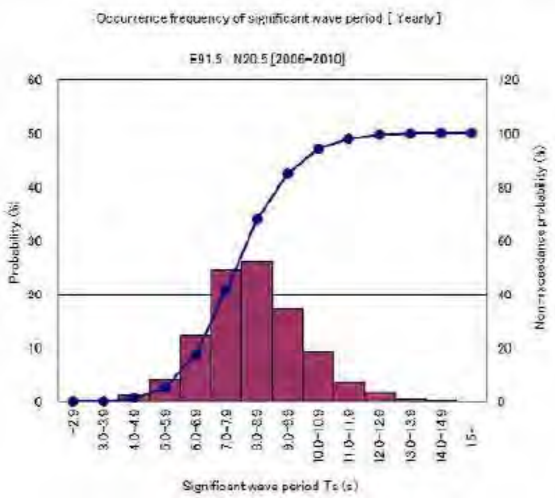
Deep water waves data at the planning site of coal fired power station in Chittagong is forecasted by the expected deep water waves data for the next 50 years based on the data at the extraction point in the north Bengal bay.
The expected frequency of deep water waves through the year from 2006 to 2010 will be shown. The expected frequency of over 1.5 meter wave height is around 65%、wave direction is most likely to be SSW.



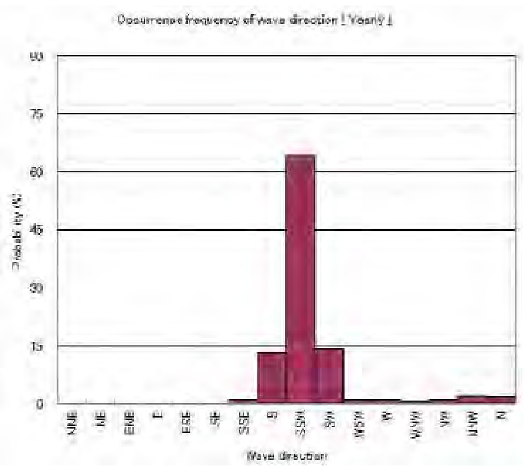
- Period : 2006.1.1～2010.12.31
- Extraction Point : Long. 91°30' E, Long. 20°30' N
- Time Interval : 1 hour
- Data Elements : Significant wave height、period and direction



Predominant Wave Height
- 0.50m～0.99m ;34%
- 1.00m～1.49m ;28%
- 1.50m～1.99m ;20%



Predominant Wave Period
- 8.0s~8.9s ;64%
- 7.0s~7.9s ;25%
- 9.0s~9.9s ;17%



Predominant Wave Direction
- SSW ;64%
- SW ;14%
- S ;13%

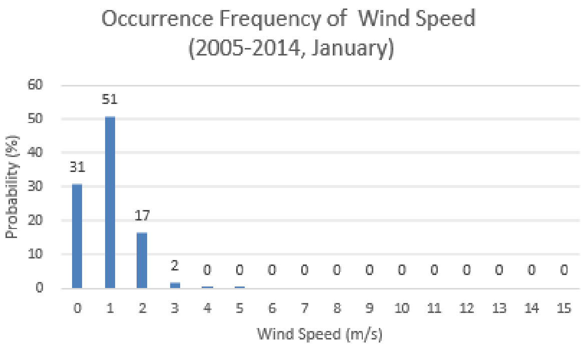
Source: "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)

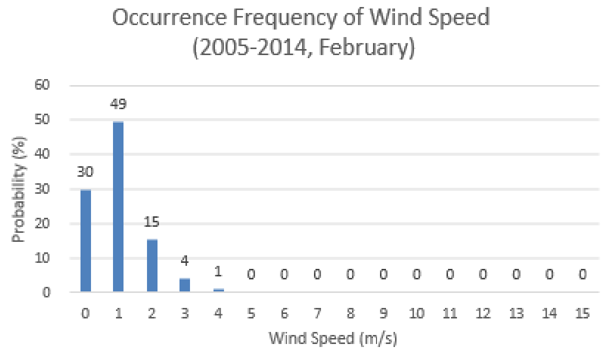
Figure 8-15 Deep Water Waves Data

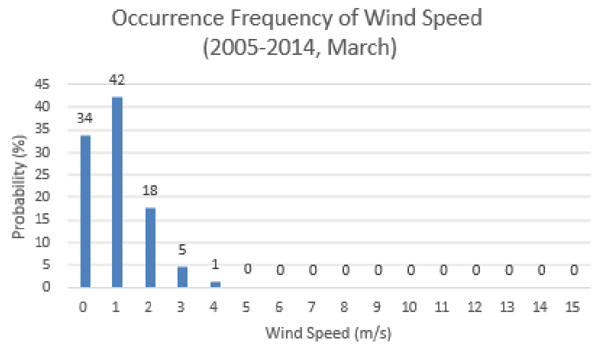
3) Wind data

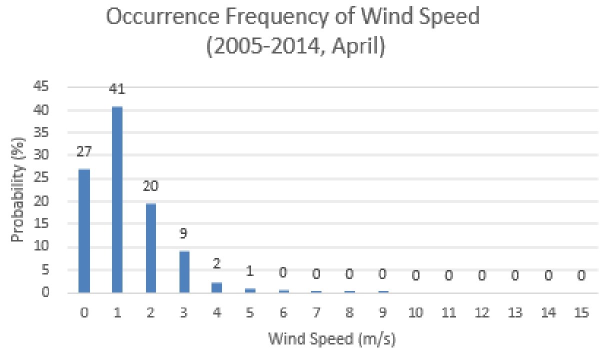
Based on “THREE HOURLY WIND SPEED AND DIRECTION” at Kutubdia which is close to the candidate site, the occurrence frequency of wind speed and direction is summarized.
Wind speed of more than 30knots was found only one time at 40knots at 15:00 PM on 17 Apr. 2009. The occurrence frequency of less than 30knots (15.4m/sec) was 99.99%. Therefore maximum allowable wind speed of 15m/sec or less for docking/ undocking and unloading work is found to be appropriate.
In terms of wind direction, North winds from November to February and South winds from April to October are most likely to occur. In winter season, “Calm” (wind speed
0.5m/sec or less) condition will be kept for a long time.

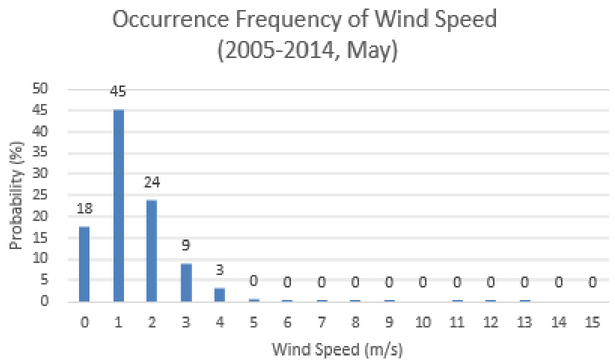
<u>Occurrence Frequency of Wind Speed</u>

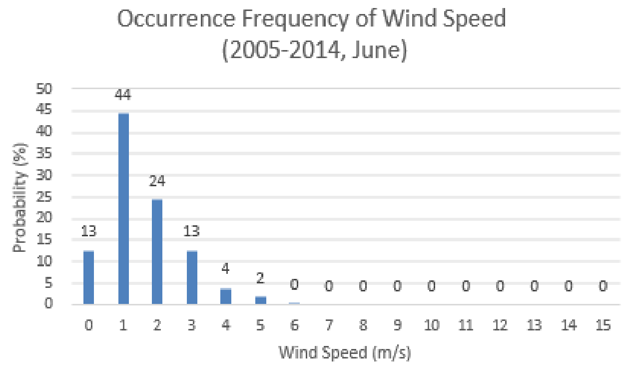


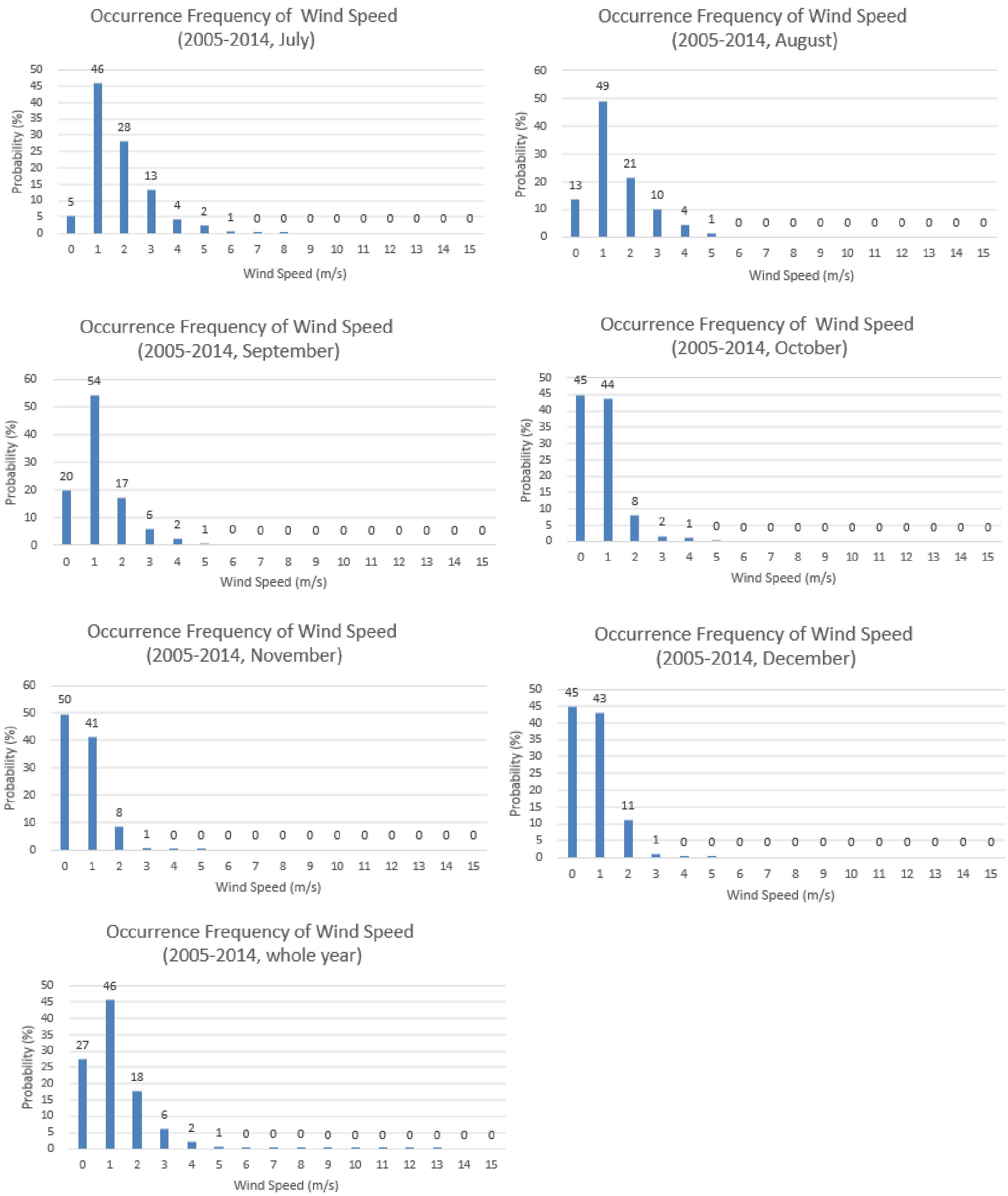










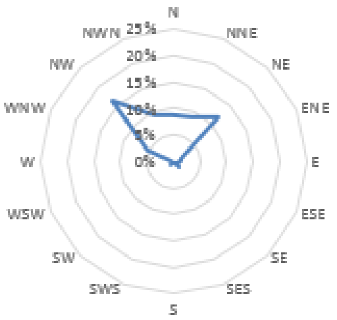


Source: JICA "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report" (March 2015, JICA/TEPSCO/TEPCO)

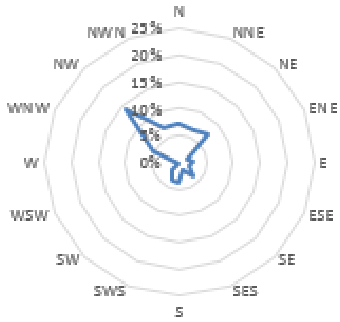
Figure 8-16 Occurrence of Wind Speed

Occurrence Ratio of Wind Direction

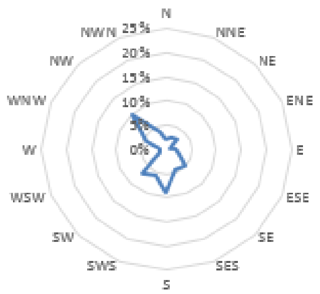
Occurrence ratio of Wind Direction
(2005-2014 January)
No Wind 32%



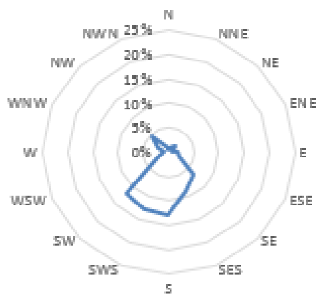
Occurrence ratio of Wind Direction
(2005-2014 February)
No Wind 31%



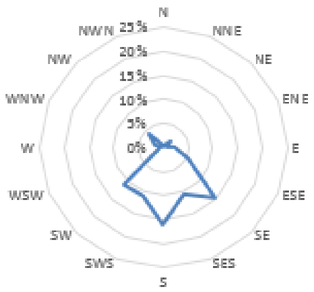
Occurrence ratio of Wind Direction
(2005-2014 March)
No Wind 35%



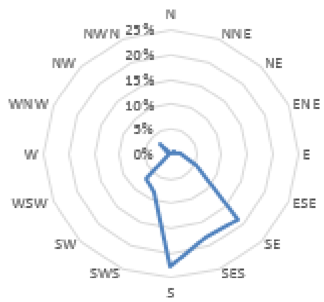
Occurrence ratio of Wind Direction
(2005-2014 April)
No Wind 28%



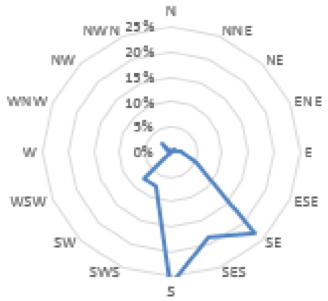
Occurrence ratio of Wind Direction
(2005-2014 May)
No Wind 18%



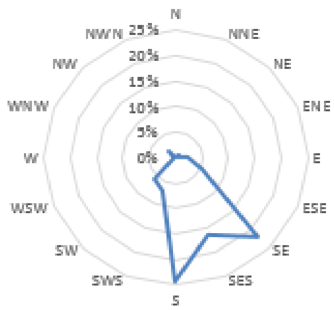
Occurrence ratio of Wind Direction
(2005-2014 June)
No Wind 13%

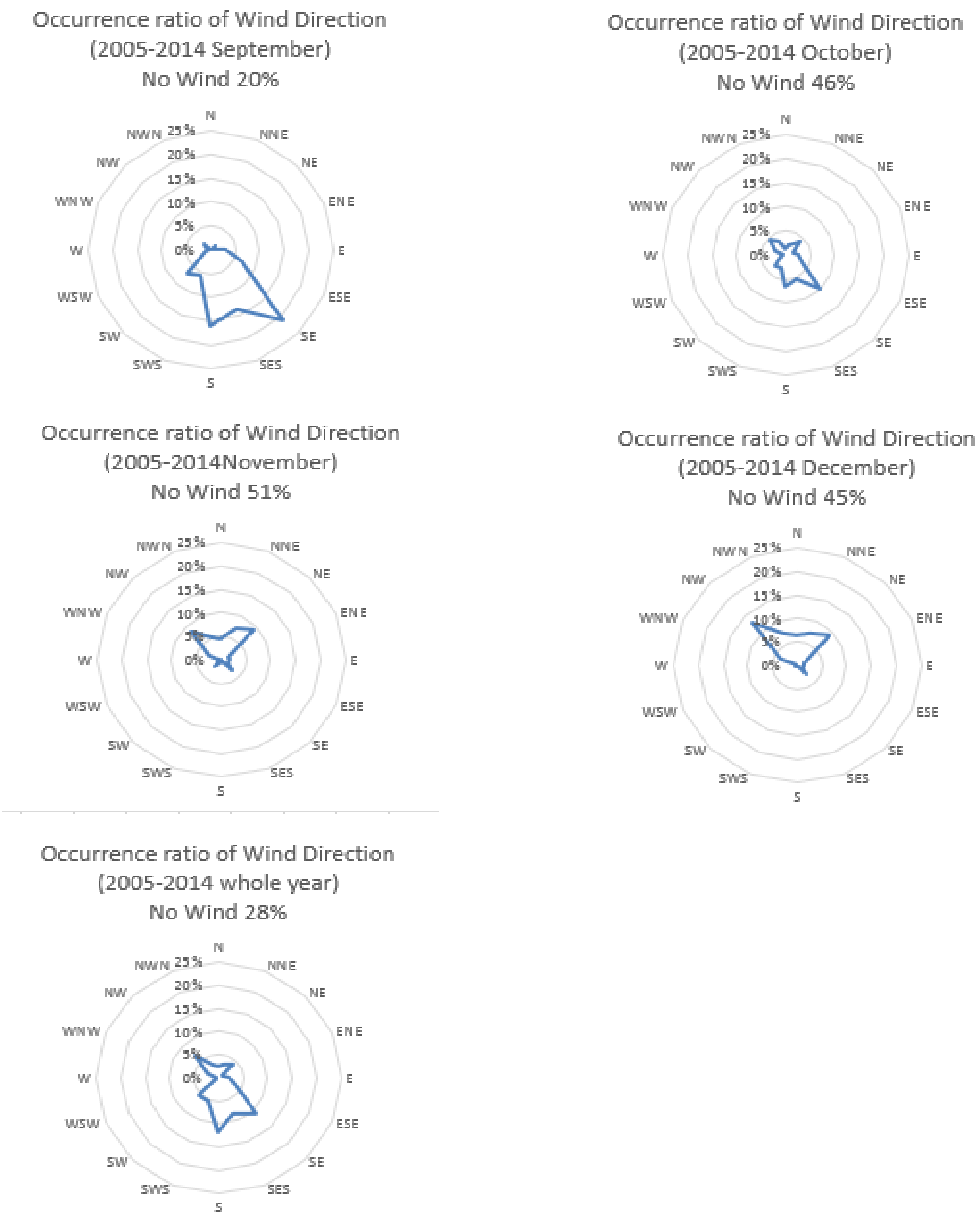


Occurrence ratio of Wind Direction
(2005-2014 July)
No Wind 5%



Occurrence ratio of Wind Direction
(2005-2014 August)
No Wind 14%





Source: JICA "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)

Figure 8-17 Occurrence of Wind Direction

〔Remark〕

In terms of wind conditions, 1 hour measurement data could not be obtained, so instead of it, "THREE HOURLY WIND SPEED AND DIRECTION" data at Kutubdia was utilized and the occurrence frequency was studied. 1 hour measurement data at near the site will be needed for the detail study.

(6) Site selection of LNG receiving terminal

1) Site selection

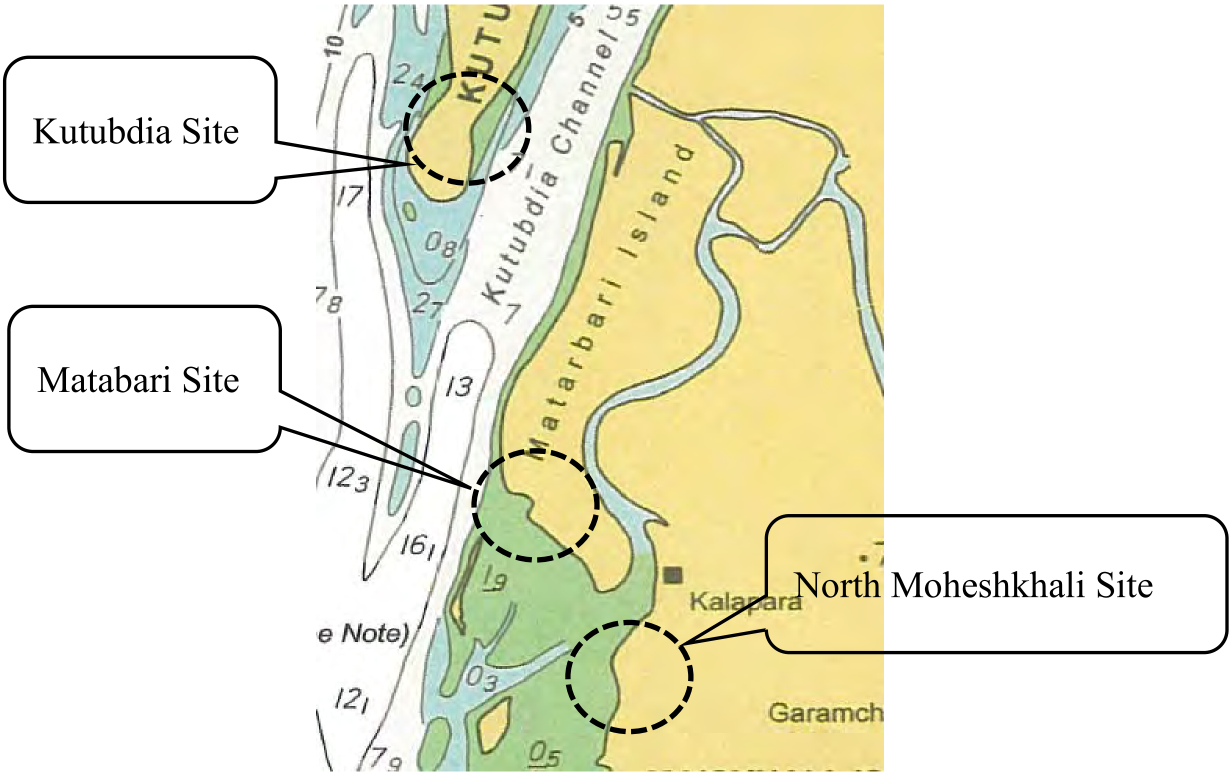
Three candidate sites of "Matarbari", "North Moheshkhali", and "Kutubdia" were selected in accordance with the above (1) to (5) criteria.

Furthermore the calmness was studied and compared in each candidate site. Above all, for Matarbari site, detail case study with three different ideas of LNG jetty design was done.

Table 8-12 Candidates of LNG Receiving Terminal LNG and Harbor/jetty Design Conditions

Case	Candidate site and condition		Remark
Case1-1	Matarbari Site	Jointly owned port	Jointly own port by coal power station and LNG receiving terminal
Case1-2		Individual port (without breakwater)	Construct LNG jetty in front of the ocean without breakwater
Case1-3		Individual port (with breakwater)	Construct LNG jetty and breakwater in front of the ocean
Case2	North Maheshkhali Site		Dredge shallow beach and construct channel and LNG jetty
Case3	Kutubdia Site		Dredge Kutubdia Channel and construct LNG jetty

Source: JICA PMSP2015 Survey Team



Source: JICA Survey Team

Figure 8-18 Candidate Sites of Land-based LNG Receiving Terminal

2) Evaluation by calmness (unloading availability)

Table 8-13 Case1-1 Jointly Owned Port Plan in Matarbari (Excavated Type Plan)

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	Entrance of channel	1.5m	94.7%＜95% By the Owner's judgement
	LNG berth	1.5m	more than 99.9% ＞ 95% Good
(Ref.)Coal port	Entrance of channel	1.5m	99.4% ＞ 96% Good
	Coal berth	1.0m	99.9% ＞ 96% Good

Source: JICA Survey Team

Note: In the feasibility study of collier, calmness was evaluated at the entrance of channel but for LNG tanker, calmness will be evaluated at the entrance of channel after turning around and root change.

Table 8-14 Case1-2 Matarbari Plan (Conventional Type Plan：Without Breakwater)

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	LNG berth	1.5m	94.7%＜95% By the Owner's Judgement
(Ref.)Coal port	Entrance of channel	1.5m	94.7% ＜ 96% Not Sufficient
	Coal berth	1.0m	93.5% ＜ 96% Not Sufficient

Source: JICA Survey Team

Table 8-15 Case1-3 Matarbari Port Plan (Conventional Type Plan：Breakwater Construction)

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	LNG Berth	1.5m	more than 96.5% ＞ 95% Good
(Ref.)Coal port	Entrance of channel	1.5m	99.2% ＞ 96% Good
	Coal berth	1.0m	96.5% ＞ 96% Good

Source: JICA Survey Team

Table 8-16 Case2 North Maheshkhali Plan

	Area	Threshold Wave Height	Rate of Effective Working Days
LNG port	Entrance of channel	1.5m	96.8% ＞ 95%　Good
	LNG berth	1.5m	more than 96.2% ＞ 95%　Good
(Ref.)Coal port	Entrance of channel	1.5m	96.8% ＞ 96%　Good
	Coal Berth	1.0m	96.2% ＞ 96%　Good

Source: JICA Survey Team

Table 8-17 Case3 Kutubdia Channel Plan

	Area	Threshold Wave Height	Rate of Effective Working Days
LNGport	LNG Berth	1.5m	more than 94.7%＜95% By the Owner’s judgement

Source: JICA Survey Team

Remarks:
a) In this study calmness analysis was not done at the candidate port. To select the candidate site, detail calmness analysis should be implemented and studied.
b) Max allowable wind speed and wave height for unloading and criteria for docking and undocking at LNG port should be fixed by the Owner in consideration to the feasibility and operation of LNG receiving terminal.
c) Evacuation method, port for evacuation, and basins in case of bad weather should be considered.

3) Evaluation result of candidate site

Table 8-18 Candidate Site Evaluation Result

Case	Case1-1	Case1-2	Case1-3	Case2	Case3
calmness	◎	○	◎	◎	○
Comparison of Cost	Cost effective	Cost effective *Filling Soil Balance	Fairly expensive (Breakwater construction)	Expensive (Continuous dredging)	Expensive (Continuous dredging)
Natural Environment	-	-	-	Mangrove forest	-

Source: JICA Survey Team

Remarks
a) For the evaluation of breakwater construction cost, continuous dredging cost, and environmental cost, reference is made to the” Study of Coal Fired Project in Chittagong”b) It is uncertain how difficult it is to secure embankment material for land creation of LNG receiving terminal yard but case1-1, case2, and case 3 will be an effective plan in order to secure a certain amount of soil volume by dredging and cut for port preparation.

8.8.5 Ground level

"The pre-FS of coal fired power station in Chittagong" shows the detail study of a flood tide caused by the ebb and flow and cyclone. With the same criteria, land creation can be planned in LNG receiving terminal.

Ground level of LNG receiving terminal facility yard can be fixed as +10.0m M.S.L with reference to the flood tide which may ocuure once in 50 years by cyclone. On the other hand, ground level of the port can be fixed as +5.0m M.S.L.

(1) Design tidal level

H.W.L. = +2.20m M.S.L M.S.L. = ±0.0m L.W.L. = -2.20m M.S.L.

(2) Storm surge height

Table 8-19 Storm Surge Height

Storm Surge Height	Average	25-year Return Period	50-year Return Period
Base on Maximum Data	4.2m	8.0m	9.0m
Base on Minimum Data	3.3m	6.2m	7.0m

Source: JICA Survey Team

(3) Design ground level

1) LNG Facilities Yard E.L. = +10.0m M.S.L.
2) Port Revetment E.L. = +5.0m M.S.L

8.8.6 Subsurface exploration

With "the pre-FS report of coal fired power station in Chittagong", the comprehensive subsurface exploration was implemented in 2012 and 2014. The result in 2014 will be shown in the following.

Subsurface at local site is composed by;

1. sand layer of 2 m thickness in the surface, then
2. alluvial sandy soil and alluvial clay of N value of 10 to 20 which thickness is 20 m, then
3. diluvial sandy and clay of N value of 30 to 40

Bearing pile for the main structure like LNG Storage Tank should be inserted to this diluvial sandy (DS).

Table 8-20 Subsurface Data (part.1)

Layer	Material	Relative Density or Consistency	Thickness of Layer (m)	SPT(N) Values
Bs	Sandy Soil	Loose to Medium Dense	0.6 to 2.0	4 to 24
Ac-1	Clayey Soil	Very Soft to Soft	0.8 to 12.7	0 to 4
Ac-2	Clayey Soil	Medium Stiff to Stiff	0.9 to 8.7	4 to 15
Ac-3	Clayey Soil	Stiff to Hard	1.1 to 9.0	15-30
As-1	Sandy Soil	Very Loose to Loose	1.1 to 6.0	0 to 10
As-2	Sandy Soil	Medium dense to Dense	0.7 to 21.9	10 to 50
Dc	Clayey Soil	Hard	1.4 to 17.3	≧30
Ds	Sandy Soil	Very Dense	0.5 to 13.2	≧50

Source: "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)

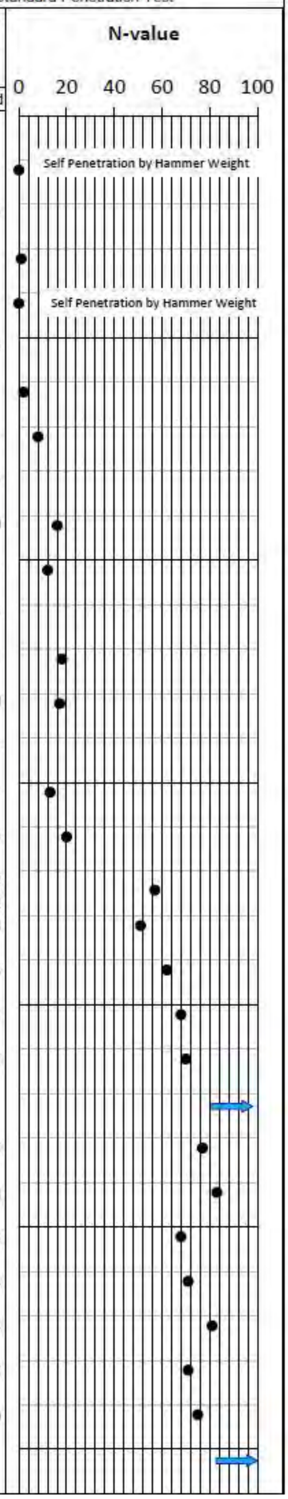
Fig. Drilling Log

Hole Number: **PP-21-2**

Project No.	S27-14	Project Name:	**Matarbari PP**
Supervisor:	Royal	Coordinate:	N:2400114.87 E:384808.77
Driller:	Matab	Date Started:	20140915
Type of Drilling Rig:	Rotary:KJC-L-1	Date Terminated:	20141007
Sheet:	1	Elevation:	MSL+1.12 m
Water Table:	GL+0.30 m	Remarks:	Wetland:Final casing depth GL-6m

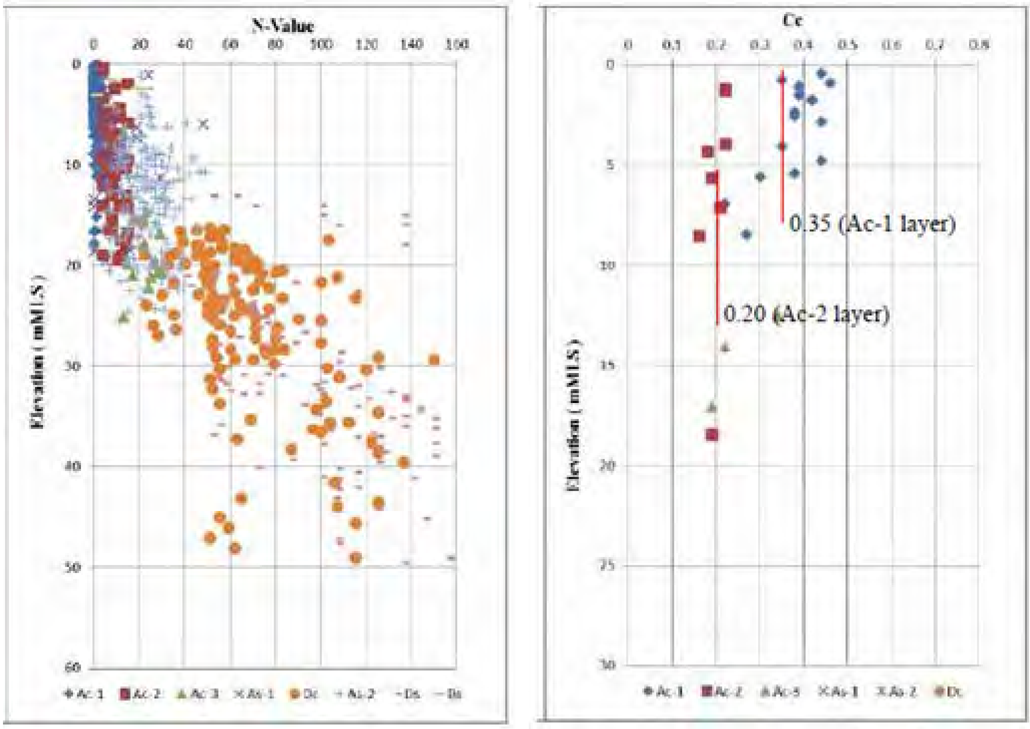
Elevation in m	Depth in m	Thickness in m	Type of Soil	Color	Relative Density or Consistency	General Remarks
1.12 / -0.68	0.00 / 1.80	1.80	Clay	Grey	Very Soft	With trace of fine grained sand, sea shell fragments, organic matter, decomprosed wood
-4.88	6.00	4.20	Silty Clay	Grey	Very Soft	With trace of fine grained sand, organic matter and mica fragments
-5.68	6.80	0.80	Sandy Silt	Grey	Very Soft	Sand is fine to medium grained. With organic matter, mica fragments.
-12.48	13.60	9.80	Clayey Sand	Grey	Medium Dense	Fine to medium grained sand. With organic matter and mica fragments. Occasionally sandy clay pocket.
-14.48	15.60	2.00	Sandy Clay	Grey	Stiff	Sand is mostly fine grained. With trace of mica fragments.
-16.18	17.30	1.70	Silty Clay	Grey	Very Stiff	With trace of fine grained sand.
		14.50	Silt	Grey	Hard	With lots of fine grained sand and trace of organic matter. With lenses of silty sand. Occasionally clayey silt

From	To	C'ter	Sample No.	N-value blows/30cm	1st	2nd	3rd
1.00	1.45	1.23	SPT-1	0	0	0	0
2.00	2.85	2.43	HP-1	REC:85/85			
3.00	3.45	3.23	SPT-2	1	1	0	1
4.00	4.45	4.23	SPT-3	0	0	0	0
5.00	5.85	5.43	HP-2	REC:85/85			
6.00	6.45	6.23	SPT-4	2	2	1	1
7.00	7.45	7.23	SPT-5	8	2	2	6
8.00	8.85	8.43	D-1	REC:85/85			
9.00	9.45	9.23	SPT-6	16	4	6	10
10.00	10.45	10.23	SPT-7	12	3	4	8
11.00	11.85	11.43	D-2	REC:70/85			
12.00	12.45	12.23	SPT-8	18	5	7	11
13.00	13.45	13.23	SPT-9	17	5	7	10
14.00	14.85	14.43	D-3	REC:70/85			
15.00	15.45	15.23	SPT-10	13	2	5	8
16.00	16.45	16.23	SPT-11	20	4	6	14
17.00	17.20	17.10	HP-3	REC:20/20			
17.20	17.65	17.43	SPT-12	57	16	25	32
18.00	18.45	18.23	SPT-13	51	14	23	28
19.00	19.45	19.23	SPT-14	62	12	24	38
20.00	20.45	20.23	SPT-15	68	11	27	41
21.00	21.45	21.23	SPT-16	70	18	23	47
22.00	22.29	22.15	SPT-17	50 /14cm	25	50 /14cm	
23.00	23.45	23.23	SPT-18	77	19	32	45
24.00	24.45	24.23	SPT-19	83	15	35	48
25.00	25.45	25.23	SPT-20	68	12	25	43
26.00	26.45	26.23	SPT-21	71	14	27	44
27.00	27.45	27.23	SPT-22	81	11	27	54
28.00	28.45	28.23	SPT-23	71	12	26	45
29.00	29.45	29.23	SPT-24	75	11	25	50
30.00	30.27	30.14	SPT-25	50 /12cm	17	50 /12cm	



Source: "Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO), Appendix-C-17-01 Drilling Logs p.94

Figure 8-19 Drilling Log



Source: Preparatory Survey on Chittagong Area Coal Fired Power Plant Development Project in Bangladesh Final Report"(March 2015, JICA/TEPSCO/TEPCO)

Figure 8-20 Subsurface Data (Part2, 3)

The surface layer, alluvial sandy and alluvial clay are relatively weak. And the foundation of LNG facility yard should be raised by 10 m as a countermeasure against the flood tide. Therefore the comprehensive soil stabilization will be needed.

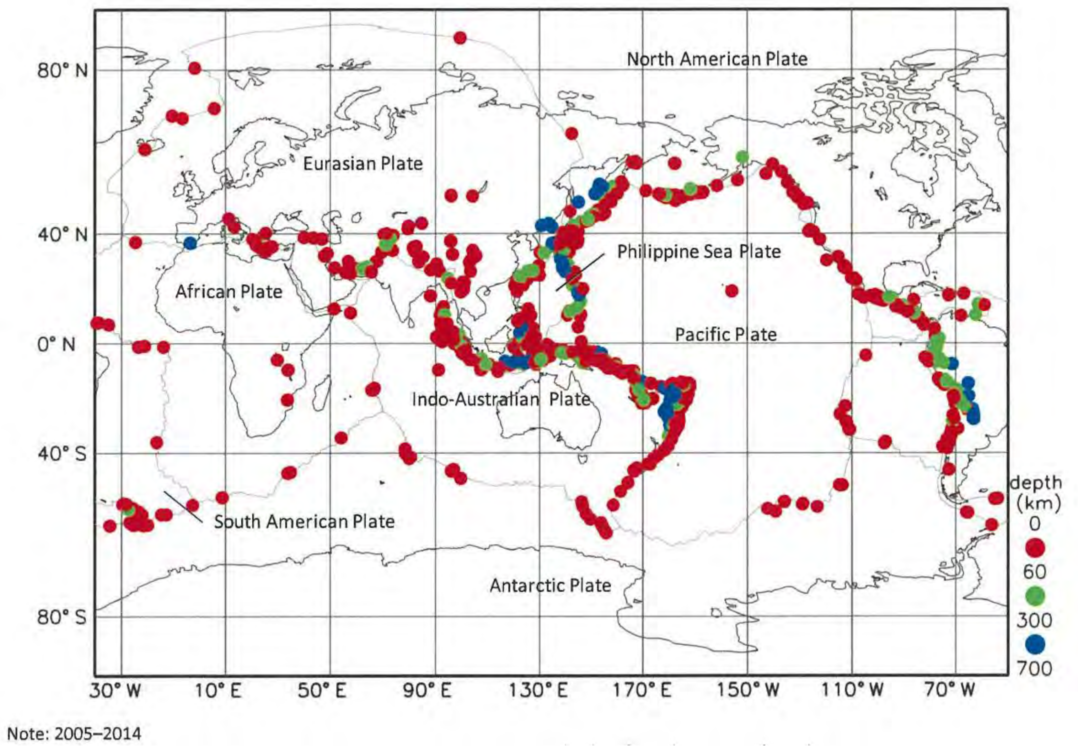
If spoil or excavated soil is used as an embankment material, the reinforcing ground of banking may be needed by the property of earth and sand.

Alluvial clay: PVD (Prefabricated Vertical Drain Method), DMM (Deep Mixing Method) Alluvial sandy: SCP (Sand Compaction Pile Method) Embankment material: DMM, etc.

8.8.7 Earthquake

(1) Distribution of earthquake centre

Worldwide hypo central distribution and plate location will be shown in the below Figure.
The boundary between Indian plate and Eurasian plate is faced in Bengal Bay and here mega scaled earthquake has been frequently occurred in the past.



Source: White Paper on Disaster Management" (Cabinet Office, Government of Japan)

Figure 8-21 Worldwide Hypocenter Distribution (for Magnitude 6 and Higher Earthquakes) and Plate Boundaries

(2) Seismic design

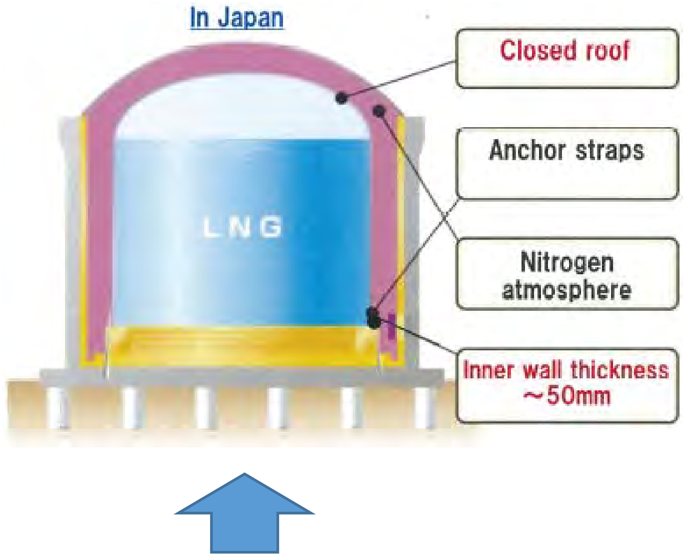
1) Seismic design standard

Bangladesh is a seismically active nation, so「BANGLADESH NATIONAL BUILDING CODE 2006」was established and applied as an earthquake resistant design code.
LNG tank and other facility in the terminal are supposed to be designed in accordance with this standard

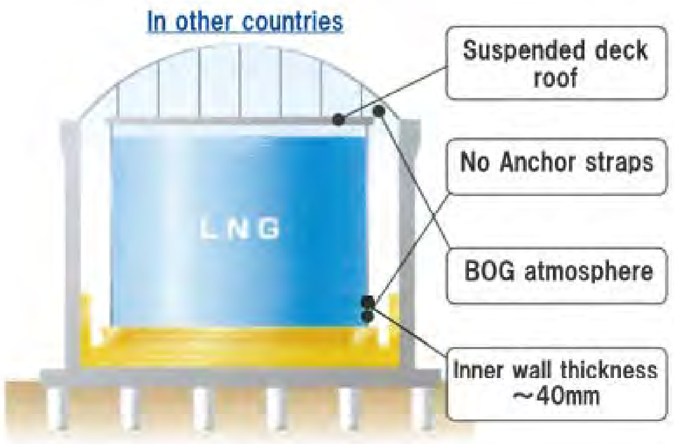
2) Earthquake- resistant LNG storage tank

Normally design seismic coefficient of LNG Storage Tank is designed as SSE 0.2g and OGE 0.1g in Japan and other countries.
In no seismically active nations like Thailand and Singapore, the suspended deck type LNG Storage Tank can be applied but in Bangladesh dome roof type (full containment type) LNG Storage Tank will be recommended, which has been already applied in Taiwan and Japan.

Dome roof type PC LNG Storage Tank



Suspended deck type PC LNG Storage Tank



Source: JICA Survey Team

Figure 8-22 Structure of Earthquake- resistant LNG Storage Tank

Source: Osaka Gas Senboku terminal

Figure 8-23 Overview of Above Ground Dome Roof Type PC LNG Storage Tank

1) In Japan anti-earthquake design procedure for LNG storage tank has been established.
2) Japanese LNG storage tank manufacturer is familiar with major international design code and standard such as API and EN.
3) Bangladesh is identified as a seismically active nation, so the dome roof type LNG storage tank is better fitted in the seismic design than the suspended deck type LNG storage tank. Dome roof type LNG storage tank has many construction experiences among the seismically active nations such as Japan and Taiwan.
4) Dome roof type LNG storage tank is superior to suspended desk type LNG storage tank in anti-sloshing performance. In the dome roof type LNG storage tank, N2 gas is filled in the gap between inner and outer tank wall, so the dome roof type LNG storage tank is more safety because LNG leakage is more detective than the suspended deck type LNG storage tank.
5) The maximum allowable capacity of the dome roof type LNG storage tank based on API and EN code and standard is seemed to be 180, 000 m3 per unit in Bangladesh.
6) In Japan 180,000m^3 or 200,000m^3 or 23,000m^3 LNG storage tanks have been already constructed and steadily operated.

Remarks

The material described an active fault in Bangladesh has not been disclosed yet but an active fault may be present near to the candidate site of LNG receiving terminal.

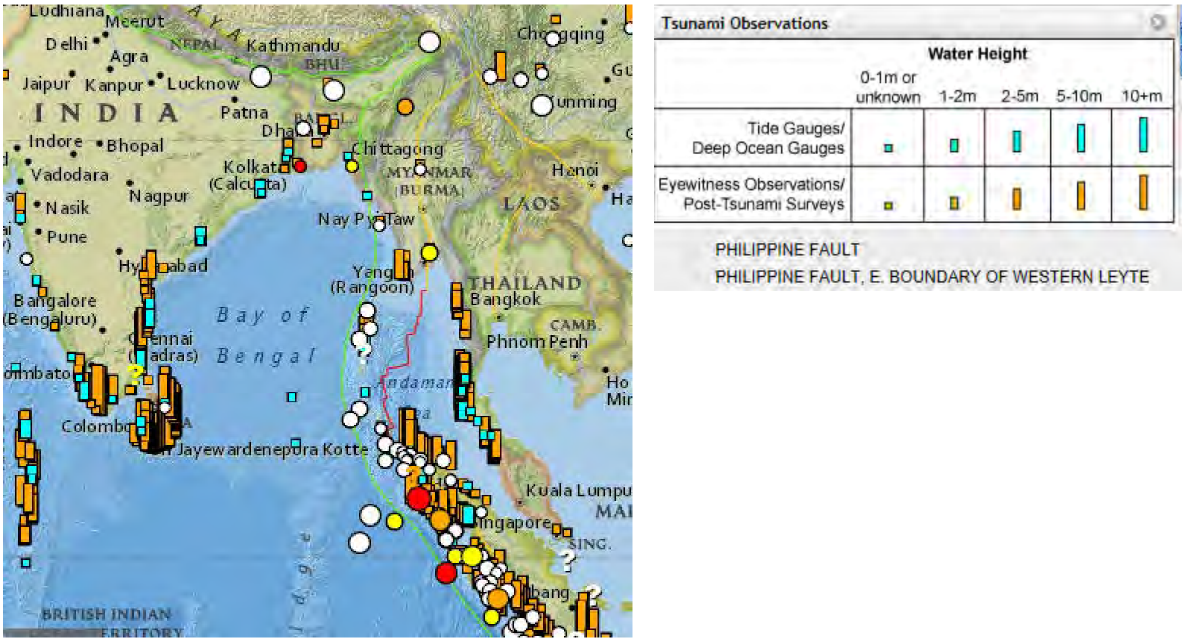
LNG Storage Tank should be designed to be far from the active fault as much as possible because the damage will be so large in case of the large scale disaster.

When feasibility study or FEED of LNG receiving terminal will be implemented, a geological survey at site should be done and the obtained data should be reflected to site selection, plot plan, and earthquake-resistant design of main equipment in the terminal.

8.8.8 Countermeasures to Tsunami

Bangladesh is very close to the border area between the plates, so Tsunami attack by large scale earthquake should be seriously considered. Tsunami hazard map in the Indian Ocean and Bay of Bengal will be shown in the below Figure.

The candidate site of LNG receiving terminal is located in the north peak of Bay of Bengal where the expected Tsunami height is 1 to 3 meter. This Tsunami height is less than that made by a cyclone, so Tsunami height may not be considered in the design of LNG receiving terminal..



Source: NOAA: National Centers for Environmental Information Natural Hazards Viewer-Tsunami Observation

Figure 8-24 Tsunami Hazard Map in the Indian Ocean and Bay of Bengal

At the feasibility or FEED stage, the countermeasure should be studied again for the large scale earthquake occurred in the boundary area between the plates in Bay of Bengal.

8.8.9 CAPEX & OPEX of on shore LNG receiving terminal

With the average cost index in the existing on shore LNG receiving terminal, CAPEX at the 1st stage (500MMCFD of NG send-out capacity, 3.5MTPA of LNG loading capacity) and the final stage (1,500MMCFD of NG send out capacity, 10.4 MTPA of LNG loading capacity) will be shown respectively in Table 8-21. Each specification of the 1st stage and final stage can be referred in the below Table.

Table 8-21 CAPEX Estimation

(Unit: US MM$)

	1st stage (500MMCFD, 3.5 MTPA)	Final stage (1,500MMCFD, 10.4 MTPA)
Land acquisition	200	200
Jetty and loading facility	100	200
Regasification facility	130	320
LNG storage tank	300	700
Others	30	80
Total	760	1,500

Source: JICA Survey Team

On the other hand, OPEX will be assumed to be varied from US$0.3/MMCF at 1st stage to US$0.6/MMCF at final stage when applied Japanese and Korean terminal operation record.

8.9 Challenges and Issues of LNG Terminal Implementation

8.9.1 Preparation for Finance

For the construction and operation of the LNG Terminal, financial preparation is significantly important to cover the capital/operational expense to be borne by the public.
In this regard, the Energy Security Fund was created last year to ensure availability of future expensive energy for funding the import of LNG, the building of LNG terminal, import of liquefied petroleum gas (LPG), construction of LPG terminal and other projects related to energy security. According to the article by Financial Express dated 22 August, 2016, “Energy set to be dearer with expensive LNG, LPG imports”, the fund was created in accordance with the BERC order over the hike of natural gas tariffs in September last year, when it increased the average prices of natural gas by 26.29 per cent. Since the distribution companies were profiting from the sale of natural gas before the price hike, the commission created the fund with the asset value of natural gas, as fixed at Tk 25 per cubic metre by the government. Some Tk 28 billion will be accumulated into this fund every year, the BERC official estimates.
As of August 2016, BERC is under finalization of guidelines for using the Energy Security Fund.
This kind of fund preparation can be further strengthen for securing the budget for LNG terminal,though well consideration of effect on economy by gas price hike should be taken in parallel.

8.9.2 Establishment of LNG value chain

(1) To ensure a stable LNG supply and reduce LNG stock period in tank by the diversification of LNG supply source and securement of LNG transportation route, the Buyer, in the LNG sale and purchase agreement, should negotiate to mitigate “Take or Pay condition” the change of destination and to induce the lower price by the cooperation with other Buyer. LNG transportation contract should be also competitive.
(2) The reliable LNG unloading, storage, vaporization, and send-out should be operated in a safe, stable, and low cost manner.
(3) LNG supply method should be diversified such as send-out gas, LNG re-loading, LNG bunkering as ship fuel, LNG truck loading to the satellite station. At the same time, the stable LNG demand should be found in power plant, industrial/commercial/residential sector, and the third party operating the terminal.

8.9.3 Operation of LNG receiving terminal

LNG receiving terminal will apparently play an important role as one of energy infrastructure year by year. The terminal should be operated smoothly at start up period and then should be operated steadily to pursue the high availability and reliability.
To achieve it, various attention is needed from the point of operating organization, facility planning, maintenance, training, anti-disaster facility, and environmental protection, etc.

(1) Operating organization

Operation of the terminal needs operating team, maintenance team and engineering team as a whole. Each team needs a skillful engineer in the gas processing field as a team leader. The beginner should study through the Vendor's seminar or others and should be given the opportunity to study in the similar LNG receiving terminal abroad, which will be very effective manner to enhance the understanding. When the commercial operation has started, operating team should take a leadership to address the operating issues.
Next, main responsibility of each team will be clarified.

- Operating team is normally organized by 4 teams and will do a time shift work in 24 hours through the year. It will also designate operating facility regarding to the requested send-out gas amount and also support LNG unloading operation in the terminal side when LNG vessel will reach to the terminal.
- Maintenance team works in a day time to grasp the operating condition of all facility though the daily check by database and establish the unique maintenance criteria designated for the terminal.
- Engineering team studies the reason of mal function in the commercial operation and will address the improvement of the facility when considering the optimum repairing plan and budget.

(2) Operation management

Operator will monitor and control all of the facility in the terminal from CCR. Especially the optimum LNG storage tank operation and special attention should be paid to the protection of tank stratification phenomenon. .
The amount of send-out gas and utility consumption should be managed for the stable operation and safety in the terminal.
Operator will also patrol the local site periodically and try to find the mal function point such as gas leakage, abnormal noise and vibration, etc.

(3) Maintenance of the facility

Maintenance team will prepare the monthly and yearly maintenance plan and the mid to long term maintenance plan with the budget by the enough discussion with operating team.
To cope with the unexpected equipment failure and system error, the utilization of "on-line call system" or remote maintenance contract with Vendor may be effective. Further as a self-maintenance measure, the optimum management of the inventory and the update information exchange with maintenance service provider will be also crucial.

(4) Education and training

Through the internal discussion (QC circle activity) to initiate the operation manual and the optimum countermeasure at if case, the operation skill at normal and emergency situation will be developed. Operator should join with the purpose to the technical tour in other terminal and seminar and/or training program by Vendor, which will develop the operation skill of the team.

OTS (Operating training simulator) has been developed in a recent year, which enables to generate various mal function cases in the monitor and evaluate operator's skill to recover from such mal function cases logically.

8.9.4 Effective terminal management

With the growing gas demand in Bangladesh in the future, the enforcement of gas demand supply management system will be more needed nation widely. Namely if LNG receiving terminal is constructed in many places to compensate the supply shortage of domestic gas, the integrated gas dispatch center will be needed to order the allocated gas send-out amount to each LNG receiving terminal. Practically the SCADA system owned by TGCL should be highly upgraded to meet this requirement.

From the view point of stable NG supply, to cope with the serious mal function at major facility and natural disaster, back up operation manner among the plural terminals should be studied and trained. Moreover in preparation for terrorist attack and riot, the terminal security plan should be seriously considered and emergency training should be carried out as a routine work.

Chapter 9 Coal Supply

9.1 National Coal Development Policy

9.1.1 Present situation of the coal policy

Currently, the progress is not seen in Coal Policy, and the future prospect is not clear, either. On the other hand, the extension plan of production in Barapukuria coal mine is advancing.

As a specific example of the new coal mine development, there are Dighipara、Khalaspir and Phulbari.The application of the exploration license of Dighipara goes out from Perobanngla and the applications of new coal mine development of Khalaspir and Phulbari also go out, but they are under suspension because the government does not accept them.

9.1.2 PSMP2010 review

Table 9-1 shows the comparison between predicted production until 2041 by domestic coal mine and predicted value in PSMP2010.

In addition, the figures in Table 9-1 are shown by a graph in Figure 9-1. The reasons that lowered amount of predicted production of PSMP2016 in comparison with that of PSMP2010 are following the fact that the Coal Policy at the time of PSMP2010 elaboration was very positiveand the PSMP Study Team with Bangladesh counter parts made a rather ambitiousproduction prediction in PSMP 2010, but based on the current situation of not positive Coal policy and on the fact that all applications for the coal development are shelved, prediction of production in PSMP2016 is rather conservative.

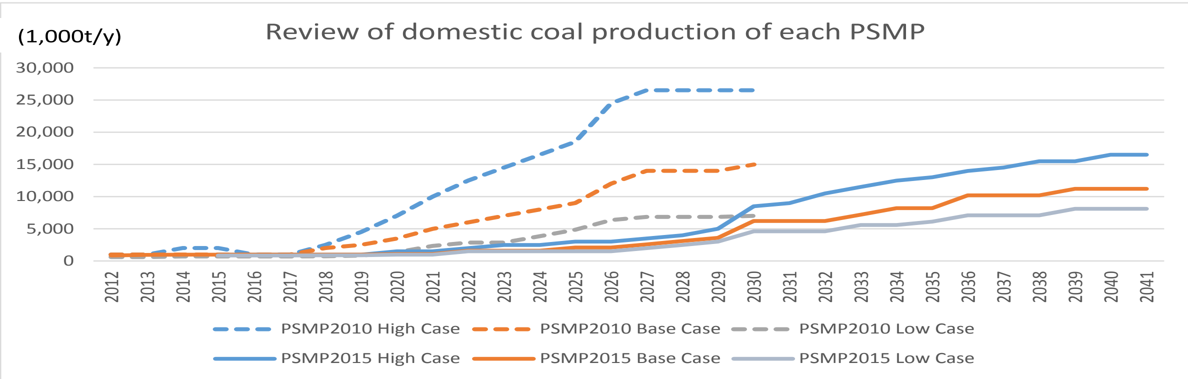
Table 9-1 Comparison of Forecasted Domestic Coal Production between PSMP2010 and This Investigation

Year	Domestic Coal Production in PSMP2010 (1,000t)			Domestic Coal Production in PSMP2016 (1,000t)		
	(Note: From 2005 to 2008 shows actual production)			(Note: From 2012 to 2013 shows actual production)		
	High Case	Base Case	Low Case	High Case	Base Case	Low Case
2012	1,000	1,000	600		855	
2013	1,000	1,000	600		947	
2014	2,000	1,000	700		1,000	
2015	2,000	1,000	700	1,000	1,000	850
2016	1,000	1,000	700	1,000	1,000	850
2017	1,000	1,000	700	1,000	1,000	850
2018	2,500	2,000	750	1,000	1,000	900
2019	4,500	2,500	850	1,000	1,000	900
2020	7,000	3,500	1,350	1,500	1,100	1,000
2021	10,000	5,000	2,350	1,500	1,100	1,000
2022	12,500	6,000	2,850	2,000	1,600	1,500
2023	14,500	7,000	2,850	2,500	1,600	1,500
2024	16,500	8,000	3,850	2,500	1,600	1,500
2025	18,500	9,000	4,850	3,000	2,100	1,500
2026	24,500	12,000	6,350	3,000	2,100	1,500
2027	26,500	14,000	6,850	3,500	2,600	2,000
2028	26,500	14,000	6,850	4,000	3,100	2,500

Year	Domestic Coal Production in PSMP2010 (1,000t) (Note: From 2005 to 2008 shows actual production)			Domestic Coal Production in PSMP2016 (1,000t) (Note: From 2012 to 2013 shows actual production)		
	High Case	Base Case	Low Case	High Case	Base Case	Low Case
2029	26,500	14,000	6,850	5,000	3,600	3,000
2030	26,500	15,000	7,000	8,500	6,200	4,600
2031				9,000	6,200	4,600
2032				10,500	6,200	4,600
2033				11,500	7,200	5,600
2034				12,500	8,200	5,600
2035				13,000	8,200	6,100
2036				14,000	10,200	7,100
2037				14,500	10,200	7,100
2038				15,500	10,200	7,100
2039				15,500	11,200	8,100
2040				16,500	11,200	8,100
2041				16,500	11,200	8,100

Remarks: YEAR shows the fiscal year in the table. The fiscal year Bangladesh is from July to June. For example, 2012 show from July, 2012 to June, 2013 in 2012

Source: JICA Survey Team



Source: JICA Survey Team

Figure 9-1 Comparison with PS2010

9.1.3 Significance of the coal development

There are two reasons that Bangladesh will push forward domestic coal development in the future.

(1) Steady supply of the increasing import charcoal

The coal demand of Bangladesh mentioned later in 9.4.1 is expected to become 60million tons in 2041. On the other hand, the demand of thermal coal in the Southern and Eastern Asia will rapidly increases. As a result, it is unknown whether Bangladesh can import overseas coal of stable quality at reasonable price. It is therefore predicted that it becomes the course of nature to make efforts to supply domestic coal instead to the possible extent.

(2) Coking coal and thermal coal

There is coking coal in some coal field in Bangladesh. The price of coking coal costs approximately 2 times in comparison with thermal coal and the demand is very huge in the world including India. Generally, foreign coutries producing coal, such as Australia are selling coking coal and middling as thermal coal after washing coal. In the case of Bangladesh, coking coal will be exported and middling will be supplied to a domestic coal fired power station. The investment effect of the coal mine development is very big.

9.2 Current Situations and Issues of Supply and Demand of Domestic Coal

9.2.1 Coal reserve of each coal field and estimated minable coal reserve

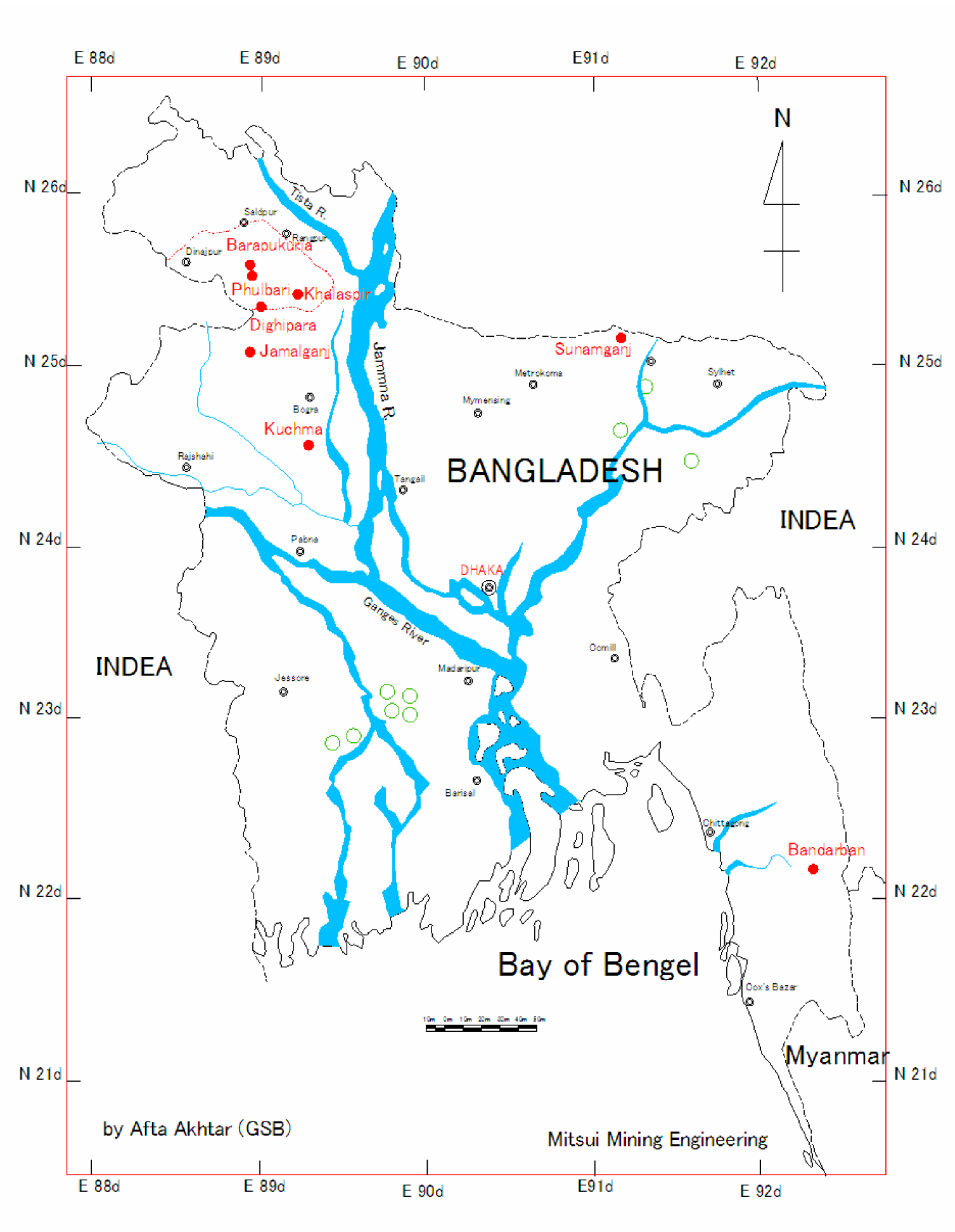
It is well known that the bituminous coal, which is called “Godwin coal” of the Permian Period as well as sub-bituminous coal to lignite of the Tertiary Era occur in Bangladesh. According to the present development data, there are five coal fields in Bangladesh, all of which located in between the Jamuna river and the Padma river in the northwestern part of Bangladesh. The measured and probable coal reserves in total are estimated to be 3.3 billion tons. According to the Draft Coal Policy (June 2007), the measured coal reserve that can be mined for the time being is estimated to be 1,168 million tons, except in Jamalgonj where coal seams are located relatively deep underground. Though there is no additional information in the study of PSMP2016, as developments continue, probable coal reserves are likely to increase. Figure 9-2 indicates the location of coal fields.

Coal in Bangladesh is generally characterized as having low ash content and low sulfur content that are in favor of the environment. It is bituminous coal with properties similar to the coal being used by power stations in Japan. Another grade of coal, which is classified into coking coal for iron production whose commodity value is very high in the market, is also available.

Meanwhile, the problem lies in its mining method. For underground coal mines, the thick coal seams (30 to 40m) pose a problem for the mining method and mining rate. For open-cast coal mines, the mining method which includes dewatering technology to prevent inundation and protect the environment has become an issue, because coal deposits accumulate in the relatively deep underground (170 to 450m) and such a coal mine tends to have an aquifer, called "UDT (Upper Dupi Tila)," over the coal seams. The upper coal seam in particular is dotted with a rice field, the places of residence of inhabitants, and the move of inhabitants, social environmental consideration become the important issue.

Table 9-2 shows the details of six coal fields that were explored and the progress in their development. The Barapukuria Coal Mine is the only operating coal mine in Bangladesh and is undergoing completely mechanized underground mining, the details of which will be described later. An open-cast coal mine development in Phulbari came to a deadlock due to the oppositions by the local people, which will give directions to the coal mine development in Bangladesh. In other words, coal mine development in Bangladesh will depend on whether the Government of Bangladesh can successfully win, as a national policy, consent from people for an open-cast mining method, which is superior to underground mining in terms of stable coal production.

Table 9-3 shows estimated minable coal reserve depending on open-cast and underground mining method. As for the quantity of actual minable coal, 438 million tons in No .1 to No.4, it is calculated based on present mining method.



Source：GSB

Figure 9-2 Locations of Coal Fields in Bangladesh[1]

1 Red points indicate coal fields.

Table 9-2 Coalfield Development Status in Bangladesh

No.	Coal field name	Develop-ment year	Exploring company (Number of borings)	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured coal reserve (100 million tons)	Measured＋probable coal reserves (100 million tons)	Remarks
1	Barapukuria (Dinajpur)	1985 -87	GSB (31)	118 -506	6	51	3.03 (Minable coal reserve by U/G: 64 million tons)	3.9	・Petrobangla and China National Machinery Import and Export Corporation (CMC) in China concluded an development agreement in 1994. BCMCL was founded in 1998. Capacity designed: One million ton /year. ・Enhancement of production is under planning. ・A small-scale open-cast mining project is feasible. For open cut mining technology introduction, Tata of the Indian company suggested open-air mining, but the government does not give a conclusion. Consent? ・A 250MW coal-fired thermal power station is in operation, and a study is on the table to build a new 125MW power station.
2	Phulbari, (Dinajipur)	1997	BHP (108)	150 -240	2	15-70	5.72	5.72	・Asia Energy has completed a feasibility study. When the company was going to engage in a large-scale open-cast coal mine development, the development project was suspended in August 2006 due to oppositions by local people. ・It is a problem that the Phulbari open-cut mining plan submitted by Asian energy did not touch about groundwater behavior and a landfill plan after mining. The biggest problem is drinking water and irrigation water measures of inhabitants. ・Although Global Coal Management has succeeded to the development interest, progress made so far is unknown.
3	Khalaspir, (Rangpur)	1989 -90	GSB (14)	257 -483	8	42.3	1.43	6.85	・The measured coal reserve is 143 million tons. ・F/S was completed by Chinese consultant of U/G mining in Shandon. But, the government was not satisfied with the F/S report. The report included ten exploration drillings and good 3D seismic exploration. ・The annual coal production plan ranges from two million to four million tons.
4	Dighipara, (Dinajipur)	1994 -95	GSB (5)	328 -407	5	62	1.5	6.0	・GSB made five borings in a 1.25 km2 area and found five coal seams. The initial probable coal reserve is 600 million tons. ・A Korean syndicate has approached Petrobangla for development and investment. ・BAPEX carried out an investigation into 2D seismic exploration in Dighipara. The report is under preparation at present.

No.	Coal field name	Develop-ment year	Exploring company (Number of borings)	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured coal reserve (100 million tons)	Measured＋probable coal reserves (100 million tons)	Remarks
5	Jamalgonj, (Bogra)	1962	GSB (10)	640-1,158	7	64	10.53	10.53	・Largest coal field in Bangladesh ・Targeting coal seam gas of CBM (coal bed methane) in deep underground ・There are three proposals to develop in Jamalgonj, which are Coal Bed Methane(CBM) for recover gas from coal seam, Underground Gasification(UCG) by Green Energy in Australia, U/G mining by Chinese company. But the government didnot give any conclude to these proposals.
6	Kuchma, (Bogra)	1959	SVOC	2,380 -2,876	5	51.8			・Targeting coal seam gas of CBM (coal bed methane) in very deep coal seam

Source: GSB and edited by JICA Survey Team

Table 9-3 Minable Coal Reserve depending on Mining Method

	Coal field name	Depth (m)	No. of coal seams	Av. thickness of composite coal seams (m)	Measured reserves (million tons)	Mining method	Minable coal reserve (million t)
1	Barapukuria (Dinajpur)	118 -506	6	51	303	U/G (15%)	45.5
2	Phulbari, (Dinajipur)	150 -240	2	15-70	572	O/C (60%)	343.2
3	Khalaspir, (Rangpur)	257 -483	8	42.3	143	U/G (15%)	21.5
4	Dighipara, (Dinajipur)	328 -407	5	62	150	U/G (15%)	22.5
5	Jamalgonj, (Bogra)	640-1,158	7	64	1,053	U/G (10%)	105.3
6	Kuchma, (Bogra)	2,380 -2,876	5	51.8			
Total					3,300		438

Source: Edited by JICA Survey Team

9.2.2 Current situation and issue of Barapukuria coal mine

(1) Overview

The Barapukuria Coal Mine was developed jointly by Petrobangla and XMC-CMC in China by an agreement of M&P (the Management, Production and Maintenance) concluded in 1994. According to the M&P Contract, CMC has transferred mechanized longwall mining method and achieved a certain degree of stable production of coal. The first contract achieved a production of 3.65 million tons against targeted 4.75 million tons during 71 months from September, 2005. Furthermore, after an international bid aiming at a production of 5.5 million tons, XMC-CMC entered again into the second contract with MPM&P (Management, Production, Maintenance & provisioning Services). This was contracted on a premise to go back in August, 2011. In this contract, the LTCC (Longwall Top Coal Caving) facilities of thick seam mining technology were introduced in December, 2012. It started operation from May, 2013. The face conveyer carries mined coal of 3m operating height and the rear conveyor installed rear of self advancing support carries collapse coal of about 2 m hight . Technical fixation and increased production in thick seam are expected.

All the underground facilities are from China. The vertical shaft is 300m long, and the skip capacity for coal hoisting is set to 3,300t/d. Coal productionis stable in recent years. Coal is supplied for neighboring Barapukuria Thermal Power Stations (125kw x 2). Remaining coal is primarily supplied for brick constructions and other purchasers in the general industry. At present, the coal mine has an annual production capacity of approximately one million tons, and a study to reinforce the production capacity is underway in order to cope with possible capacity increase of the power station. The mine is also planning to expand its annual production up to 1.5 million tons in the future.

(2) Production results

The amount of production and sales of the Barapukuria coal mine are shown in Table 9-4. PDB in the table means the sales volume for the Barapukuria power station and the coal mine has always the coal stock of two months at the mine for the Barapukuria power station. LTCC face operated in 2013 and the production became stable and rising. Production decreased due to water burst and delay of withdrawal & installation of a face in 2014/2015. However, it is thought that it is near to achieve 1 million tons of production, a target of original existing facilities. On the other hand, the sales price of the coal for the power station is US$130/t (from May, 2015) and Tk 13,680[2]/t for the local buyer (from January, 2014, including VAT). This price level, comparing with a mine mouth price of Australian coal of similar coal quality, is considerably higher than that of Australia which is around US $ 50-60 as ofMarch, 2015.
However, the coal price for a local buyer was lowered to Tk 8,000/t(US$102.5) on May 19, 2016 because an overseas coal price became cheaper.

[2] When ONE US$ is to be 78Tk (March 2014), Tk 9,200 is US$ 118.

Table 9-4 Coal Production and Sales Records at Barapukuria Coal Mine

Year	Production (t)	Sale (t)	
		PDB	Others buyers
Till June, 2004	91,038		70,132
2004-2005	87,143		74,768
2005-2006	303,016	209,235	45,020
2006-2007	388,376	460,231	5,707
2007-2008	677,098	491,354	10,393
2008-2009	827,845	532,488	258,081
2009-2010	704,568	501,132	319,255
2010-2011	666,635	463,923	107,795
2011-2012	835,000	499,972	332,526
2012-2013	854,804	643,978	288,266
2013-2014	947,125	524,143	338,618
2014-2015	6,75,776	5,222,129	313,405
Total	7,058,423	4,326,458	2,163,965

Souce：Annual Reportof 2-14-2015, Barapukuria Coal Mining Co. Ltd

Table 9-5 Change of the coal sales price to PDB (Barapucuria power station)

Sl No.	Date on which prices fixed	Price of coal/t (US$)
1	29 May 2001	61.50
2	July 2008	71.50
3	July 2010	85.50
4	01 Feburuary 2012	105.00
5	01 May 2015	130.00

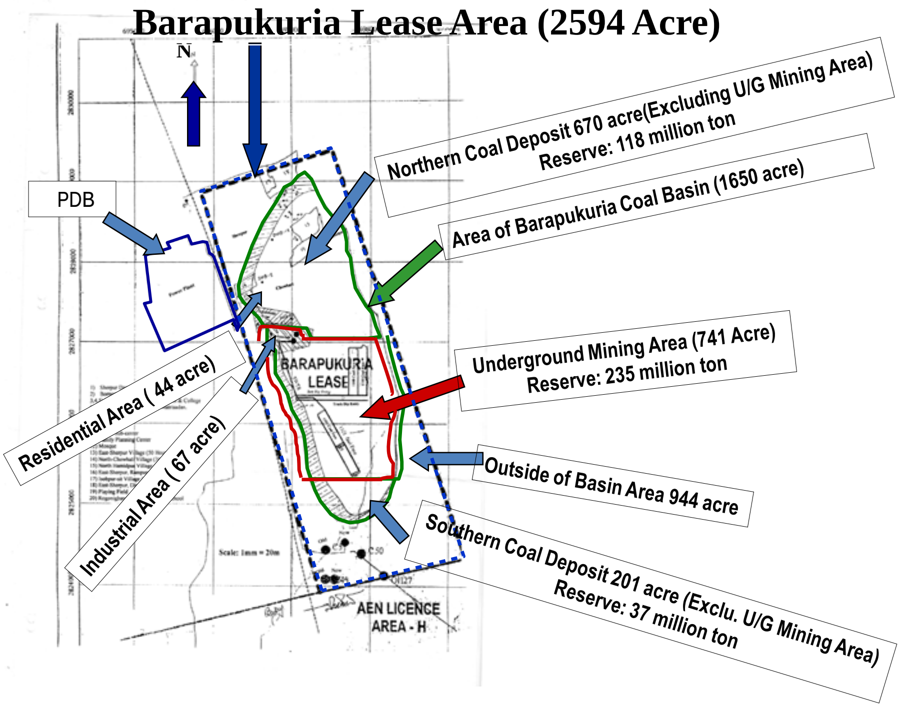
Souce：Annual Reportof 2-14-2015, Barapukuria Coal Mining Co. Ltd

(3) Expansion plan of the mine

An expansion planof the mineis composed of Southern part (reserves 37 million tons) and Northern part (reserves 118 million tons). The area surrounded in a red line shows an existing mine and the area surrounded in a green line shows expansion plan in Figure 9-3. Figure 9-4 shows the details of Northern part and Southern part. Attention is to be paid to the Northern part development where it is proposed to examine open cast mining method.

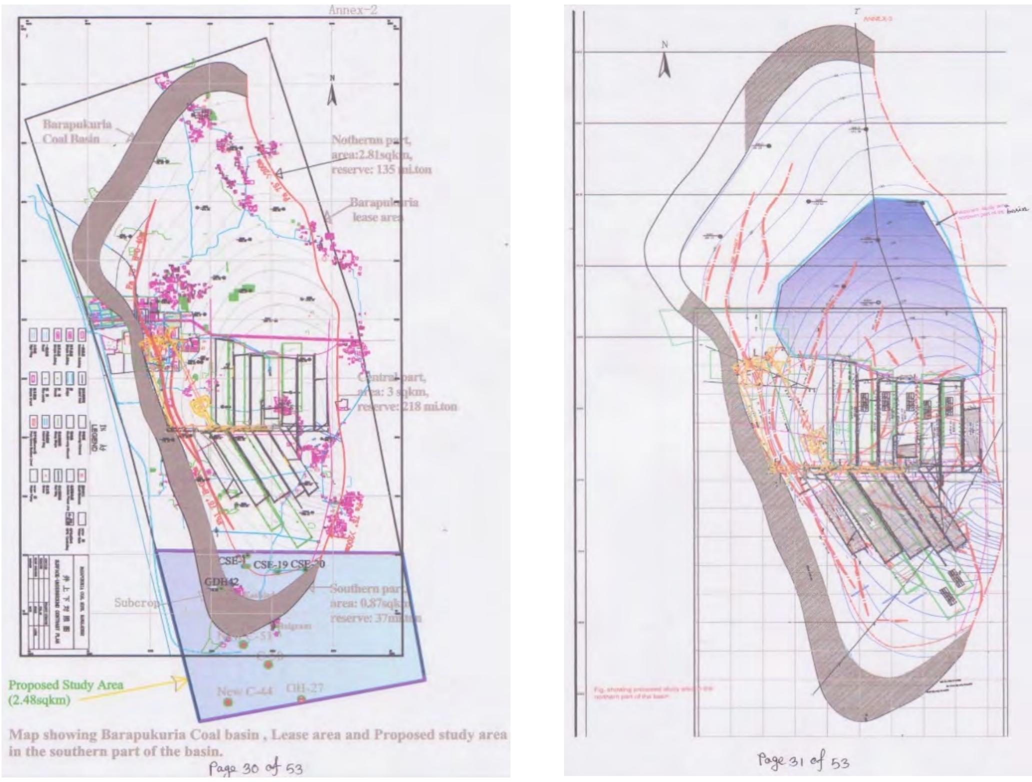
The plan will be along with suggestions of PSPM2010 that opencast mining method in Bangladesh by a small pilot plan should be carried out and technical issues and social environmental problems should be examined at first through the pilot plan. The hydrological survey by six trial borings is already finished and a report is completed. The judgment of the Bangladesh government is awaited now.

Barapukuria coal mine is the first underground coal mine in Bangladesh. The accumulated experience in the past 10 years such as coal mining technology, coal mine administration, and environmental measures is very valuable. The Barapukuria coal mine has the leadership role as a model coal mine, and their practical accomplishment will become references of new investment, necessary technical standards and the production cost for the future Bangladesh new coal mines.



Source: Barapukuria Coal Mining Co. Ltd

Figure 9-3 Expansion Plan of Barapukuria



Source: Barapukuria Coal Mining Co. Ltd

Figure 9-4 Expansion Plan of South Area (at left) and North Area (at right)

(4) Issues

(a) The stabilization of production in the deeper place than 2nd Slice[3] by LTCC.

LTCC face operated from May, 2013, and Face 1210, Face 1206 were finished. The mining height was 3m in original at 1st Slice and the mining height of these LTCC faces was total 5m by mechanical mining height (3m) plus caving height (2m) and the caving height is planned to increase more. It is under examinination now but the person in charge did not seem to have a particularly big problem.

(b) Increased production

The present transporting capacity of a shaft skip to carry out the mined coal to the surface is small with 8 tons. It will be possible to increase it to around 1.2 million tons per year by extension of the operating time of skip and the reinforcement of an underground coal reserve pocket. When more than 1.5 million tons per year production is foreseen, new investment will be required to upgrade capacity of the skip or to make a new skip shaft.

(c) An aspect of technology transfer to Bangladesh engineer and worker

Technology transfer at Barapukuria Coal Mine is very important to predict the future development and production at underground coal mines in Bangladesh.

- Regarding the methods of the technology transfer, there is "On the Job Training" and "Classroom within MPm&P Contract" between China and BCMCL. Safety control items are exceptionally very important in technology transfer program.

- The production technology and safety technology are particularly important in various kinds of technical acquisition. The safety technology is the most important among them. In Japan, the coal mine corporate strategy of "Safety First, The Production Second" has been demanded from old days.

9.2.3 An aspect of undeveloped coal field

Obvious progress was not found as mentionedin REMARKS of the Table 9-2 for the present situation of each coal field.

9.2.4 Forecast of domestic coal production

Table 9-6 shows forecast of domestic coal production until 2014 including future coal mine development program.

[3] When thick seam is mined by longwall mining method in underground, thick coal seam is divided into some thicknesses of coal seam because all seams can't be mined at a time. 2nd slice is called coal seam mined secondly.

Table 9-6 Performance and Forecast of Domestic Coal Production

Year	Total coal production (High Case) (1,000t/y)	Total coal production (Base Case) (1,000t/y)	Total coal production (Low Case) (1,000t/y)	Production of Domestic Coal Mine (1,000t/y)														
				Existing Coal Mine & New O/C					New Coal Mine (U/G & O/C)									
				Barapukuria U/G & new O/C					Kalaspir(U/G)			Dighipara(U/G)			Phulbari(O/C)			
				Under Ground mining (U/G)			Open Cast mining(O/C)		U/G			U/G			O/C			
				(HC)	(BC)	(LC)	(HC)	(BC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)	(HC)	(BC)	(LC)
2005-6		303			303												
2006-7		388			388												
2007-8		677			677												
2008-9		828			828												
2009-10		705			705												
2010-11		667			667												
2011-12		835			835		F/S & Const-ruction Term										
2012-13		855			855												
2013-14		947			947												
2014-15		676			676												
2015-16	1,000	1,000	850	1,000	1,000	850											
2016-17	1,000	1,000	850	1,000	1,000	850											
2017-18	1,000	1,000	900	1,000	1,000	900			F/S & Const-ruction Term						F/S & Const-ruction Term		
2018-19	1,000	1,000	900	1,000	1,000	900											
2019-20	1,000	1,000	900	1,000	1,000	900						F/S & Const-ruction Term					
2020-21	1,500	1,100	1,000	1,500	1,100	1,000											
2021-22	1,500	1,100	1,000	1,500	1,100	1,000											
2022-23	2,000	1,600	1,000	1,500	1,100	1,000	500	500									
2023-24	2,500	1,600	1,000	1,500	1,100	1,000	1,000	500									
2024-25	2,500	1,600	1,000	1,500	1,100	1,000	1,000	500									
2025-26	3,000	2,100	1,000	1,500	1,100	1,000	1,500	1,000									
2026-27	3,000	2,100	1,000	1,500	1,100	1,000	1,500	1,000									
2027-28	3,500	2,600	1,500	1,500	1,100	1,000	1,500	1,000	500	500	500						
2028-29	4,000	3,100	2,000	1,500	1,100	1,000	1,500	1,000	1,000	1,000	1,000						
2029-30	5,000	3,600	2,500	1,500	1,100	1,000	1,500	1,000	1,500	1,000	1,000	500	500	500			
2030-31	8,000	5,700	3,600	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	1,000	1,000	1,000	500	500	500
2031-32	9,000	6,200	4,100	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	1,500	1,000	1,000	1,000	1,000	1,000
2032-33	10,500	6,200	4,100	1,500	1,200	1,100	3,000	2,000	2,000	1,000	1,000	2,000	1,000	1,000	2,000	1,000	1,000
2033-34	11,500	7,200	4,600	1,500	1,200	1,100	4,000	2,000	2,000	1,000	1,500	2,000	1,000	1,000	2,000	2,000	1,000
2034-35	12,500	8,200	4,600	1,500	1,200	1,100	4,000	2,000	2,000	2,000	1,500	2,000	1,000	1,000	3,000	2,000	1,000
2035-36	13,000	8,200	5,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,000	1,000	1,500	3,000	2,000	1,000
2036-37	14,000	10,200	5,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,000	2,000	1,500	4,000	3,000	1,000
2037-38	14,500	10,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	4,000	3,000	2,000
2038-39	15,500	10,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	5,000	3,000	2,000
2039-40	15,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	5,000	4,000	2,000
2040-41	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000
2041-42	16,500	11,200	6,100	1,500	1,200	1,100	4,000	2,000	2,500	2,000	1,500	2,500	2,000	1,500	6,000	4,000	2,000

Remarks: The arrow in the Table shows a run-up term including authorization for the coal mine development, construction.

Source：JICA Survey Team

9.3 The Present Aspect and Issues of the Import coal

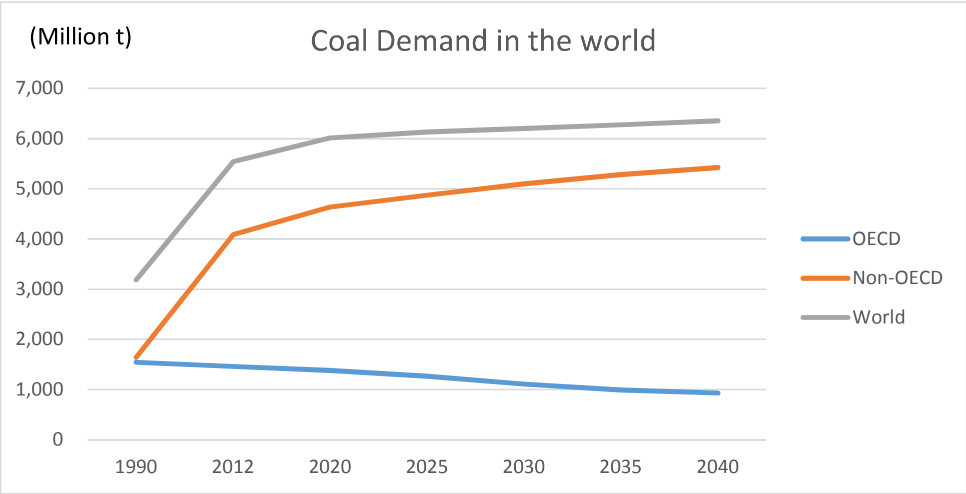
9.3.1 General view

Figure 9-5 shows the quantity of world coal demand until 2040 in New Policies Scenario[4] of World Energy Outlook of IEA. Coal demand for Non-OECD countries increases rapidly from the Figure. The quantity of demand for Non-OECD countries is expected to increase five-fold of the demand of current OECD countries. China and India occupy this main increase as shown in Figure 9-6.

On the other hand, trend of coal import by Southeast countries as shown in Figure 9-6 is important for Bangladesh. Figure 9-7 shows the coal import trend of Southeast countries excluding China and India to begin with Malaysia, Thailand and Philippines which areimportant coal consumer countries. It is in particular a trend of these past five years to pay attention. Table 9-7 shows the import quantity of each country.

It is obvious from the Table that the coal import of each country suddenly increases. In addition, the result of our investigation found that Bangladesh, actually, imports coal of approximately 4 times bigger than the volume shown in the Table. With this statistical discrepancy, the figures in Figure 9-7 and Table 9-7 should be interpretated with prudence.

It will be difficult to predict exactly how much coal Bangladesh can import sustainably and economically depending on coal quality, price, concession, but it seems that Bangladesh will have a tough time to procure coal given the prospected coal demand in Southeast in the near future. Therefore, if Bangladesh lowers the specification of the coal quality compared with that of circulating coal now, 20-30 million tons of coal will be imported in a stable manner at a stage in 2030 from India, Indonesia, Australia or some of African countries. However, sincethe quantity of import coal demand for Bangladesh in 2040 is expected to be around 60 million tons as shown in Table 9-12, solutions must be found for many issuessuch as unstable coal quantityand quality as well as coal price.

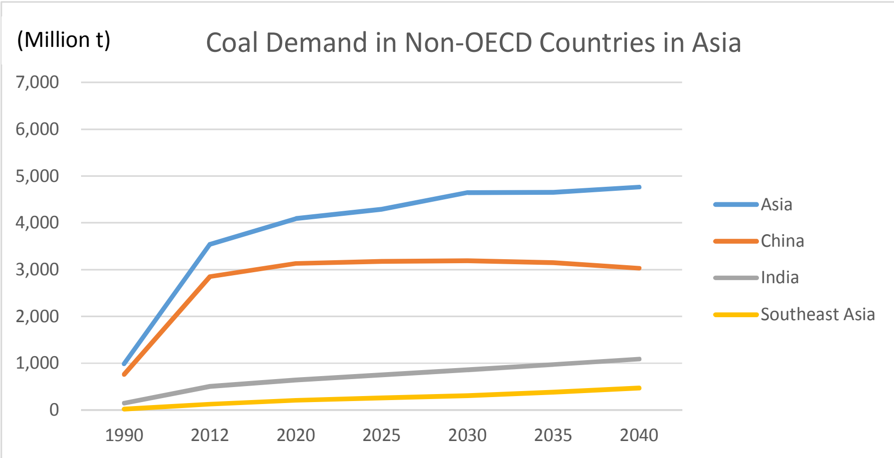


Source: Coal market outlook by World Energy Outlook 2014

Figure 9-5 Forecast of Coal Demand in the World

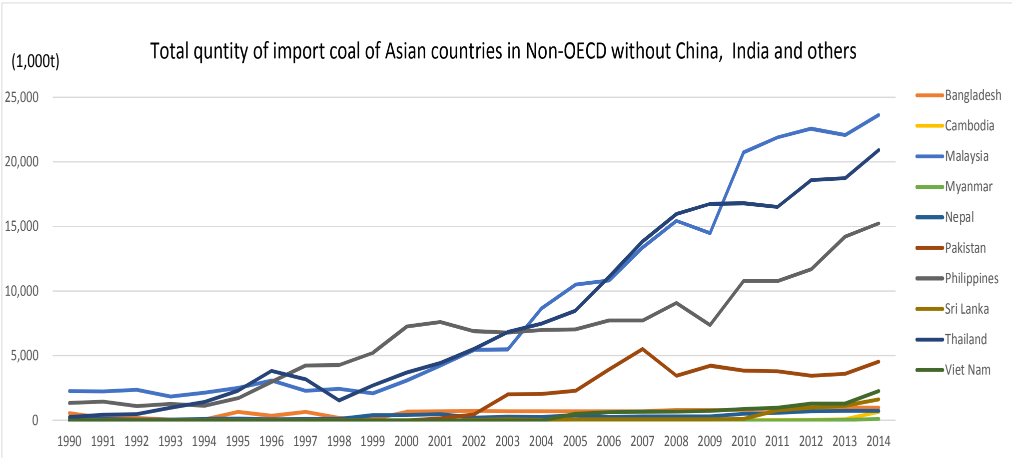
[4] The World Energy Outlook 2014 (WEO-2014) presents projections for three scenarios. The Current Policies Scenario is based on those government policies and implementing measures that had been formally adopted as of mid-2014. The New Policies Scenario, which is WEO's central scenario, takes into account the policies and implementing measures affecting energy markets. The 450 Scenario is projection considering control global warming until 450ppm.

As for the prediction of EIA (Energy Information Administration, United States Department of Energy), it may be said that New Policies Scenario watches a predictive number modestly because Current Policies Scenario of IEA is near.



Source: Coal market outlook by World Energy Outlook 2014

Figure 9-6 Forecast of Coal Demand in Non-OECD Countries in Asia



Source: Coal Information, IEA

Figure 9-7 Quantity of Import Coal of Southeast Asian Countries in Non-OECD without China, India and Others

Table 9-7 Quantity of Import Coal of Asian Countries in Non-OECD without China, India and Others for the Past 5 Years

(1,000t)

	2009	2010	2011	2012	2013	2014
Malaysia	14,477	20,737	21,881	22,558	22,064	23,611
Thailand	16,740	16,802	16,510	18,586	18,726	20,909
Philippines	7,367	10,772	10,755	11,681	14,199	15,224
Pakistan	4,227	3,838	3,782	3,446	3,598	4,524
Viet Nam	724	884	978	1,295	1,308	2,260
Sri Lanka	100	108	760	962	1,131	1,617
Bangladesh	800	800	924	1,000	1,000	988
Nepal	307	489	583	698	724	724
Cambodia	16	17	19	21	96	642
Myanmar	0	0	0	8	47	113
Totl of Asia in Non-OECD without China, India and others	44,758	54,447	56,192	60,255	62,893	70,612

Source: Coal Information, IEA

9.3.2 Import coal price

Present coal price has a tendency to fall due to global oversupply. Figure 9-8 shows the change of FOB coal price of 6,700kcal/kg at Newcastle Port from 2002 through 2015 in terms of coal price (¢) per 1,000kcal/kg. The coal price gradually declines from 2011 and is still declining now. There is a prediction that the price will in turn start to increase around 2020, but the percentage of such rise is not identified.

The prediction of coal price until 2040 is not easy under present situation, but Figure 9-9 shows a prediction of coal price starting from October, 2015 using the approximation of straight line, except when the price shows substantial change in a rather brutal manner.

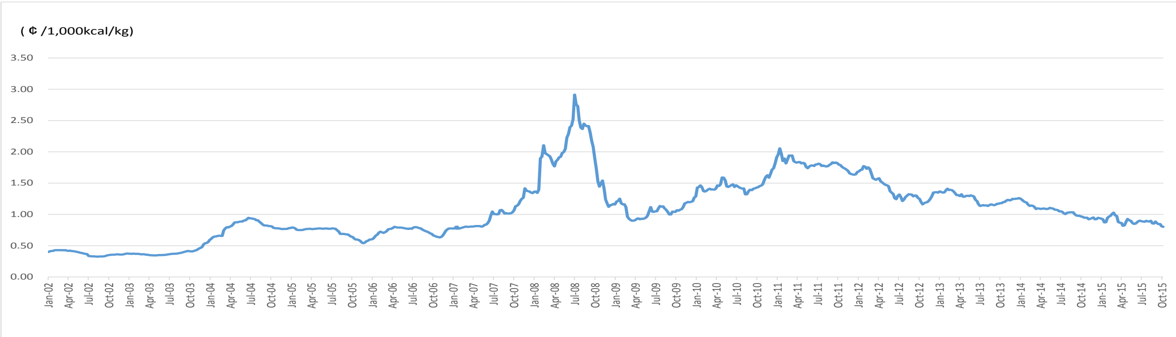
In addition, there is some difference in coal price (¢) per 1,000kcal/kg by the calorific value of the coal. Table 9-8 shows the mean weight of the coal price of each calorific value when 6,500kcal/kg is assumed as 1.000 in Indonesian Coal Index (ICI)[5] which Argus announces for the past 2 years.

Using this differenciation by calorific value, coal price prediction until 2040 of 6,300kcal/kg and 4,700kcl/kg is made in Table 9-9. This prediction is based on an assumption that 6,300kcal/kg will be approximately equal to 6,500kcal/kg and is adopted Weight 1.000 and 4,700kcl/kg will be equal to 5,000kcal/kg and is adopted Weight 0.919.

Table 9-10 shows predicted coal price of 6,300kcal/kg composed of CIF price and an unloading expense in Chittagong, on a premise to import from Australia. Equally, Table 9-11 shows predicted coal price of 4,700kcl/kg.

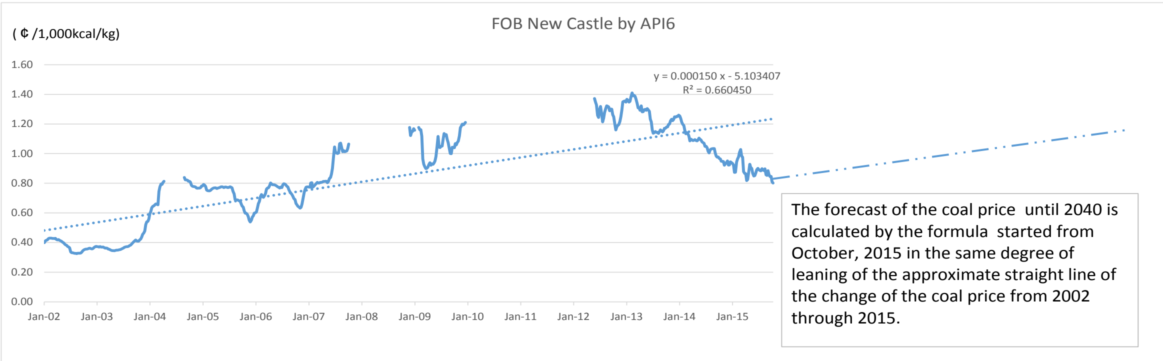
As a result, coal cost becomes generally about half compared with the forecast of coal cost in PSMP2010.

[5] Indonesian Coal Index / ICI (Coal) The ICI (Indonesian Coal Index) reflects the spot price of five key grades of Indonesian coal — 6,500 (ICI 1), 5,800 (ICI 2), 5,000 (ICI 3), 4,200 (ICI 4) and 3,400 (ICI 5) kcal/kg GAR. It is published weekly and is the average of the Argus fob Indonesia price as reported in the Argus Coal Daily International report and the PT Coalindo Energy weekly panel system. The full database of time series data is available from 2006.



Source: API6, by Argus

Figure 9-8 Coal Price of 1,000kcal/kg Movement at Newcastle Port in Australia



Source: API6, by Argus

Figure 9-9 Forecast of Coal Price of 1,000kcal/kg

Table 9-8 Weight of Coal Price by Calorific Value by ICI, Indonesia

6,500 Kcal/kg	5,800 Kcal/kg	5,000 Kcal/kg	4,200 Kcal/kg	3,400 Kca/kg
1.000	0.977	0.919	0.769	0.638

Source: Indonesian Coal Index

Table 9-9 Forecast of Coal Price of 1,000kcal/kg to High Grade Coal and Low Grade Coal

Year	₵/1,000kcal/kg for High grade coal	₵/1,000kcal/kg for Low grade coal	Coal Price(US$)	
			6,300kcal/kg	4,700kcal/kg
2015	0.80	0.74	50.5	34.6
2020	1.07	0.99	67.7	46.4
2030	1.35	1.24	85.0	58.3
2040	1.62	1.49	102.2	70.1
2050	1.90	1.74	119.5	81.9
2060	2.17	1.99	136.8	93.8

Source: JICA Survey Team

Table 9-10 Total Cost including FOB, Freight, Insurance and Handling Cost from Australia

Year	FOB Price of 6,300kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	50.5	15.0	16.0	81.5	0	65.5
2020	67.7	17.8	17.8	103.3	0	85.5
2025	85.0	20.5	19.7	125.1	0	105.5
2030	102.2	23.2	21.5	147.0	0	125.5
2035	119.5	26.0	23.4	168.9	0	145.5
2040	136.8	28.7	25.2	190.7	0	165.5

Source: JICA Survey Team

Table 9-11 Total Cost including FOB, Freight, Insurance and Handling Cost from Indonesia

Year	FOB Price of 4,700kcal/kg (US$)	Freight & Insurance (80,000t class) (US$)	Case A		Case B	
			Handling Cost (US$)	G. Total of Coal Price at Chittagong CFTPP(US$)	Handling Cost(US$)	G. Total of Coal Price at Chittagong CFTPP(US$)
2015	34.61	9.1	16.0	59.7	0	43.7
2020	46.43	10.7	17.8	75.0	0	57.2
2025	58.26	12.4	19.7	90.3	0	70.7
2030	70.09	14.1	21.5	105.7	0	84.1
2035	81.92	15.7	23.4	121.0	0	97.6
2040	93.76	17.4	25.2	136.4	0	111.1

Source: JICA Survey Team

9.4 Prediction of Coal Demand & Supply

9.4.1 Prediction of coal demand & supply

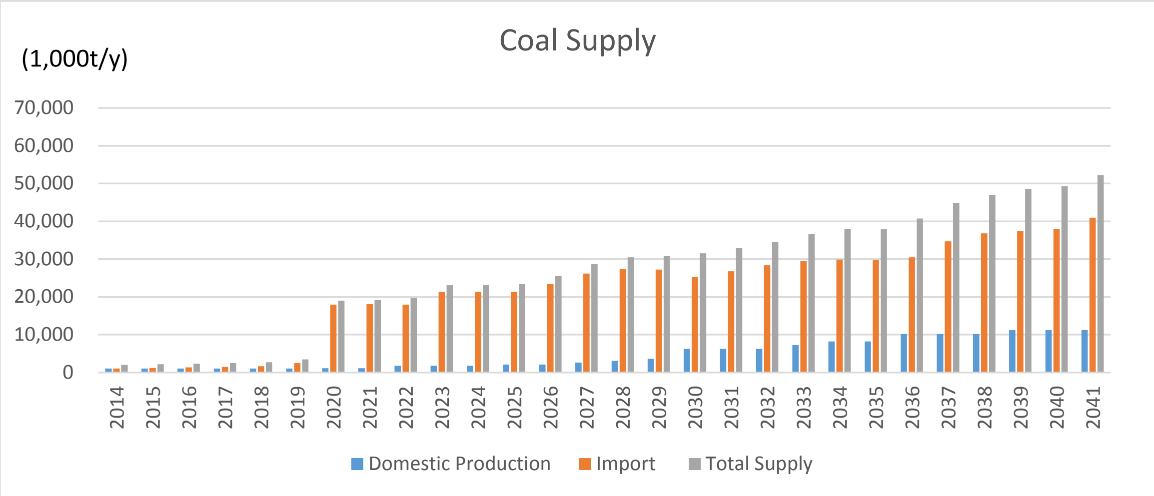
Table 9-12 shows domestic supply and demand of the coal until 2041. Figure 9-10 shows the coal supply and demand by a graph. Since coal demande of for power generation is predominant, demand quantity was predicted based on a new coal-fired power station construction plan.

Table 9-12 Prediction of Coal Demand & Supply

(1,000t)

		2015	2020	2025	2030	2035	2040	2041
Supply	Domestic	1,000	1,100	2,100	6,200	8,200	11,200	11,200
	Import	1,163	17,905	21,304	25,311	29,739	38,041	40,977
	Total	2,163	19,005	23,404	31,511	37,939	49,241	52,177
Demand	Power	430	16,339	19,460	26,082	30,860	40,486	43,067
	Non-power	1,733	2,666	3,944	5,429	7,079	8,755	9,110
	Total	2,163	19,005	23,404	31,511	37,939	49,241	52,177

Source: JICA Survey Team



Source: JICA Survey Team

Figure 9-10 Coal Supply

9.4.2 The issue of coal supply

(1) Implementation of imported coal infrastructure in the F/S.

- The F/S for the CTT (Coal Transshipment Terminal) planned in the Matarbari area has already been completed (Source: Preparatory Survey for the Construction and Operation of Imported Coal Transshipment Terminal Project in Matarbari Area in People's Republic of Bangladesh (as a PPP infrastructure project)).

- In this plan, phased development for CTT was recommended to provide sufficient flexibility, i.e., to expand the CTT when the power generation program development and realistic commission operation date (COD) become certain.

- The first phase of the CTT will commence operation in 2025 (planned amount of coal: 10.4 million t/year); the object of the second phase will include those power stations that commence operation by 2029 (amount of coal: 25.6 million t/year) and use the CTT.

- For the future, with an increase in the development of new coal-thermal power plants there is a need to implement the F/S for the infrastructure and plan for efficient coal transportation.

- The actual value of the loading and unloading situation in the Bay of Bengal is important.

(2) Construction Based on the F/S

- For CTT (Coal Transshipment Terminal), efficient coal supply operation while ensuring long-term stability is desired. When planning in Bangladesh, it is important to take into account the natural characteristics such as the broad expanses of sand, cyclones and high rainfall, and the protection of precious animals and plants.

- When importing coal over a long period of time, facility planning that can respond to changes in the type of coal is desirable as, depending on the coal mine reserves, future coal mines and countries may change.

- The promotion of mechanization and securing of stable supply for offshore loading and unloading by floating crane; the implementation of early construction of the CTT.

9.4.3 Coal demand of industry

The quantity of coal demand for domestic industry in Table 9-12 is predicted based on a growth rate of Table 9-9 for the past 5 years. It is difficult to grasp the real coal consumption. Table 9-13 is data from an annual report of the Bangladesh Statistics Bureau, but the real import amount is considered to be enormous. The figure of statistics seems to reflect the import from the sea route mainly. The import by the land route from India seems not included in this table.

The main industry of coal consumption in Bangladesh is brick factory and there are small rolling mil factories (foundry) in addition. As for the coal consumption of brick factories, the quantity of brick production of 34/unit x 3500unit=119,000 units by operation for six months requires 700t of coal. Generally, typical production quantity of the brick per one factory is 1lakh (100 thousand units). Therefore, 1,000 brick factories consume 700,000tons of coal per year.

Table 9-13 Data of Quantity of Import Coal by Bangladesh Bureau of Statistics

Year	Cord No.	Item	Import amount (t)	Import price (BDT)	@ BDT/t
2019/2011	2701	Coal & Briquette	59,778	476,813,100	7,976
	2704	Coke and Semicoke of coal	4,464	104,318,000	23,316
2011/2012	2701	Coal & Briquette	56,636	411,608,100	7,268
	2704	Coke and Semicoke of coal	3,903	103,100,000	26,416
2012/2013	2701	Coal & Briquette	82,228	495,411,576	6,025
	2704	Coke and Semicoke of coal	3,359	90,888,657	27,058
2013/2014	2701	Coal & Briquette	NA	NA	NA
	2704	Coke and Semicoke of coal	2,645	65,094,975	24,616

Source: Bangladesh Bureau of Statistics (BBS)

9.4.4 The quality of import coal for industry

JICA Survey Team carried out a field work asking questions to a coal seller nearby Fatulla Station of the river mouth of Madaripur of Dhaka City. He was selling Indonesian, Indian and Chinese coal, among which Indonesian coal was major coal at the time of investigation.
The sales covered three kinds of calorific value, 5,000, 6,500 and 7,500kcal/kg and annual sold volume was 20,000t - 30,000t. The coal was shipped by a boat from Chittagong. Table 9-14 shows analysed contents of the coal which the coal seller sold. The quality such as the calorific value is good, but sulfur content is high. The coal imported by land by the northeast Indian side of the Bangladeh has also high sulfur content and the Bangladesh goverment is prohibiting import of high sulfur coal, but controlis not easy.

Table 9-14 Coal Quality for a Brick Factory

Item	Unit	Base	Coal sample	
			Indonesia A	Indonesia B
Total moisture	wt%	AR	11.0	4.8
GCV (HHV)	kcal/kg	AR	6,360	7,100
	MJ/kg		26.7	29.7
NCV (LHV)	kcal/kg	AR	6,140	6,880
	MJ/kg		25.7	28.8
[Proximity analysis]				
Moisture	wt%	AD	5.7	3.4
Ash			6.9	8.8
Volatile Matter			44.0	43.8
Fixed Carbon			43.4	44.0
Total Sulphur	wt%	Dry	2.71	0.86

Source: JICA Survey Team

9.5 Environmental and Social Aspects of Coal Development

9.5.1 Environmental Impact Assessment

Basic rules of Environmental Impact Assessment are given by Environment Conservation Act 1995. The clause 12 of the Act "No industrial unit or project shall be established or undertaken without obtaining, in the manner prescribed by rules, an Environmental Clearance Certificate from the Director General". Environment Conservation Rules 1997 (subsequent amendments in 2002 and 2003) stipulate the procedures and required documents by categories (see Table 9-15).

Table 9-15 EIA Categories and Required Clearance and Documents

Category	Required clearance	Required documents
Red	Location clearance, Environmental Clearance	Feasibility Study report (FS report), IEE or EIA, Resettlement Action Plan (RAP), No Objection Certificate of the local authority (NOC), Emergency and pollution minimization Plan
Orange B	Location clearance, Environmental Clearance	FS report, IEE, NOC, Emergency and pollution minimization Plan, RAP
Orange A	Location clearance, Environmental Clearance	General Information, Raw materials and the manufactured product, NOC, Process flow, Layout, Effluent discharge arrangement, RAP
Green	Environmental Clearance	General Information, Raw materials and the manufactured product, NOC

Source: Environment Conservation Rules 1997

MOE has prepared various guidelines of EIA such as Guidelines for Industries in 1997, EIA Guidelines for Coal Mining, Guidelines for Gender Responsive Environmental Management. All the coal and gas development projects have to apply Environmental Clearance to DOE of Dhaka, Chittagong, Khulna, or Rajshahi Division. It is not clear that which categories should be applied to various kinds of Gas and coal projects (see Table 9-16).

Table 9-16 EIA Guidelines for Gas and Coal Sector

Activities	Category	Guidelines to be referred
Coal exploration	?	EIA Guideline for Coal Mining
Coal mining	Red	EIA Guideline for Coal Mining
Coal storage	?	EIA Guidelines for Industries in 1997
Coal Power Plant	Red	EIA Guidelines for Industries in 1997

9.5.2 Experienced environmental and social impact of coal development

Currently there is only one coal mine in operation. Information is gathered from Barapukuria Coal Mining Co. Ltd (BCMCL) and literatures.

(1) Environmental and social impact of Barapukuria Coal Mine

EIA report and Environmental monitoring reports were prepared for the Barapukuria Coal Mine project. But both of them are not disclosed by BCMCL. BCMCL does not submit the monitoring reports to DOE periodically. There are many reports and articles which suggest various Environmental and Social impact caused by the project. Based on the hearing, articles and reports, 320 households were resettled and 622 acers of land were acquired at the construction stage. After the subsidence happened, fish farming has started, wildlife has commenced to use the pond as their habitat. But 2,500 people were additionally resettled by the subsidence, and 15 villages were affected by lowered underground water (see Table 9-17). Compensation measures have been taken but some affected people are thinking that compensation is not enough (see Table 9-18). It seems that Environmental and Social impacts are not fully controlled.

Table 9-17 Reported Environmental and Social impact by Barapukuria Coal Mine

Items	Impact	Source
Tremor	Tremor is experienced by local people.	Hearing from BCMCL
Subsidence	Subsidence area is 627 acres (2.5 km2). Compensation to the affected land, houses and others was finished and issues are solved.	Hearing from BCMCL
	Subsidence started in 2008 and lowered around 1m. 2,500 people in seven villages are affected. Eight to ten “tin sheds” are proposed by BCMCL. Government is planning to establish Coal City for 10,000 families.	Hoshour (2011)
Underground water degradation	Underground water level was lowered and 15 villages lost their access to water.	Hoshour (2011)
Water pollution	2200m3/h treated water is discharged into river. People are using the treated water for irrigation. People are growing fishes at the pond of the subsidence area and wildlife is using the pond.	Hearing from BCMCL
	30ton/hr waste water is drained that is mainly acidic in nature and rest of water is recycling. AMD, classified as hard water, contains harmful heavy metals and metalloids like HCO3-, Na+, Ca+ which have a tendency to leach out over a period of time.	Akter et al. (2015)
	The chemical properties of surrounding water such as concentration of Calcium, Magnesium, Lead, Iron, Copper, Zinc etc are greatly increased by the mixing of coal water and greatly impacts on the farmer’s field soil.	Hasan (2013)

Items	Impact	Source
Soil contamination	By releasing heavy metals which are associated with coal such as aluminium (Al^{3+}), zinc (Zn^{2+}) and manganese (Mn^{2+}), AMD is affecting directly and indirectly on the Environment and Ecosystem.	Mohanta (2015)
	The chemical properties of surrounding soil of coal mine, such as concentration of Ca, Mg, Pb, Fe, Cu, Zn etc is greatly increased by the farmer's field soil.	Rashid (2014)
Land acquisition	622.28 Acres of land were acquired.	Hearing from BCMCL
Resettlement	320 households were resettled during construction stage.	Hearing from BCMCL

Table 9-18 Reported Social Conflict of Barapukuria Coal Mine

Year	Social conflicts	Source
2011	The national committee to protect oil, gas, mineral resources, ports and power on Monday enforced a six-hour road and rail blockade at Phulbari in Dinajpur, demanding implementation of its seven-point demands including compensation for Aman crops near Barapukuria coal mine area.	New Age (March 29, 2011)
2011	Local peoples blocked railways and a highway protesting the government's plan for open pit mining. Thousands of people demanded compensation for loss of aman crops and postponement of the ongoing land survey. Hundreds of people from Chowhaati, Durgapur, Shahgram, Rambhadrapur, Yousufpur and Bagra villages attacked the 'National Committee' members. At least five people were injured during the ten-minute-long clash.	The Daily Star, (May 5, 2011)
2011	Barapukuria coal miners and staffers stopped production at the mine, demanding regularisation of their jobs.	The Daily Star, (Aug. 24, 2011)
2012	At least 20 people, including three policemen, were injured as thousands of villagers protested and clashed with police. The protestors were demanding disbursement of money granted under the authorities' compensation package; the affected people have been agitating since 2009 after at least 627 acres of land subsided at 10 villages.	The Daily Star, (July 9, 2012)

(2) Accident at Barapukuria Coal Mine

Two serious accidents have been reported by Hoshour (2011) so far. One of it is a fatal accident of a British mining expert by a gas leakage happened in 2005. Second one is a roof cave causing one person dead and 19 wounded in 2010.

9.5.3 Environmental and social risk of coal development

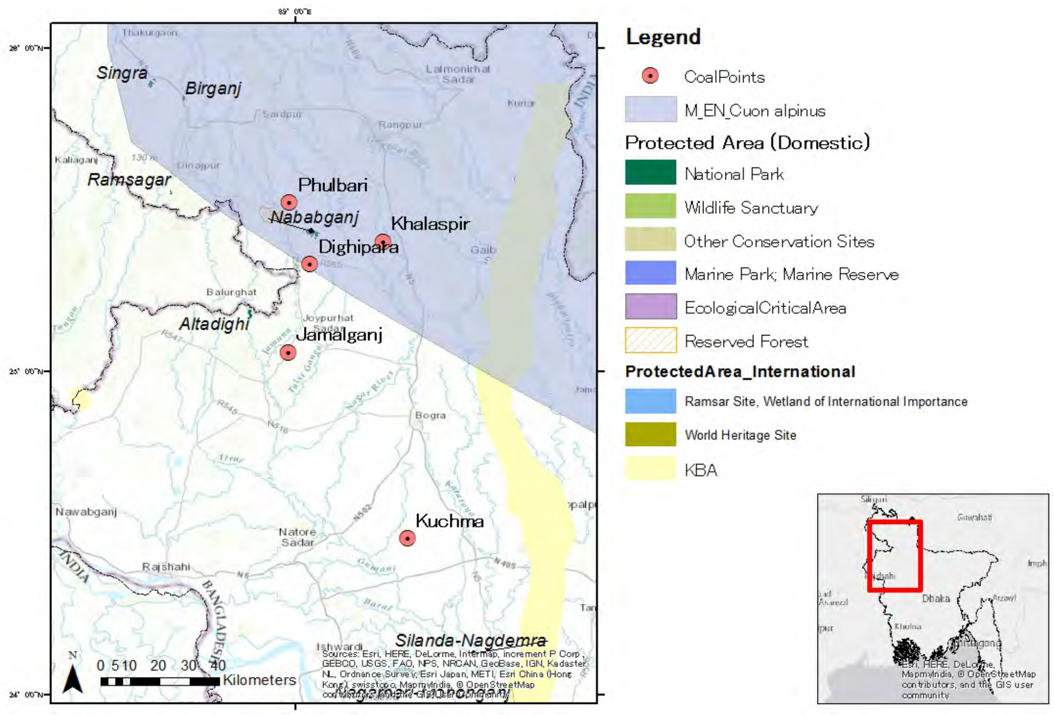
There are several potential coal mine areas in Bangladesh. Among them only one project, Phulbari, has prepared the EIA report which is fully opened on the web. Based on the EIA reports of the Phulbari Coal mine various impacts are expected as shown in Table 9-19. The impacts are larger than Barapukuria because the mining method is open cut.

Table 9-19 Main Environmental and Social Impact Described in the EIA Report of Phulbari Coal Mine

Items	Impact
Soil	Topsoil removal would be 4,300 hectares.
Air	The maximum predicted PM10 (24-hour) concentrations deriving exclusively from Project emissions exceed the residential area standard of the Government only at two locations during year 5 assessment stage.
Surface water	The net result of this land settlement is that some small areas, especially the area immediately to the north of the mine site, could be inundated during a 100-year flood to depths of around 0.2–0.5 m. As it is anticipated that much of this low flow release will be extracted by irrigators, it can be concluded that the mine dewatering flows are unlikely to cause any hydrologic or hydraulic problems in the Little Jamuna River. The Khari Pul creek (which is actually more of a drainage channel, with water flows of 0.3 m3/sec (12 m3/sec during extreme rainfall) carries the untreated wastewater from Barapukuria Coal Mine (just north of the Project area).
Ground water	Dewatering activities will have potential impacts on the local and regional hydrogeological regime, with predicted groundwater drawdown of approximately 25 m at a distance of 4 km from the mine pit, and 15 m at a distance 6 km. This may result in (i) reduction in groundwater availability to the local farming community, Phulbari township, and nearby villages; (ii) reduced baseline flow into watercourses and Ashoorar Beel during the dry season; (iii) land settlement; and (iv) a general reduction in groundwater quality.
Subsidence	Land subsidence in the order of 2 meters (m) at the mine crest, reducing to 0.02 to 0.4 m at a distance of about 5 km from the mine.
Biological Environment	The Project could potentially result in the direct loss of some common habitats. No Sal forests or major Beels will be directly affected by mining activities, but indirect effects may occur as a result of watercourse diversion, discharge of excess mine site-treated “dirty” water, increased sediment load resulting from land clearing and earthworks, mine dewatering activities, and groundwater discharge to watercourses. Other impacts may include weed invasion and elevated noise levels.
Land acquisition	Approximately 5,933 ha of land will be required. Most of them are for the Mine Footprint (85.5%). Other activities are new areas for town and village resettlement sites and the realignment of transport (rail and road) infrastructure.
Sociocultural Environment	Current estimates are that about 9,000 households (some 40,000 people), including some residents at the extreme eastern end of the Phulbari township, will have to be relocated. Population displacement will occur in all four upazilas, with Phulbari being the most affected. In addition, up to 160 households may have to be relocated for the realignment of rail and road corridors.

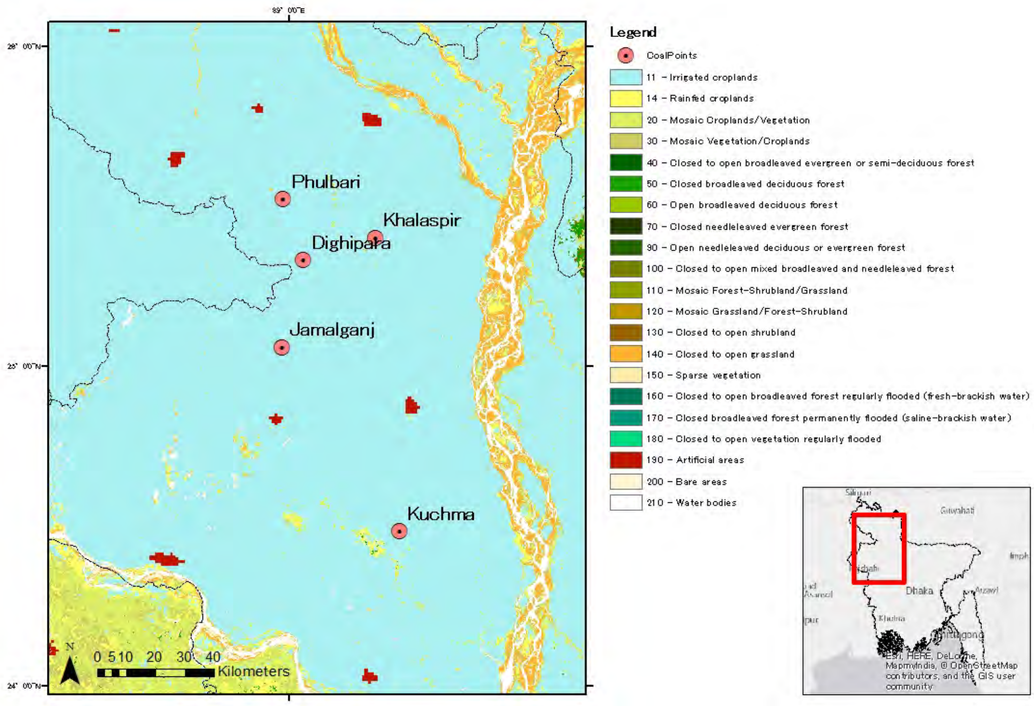
Source: JICA Survey Team

It is not clear that how much environmental impacts will be anticipated for the other four mines. But the impact items would be similar as Phulbari because the locations are ‘Irrigated croplands’ same as Phulbari coal mine (See Figure 9-12). The direct impact on the protected areas will be avoided as the locations are outside of the protected areas. Phulbari, Khalaspir, and Dighipara are in the distribution areas of Dhole (Cuon Alpinus) (See Figure 9-11). Then the impact on bushes and forest area should be minimized and offset mitigation should be considered. Even if underground mining method is selected, some amount of resettlement and land acquisitions will not be avoided. And there is a possibility of people’s protest. Then detail social survey and compensation planning in participatory style is recommended.



Source: JICA Survey Team

Figure 9-11 Possible Coal Mines and Protected Areas



Source: JICA Survey Team

Figure 9-12 Possible Coal Mines and Land Use

Source:
Akter et al. (February 2015) “Degradation of the Surface and Subsurface Water Quality on the Adjacent Area of Barapukuria Coal Mine due to the Improper Effluent Treatment of Mine Waste Water”, International Journal of Emerging Technology and Advanced Engineering Volume 5, Issue 2
Hasan et al. (2013) “Environmental Impact of Coal Mining: A case study on Barapukuria Coal Mining Industry, Dinajpur, Bangladesh” J. Environ. Sci. & Natural Resources, 6(2): 207 - 212, 2013
Kate Hoshour, (March 4, 2011) "Massive protest against Phulbari & Barapukuria coal mines in Bangladesh" International Accountability Project.
Rashid et al. (2014) “Environmental Impact of Coal Mining: A Case Study on the Barapukuria Coal Mining Industry, Dinajpur, Bangladesh” Middle-East Journal of Scientific Research 21 (1): 268-274, 2014
The Daily Star, (May 5, 2011) "Siege protesting open pit mining to continue today"
The Daily Star, (Aug. 24, 2011) "Miners strike halts Barapukuria coal production for 2nd day"
The Daily Star, (July 9, 2012) ”20 injured as Dinajpur land subsidence victims, cops clash,"
Tusher Mohanta et al. (July 2015) “Case study on surrounding area of Barapukuria coal mine impeding soil fertility” International Journal of Scientific & Engineering Research, Volume 6, Issue 7

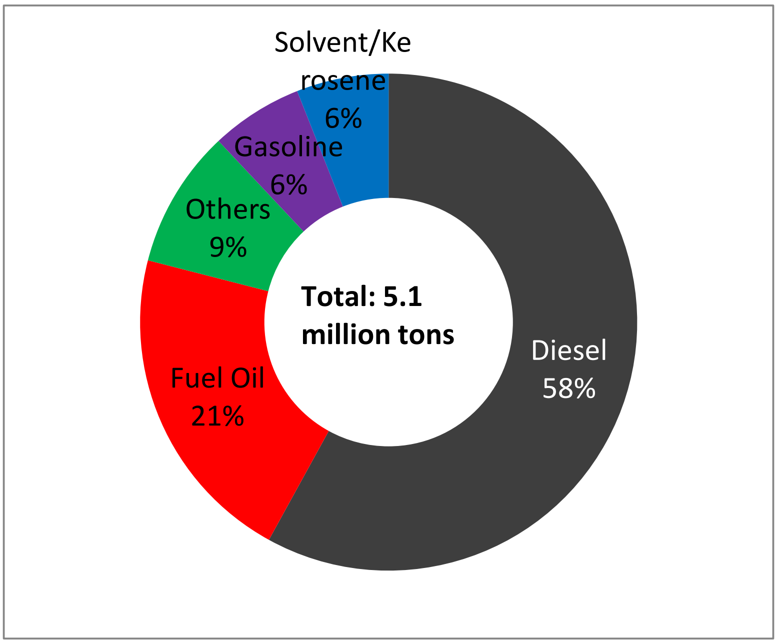
Chapter 10 Oil Products Supply

This Chapter refers to the information collected and analyzed in the JICA-supported survey "Data Collection Survey on Integrated Development for Southern Chittagong Region," (hereafter referred as JICA "Southern Chittagong Survey") Progress Report (January, 2016), especially on the supply plans. For the demand projection on oil products, this Chapter refers to Chapter 20.

10.1 Forecast of Oil Import

10.1.1 Oil demand

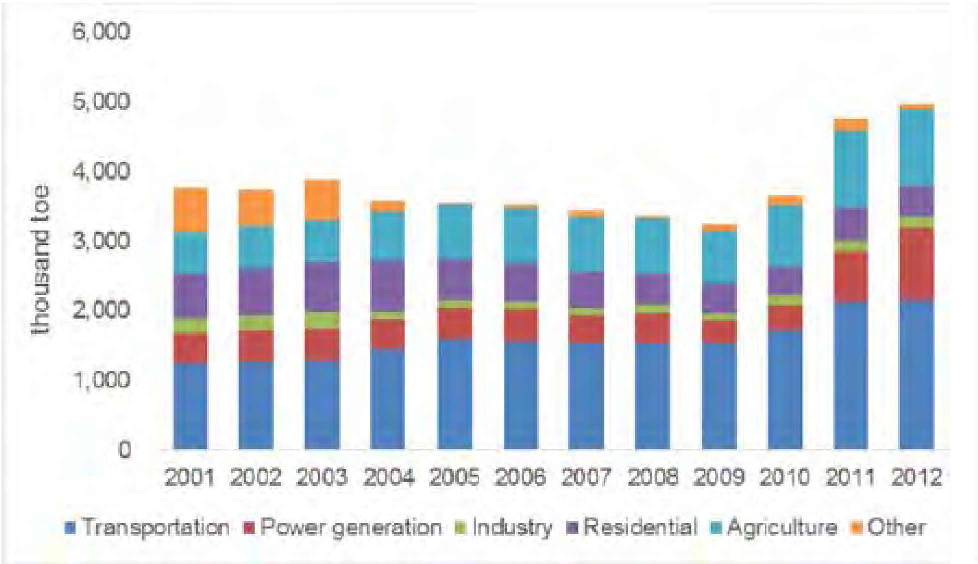
Bangladesh produces a small amount of condensates (about 7,800 barrels per day as of December 2014), from natural gas fields. Condensates are fractionated to petroleum products, such as liquefied petroleum gas (LPG) and motor gasoline and are marketed in the domestic oil market. The domestic condensate supplies only about 5% of the total domestic oil demand in Bangladesh, and the country's most of the oil demand is met with import from abroad. The country's annualized oil demand from 2012 to 2013 was 5.1 million tons (about 105,000 barrels per day) according to the obtained data from the Energy Division, Ministry of Power, Energy, and Mineral Resources. More than half of the demand was diesel oil because it is extensively used in various sectors from transportation to power generation, industry, and agricultural sector. The share of fuel oil is relatively high as it is still widely used in the industrial sector. The share of motor gasoline, on the other hand, is low as in Bangladesh motorization process is still at an early stage and the car ownership remains low, as previously described in Chapter 6.



Source: Energy Division, MoPEMR

Figure 10-1 Oil Demand by Products (2012-2013)

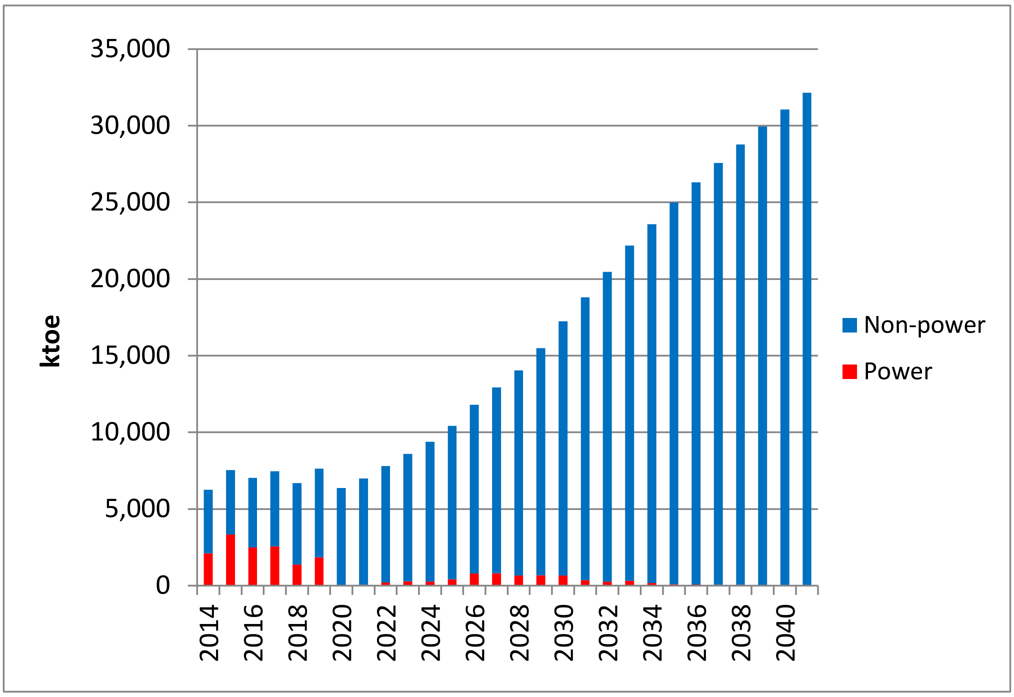
Bangladesh's oil demand has rapidly grown in the last decade backed by the country's high economic growth. The country's oil demand has increased by 1.6 times from 2002 to 2012, and its annual average demand growth rate during the period reached 4.9%. While the demand growth is observed in all sectors, demand in the power generation sector in particular observed the highest growth rate (6.6%).



Source: IEA Energy Balance for non-OECD Countries, 2014 edition

Figure 10-2 Bangladesh's Historical Oil Demand by Sector

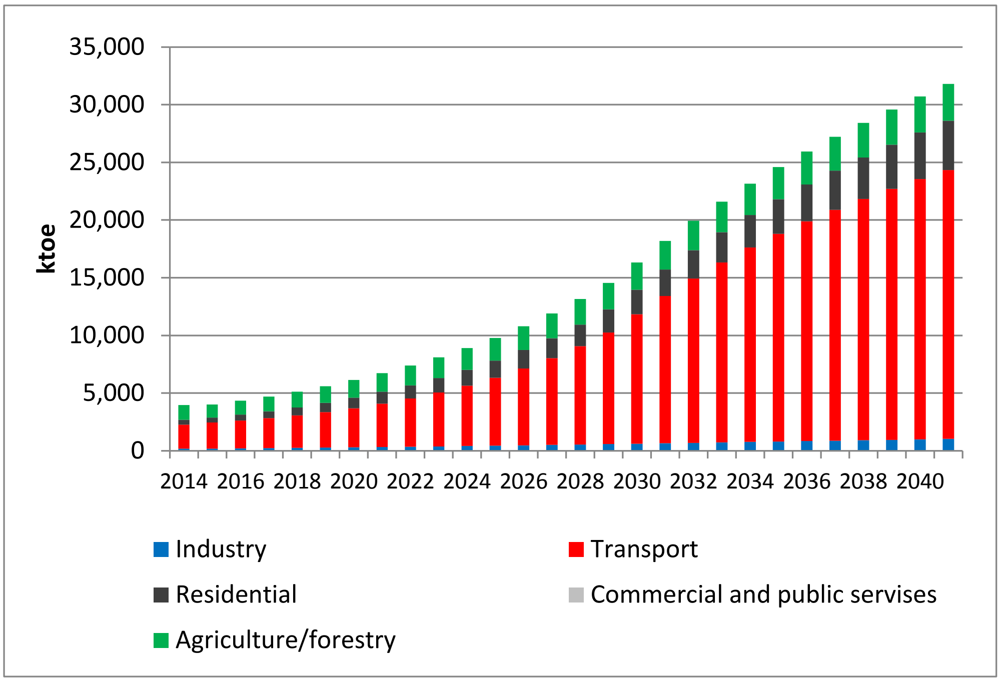
As shown in the below figure, JICA Survey Team forecasts that the country's total oil demand (power sector and non-power sectors) will increase six fold from 2014 to 2041, in average 7.0 % p.a.. Oil demand for power sector will continue to grow until the mid 2020s with the increase of the country's power demand. The demand in power sector, however, will turn into a declining trend because most of the oil products in power sector are consumed by "rental", "quick rental" and captive power generations, and when a large scale power generation becomes online (e.g. an ultra super critical coal power generation) in the mid 2020s, these oil-fired power generations will be retired or kept for stand-by capacity.



Source: JICA Survey Team

Figure 10-3 Oil Demand Projection (Power and Non-Power)

On the other hand, the oil demand from other sectors, most notably in the Transportation sector, is likely to continue its high growth rate and become 10-times more in 2041 than in 2015. This is because the car ownership in Bangladesh is expected to increase as its per-capita income growth, and the country's economic expansion will be associated with high transportation demand of goods and passengers.



Source: JICA Survey Team

Figure 10-4 Oil Demand Projection for Non-Power Sectors, 2014 to 2041

In general, oil demand growth is accelerated when the country's per-capita income approaches to USD 3,000. As 'discussed in Chapter 5, JICA Survey Team projects that Bangladesh's GDP per capita (real) as of 2041 will reach about 3,000 USD.

Though the actual demand growth rate in non-power sector of Bangladesh from 2004 to 2013 was approximately 4%, the PSMP2016 Survey team projects that the future demand growth will be higher than the historical level. Furthermore, Bangladesh used to heavily depend on the domestic natural gas for its transportation sector; however, as the domestic natural gas production declines and the demand in power sector is growing, the demand on natural gas for the Transportation sector is expected to decline, and this reduction will also contribute to oil demand growth in the Transportation sector. Given all these factors, the average growth rate of non-power oil demand is assessed at 7.2% until 2041, and becomes 8-times more than in 2015.

10.1.2 Oil import supply – current status

Because the domestic oil production in Bangladesh is very small, the country depends on import for most of the country's oil needs. The country has one refinery in Chittagong; but its refining capacity is not sufficient to meet the country's total oil demand, and the country imports oil products for the remaining demand. State-owned Eastern Refinery Limited (ERL), the country's only refinery, was built in 1967, and its existing capacity is 1.5 million tons per year. Most of the crude oil processed at ERL is imported from Saudi Arabia and UAE.
Because the country's current oil demand is 5.1 million tons, the remaining 3.6 million tons are met by product imports. Oil products are imported mainly through foreign national oil companies, such as Kuwait Petroleum Corporation or Petronas of Malaysia.

10.1.3 Oil import supply – future projects

As the domestic refining capacity is smaller than the domestic demand, the demand growth automatically increases oil product imports. Bangladesh has several projects to meet the import growth. Domestic refining, to be elaborated in the later section has multiple advantages, such as lower freight cost and lower price volatility against product imports, and is a usually preferred option for an oil importer.

(1) Expansion of Eastern Refinery (ERL)

ERL has a plan to expand its existing capacity from 1.5 million tons to 4.5 million tons. The company plans to finance the expansion project by itself, but it may invite foreign investors by forming a joint venture[1].5 Even after the capacity expansion, however, the domestic refining capacity will be short to the domestic demand. The company, therefore, considers another expansion of the domestic refining capacity, when the expansion of Eastern Refinery is successfully done. The location and the size of the additional capacity expansion have yet been determined[2].

(2) Single Point Mooring (SPM) system project

Shallow draft along the coast of Chittagong has prohibited a direct access of larger-sized tankers, and thus caused a higher shipping cost of crude oil to refinery as lightering operation is required to deliver crude oil. Bangladesh plans to build a single point mooring system offshore Matarbari Island in order to approach this problem. It is reported that China Petroleum Pipeline Bureau (CPP) will undertake the construction of SPM system, and Chinese EXIM bank will provide financial support to the project[3]. Expected construction cost is USD 630 million and expected year of completion is 2018.

SPM system is planned to be built at 60 km offshore from Matarbari Island where the water depth is 27m.The discharged pipeline will be built to the tank terminal that plans to be built in Maheshkhali Island,. The tank terminal will have six crude oil and oil product tanks whose combined capacity will be 2.4 million tons. The discharge pipelines are of two types: one for crude oil and the other for oil product. Discharged crude oil and oil product will be shipped to Eastern Refinery in Chittagong through newly constructed crude oil and oil product pipelines. The capacity of the pipelines is 4.5 million tons per year each. Major components of SPM system are as shown in Table below.

Table 10-1 Major Components of SPM System

Component	Role
Floating Buoy	Floating object that is moored to seabed
Floating Hoses	Hoses to transfer crude oil and oil products from tanker to buoy
Under-buoy Flexible Hoses	Hoses to transter crude oil and oil prodccut from buoy to onshore facility
Anchors	Object to fix the location of the entire SPM sysmte
Pipe-Line End Manifold	Facility to connect flosting hoses to tanker's discharging facility

Source: “Southern Chittagong” Survey Team

[1] JICA “Southern Chittagong” Survey team interview with the Energy Division of MoPEMR, June 7, 2015.
[2] JICA “Southern Chittagong” Survey team interview with the Energy Division of MoPEMR, June 7, 2015.
[3] “Chinese firm gets SPM project Energy division to prepare commercial contract,” New Age, 18 January 2015 (http://newagebd.net/87278/chinese-firm-gets-spm-project/#sthash.oIoMyYNT.dpuf)

(3) New refining and petrochemical complex by Kuwait

Kuwait Petroleum Corporation (KPC), the Kuwaiti national oil company, is considering investing a refining and petrochemical complex in Maheshkhali Island in Southern Chittagong. The project emerged in an agenda of the summit meeting when Prime Minister Hasina visited Kuwait in 2000. Although there had not been any progress since then, a delegation of KPC visited Dhaka in May 2015, and they requested to prepare for 1,000 acre (approximately 400 ha) land for the new refining and petrochemical complex in Maheshkhali Island[4]. The planned crude oil distillation capacity is 8.0 million tons and the expected construction cost is USD 6.0 billion. It is reported that the refinery will be built either through a joint venture between KPC and Bangladesh Petroleum Corporation (BPC), or with other international oil companies. KPC considers further expansion beyond 8.0 million tons at a later stage. The size of the refinery, however, could be too large for the domestic oil demand in Bangladesh if the demand would not grow as projected. If that is the case, the surplus capacity would be used for oil product export to neighboring countries.
The detailed configuration of the refining facilities has not been published by KPC as of writing this report. The following table is an expected configuration of the refinery project.

Table 10-2 Expected Configuration of Refinery

Unit	Capacity ('000 tons/y)	Duty
Crude Distillation Unit (CDU)	160	Split crude oil into various hydrocarbon fractions by distillation process
Naphtha Hydrotreating Unit (NHT)	25	Remove sulfur, chlorite, nitrogen, oxygen, metallic compounds in heavy naphtha stream distilled from CDU process to protect CCR catalyst by hydrotreating process.
Kerosene Treating Unit (KTU)	12	Remove sulfur and other inpurities from kerosene stream distillated from CDU process to meet the product specification of Jet A1.
Continuous Catalytic Reforming Unit (CCR)	25	Reform heavy naphtha straight-run from NHT to High Octane Mogas Blending components (reformate) by removing hydrogen with catalysts.
Residue Fluid Catalytic Cracking Unit (RFCC)	35	Convert heavier stream taken from CDU process to lighter stream such as naphtha and diesel oil components with catalysts.
LPG Treating Unit (LTU)	7	Remove sulfur from LPG stream taken from CDU and CCR process to meet the product specifications.
RFCC Naphtha Treating Unit (NTU)	6	Remove sulfur and other inpurities from naphtha stream taken from RFCC process to meet the product specification of motor gasoline.
Propylene Recovery Unit (PRU)	4	Recover propylene from LPG stream to produce high purity propylene.

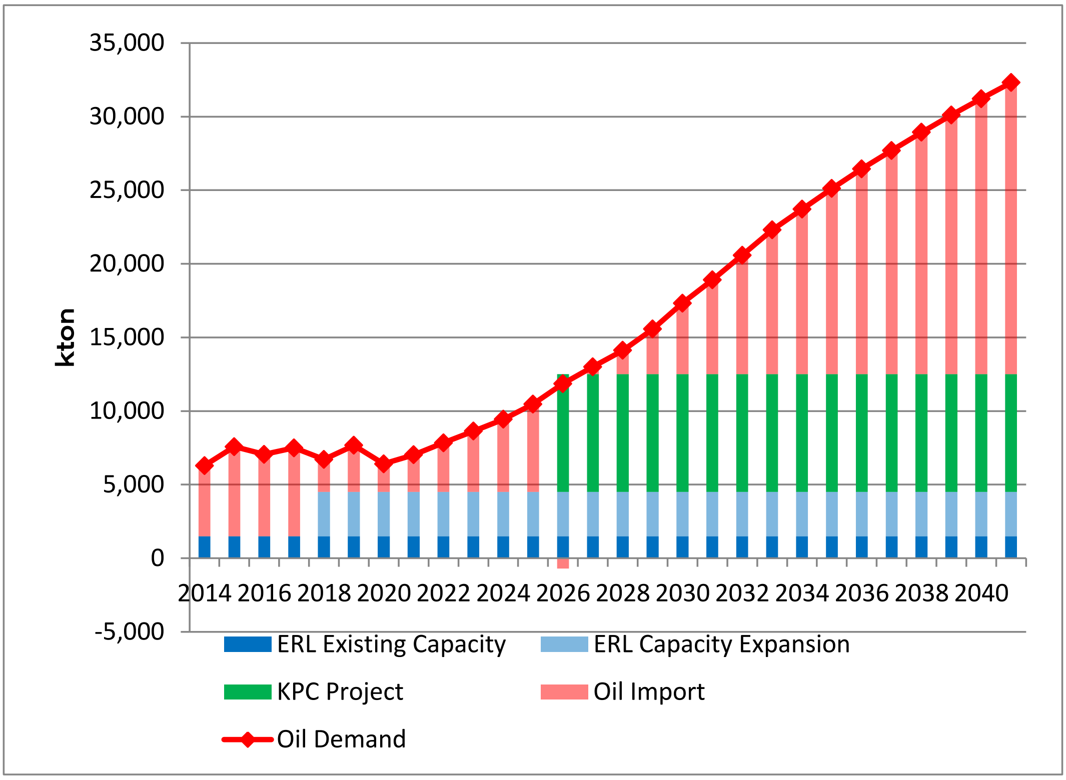
Source: "Southern Chittagong" Survey Team

The project is still at a preliminary stage and the detailed project schedule has not been determined.

[4] "Kuwait to get Maheshkhali land for oil refinery," Financial Express, 25 May 2015 (http://www.thefinancialexpressbd.com/2015/05/25/93953)

10.1.4 Oil supply and demand balance

Oil demand supply balance in Bangladesh is estimated as shown in the below figure. Because the completion year of KPC refinery project has not been determined, its start-up year is tentatively set at 2025 in the following figure[5]. As mentioned above, even with the expansion of Eastern Refinery (ERL), KPC's new refining project or any new refinery expansion by the government, the oil import will continue to increase, as far as the oil demand will sharply grow.



Source: JICA "Southern Chittagong" Survey Team and PSMP2016 Survey Team (project information), and JICA PSMP2016 Survey Team (demand projection)

Figure 10-5 Total Oil Demand & Supply Projection from 2014 to 2041

10.2 Oil Refinery v.s. Oil Import

For a country that has a shortage of refining capacity against the domestic oil demand like Bangladesh, it is important to consider how the country will secure oil product supply, especially whether the country will build a refinery to meet the domestic demand or continue to depend on product import. Building a refinery will obviously bring multiple benefits to the country. Having a refinery will provide more options to secure oil products. If the country has a refinery, the country can import various kinds of crude oil from abroad and thus can diversify its oil supply sources as long as it can be processed at the refinery. Having a refinery also brings a freight cost-saving effect. Crude oil tanker is usually larger than oil product tanker because the size of cargo traded at crude oil market is usually larger than that at oil product market. Freight cost for a large tanker is obviously cheaper than that for a smaller tanker used for product imports. Importing oil in the form of crude oil can also ease negative

[5] Initially, the project completion was plannedto be in 2018. However, the progress of the refinery project is still at an early stage where FEED has not yet started, land acquisition and financing arrangement have not been completed, it is likely to take about 10 years to complete a green-field refinery project. In a similar refiner project in other emerging countries such as Vietnam, it has taken more than 10 years from the initial announcement of the project t commercial operation.

impact of price volatility. Crude oil prices are notoriously volatile, but its price volatility is relatively lower than that of oil product prices. Furthermore, enforcing and monitoring quality specifications of oil product will be easier, if the country can refine its products by itself and does not need to monitor oil product imports from various refineries aboard.

Refinery construction option, on the other hand, certainly has disadvantages against oil product import option. The largest disadvantage is, of course, its need to secure large upfront investment money. Building a greenfield refinery with upgrading capacities often needs several billion dollars and this often becomes the largest obstacle to build a refinery for all countries. Even after the country can build a refinery, it still has a risk of underutilization and low refining margin. Refining industry, particularly in Asia market, has chronically harsh business environment due to excess capacity in the region. Investors in a new refinery have to bear in mind this business risk.

Table 10-3 Pros and Cons of Constructing a Refinery compared with Product Import

Pros	Cons
- More oil product procurement option (diversification of oil product procurement) - Lower freight cost - Lower price volatility - Oil product control	- Large upfront capital expenditures - Risk of low utilization depending on domestic and export demand - Risk of low refining margin for a long period of time

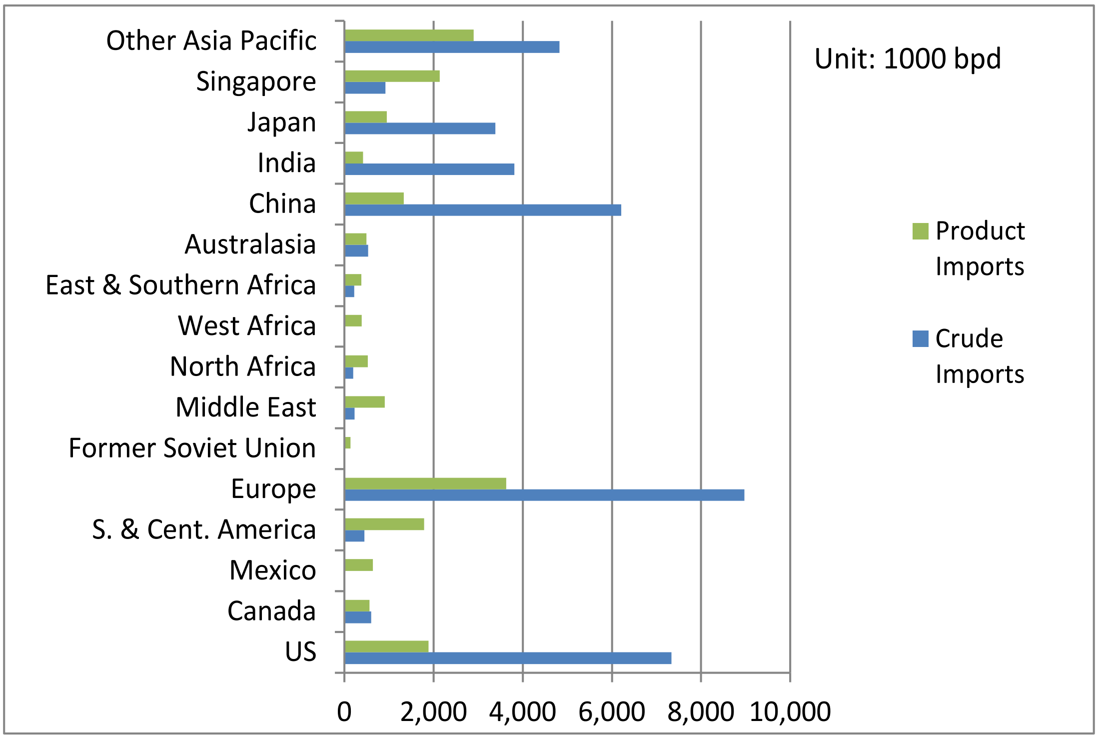
Source: JICA "Data Collection Survey on Integrated Development for Southern Chittagong Region"Survey Team

In the case of refinery and petrochemical project in the southern Chittagong, the project is initiated by KPC and the challenge of large upfront capital investment may be addressed by KPC or other potential investors which KPC may invite. Securing a sufficient fund or finding a reliable operator will maximize the benefits of refinery building and operation.

10.3 Refinery Development – World Trend and Implication to Bangladesh

As described in the above, BPC is planning to construct a new refinery in Moheshkhali area to secure the supply of oil products in Bangladesh. However, Refining industry is matured and considered one of the most competitive industries and merger and re-structuring among refineries are often observed. As discussed in the following section, in Asia, refining margin is lowering, which makes the payout period very long and a huge up-front investment cost difficult to rationalize. Therefore, in Bangladesh, it is quite critical to understand the marketing and operational environment at the planning stage.

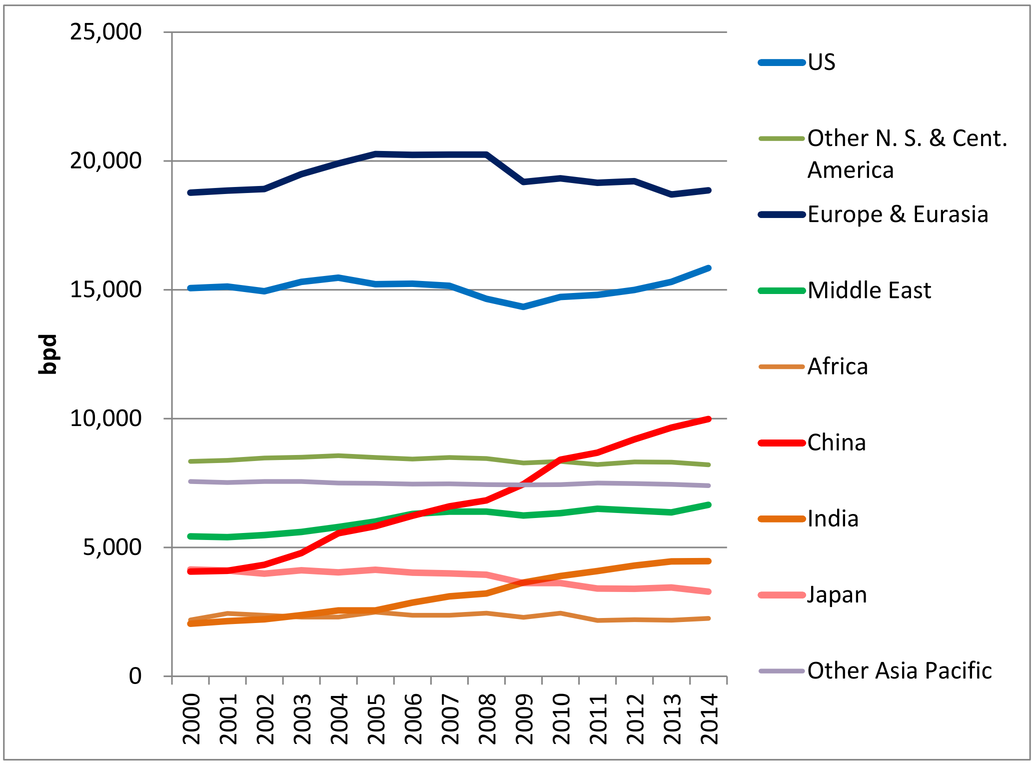
According to the BP Statistics, 37,682,000 bpd of crude oils were refined and converted to oil products in 2014. Among those, or 19,054,000 bpd or 50% of the oil products were sold through the oil product market. This fact shows that a market-impact free refinery is impossible, and that the import/export of oil product is also unavoidable.



Source: BP Statistics 2014

Figure 10-6 Crude Oil and Oil Products Trade

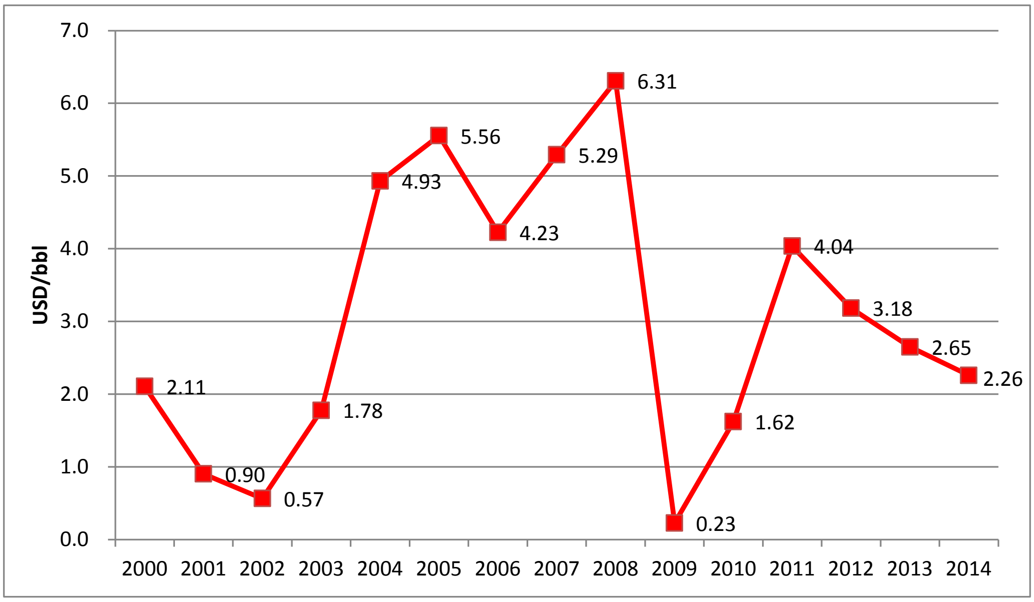
Oil product demand is growing in China, India and Middle East countries. However, demand in Japan, European countries and some other countries in Asia and Pacific region are declining. In Japan, significant refining facilities has been abandoned and demolished, such included 160,000 bpd of modern refinery in Muroran as part of restructuring of the refining industry in Japan. In Thailand, two advanced 160,000 bpd refineries in Map Ta Phut area, commissioned in 1996, were merged together in early 2000s to maintain competitiveness. In UK, several refineries are decommissioned and some of them were converted into tank terminals. UK tank terminal operators are benefited out from futures trading; such includes taking advantage of Contango situation.



Source: Prepared by the JICA Survey Team based on BP Statistics 2014

Figure 10-7 Refinery Throughput Trend

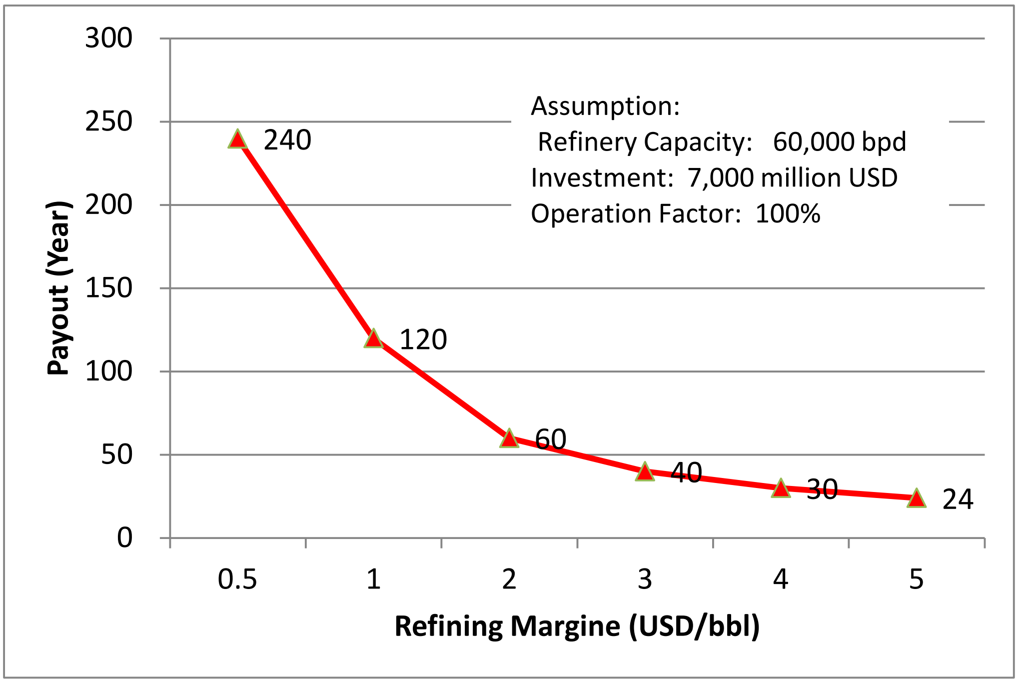
In fact, the refining industry has suffered from low refining margin for the last decade and forecast to continue:



Source: Prepared by the JICA Survey Team based on BP Statistics, 2014

Figure 10-8 Refining Margin

The refining margin has been in the range of almost zero to 6 USD/bbl for the last decade. Simple economics for constructing reasonably competitive refinery with 160,000 bpd capacity of heavy cracking capability, and assuming the investment cost of USD 7,000 million, would take more than 20 years to recover the capital investment at the refining margin of 5 USD/bbl.



Source: Prepared by the JICA Survey Team based on BP Statistics, 2014

Figure 10-9 Refinery Payout

Strategic storage of crude oil and refining capacity was once believed to be a key element for national energy security in Japan before 11 March 2011 (Japan earthquake and tsunami). These crude oil storage and refining capacity were proved to make no contribution to the supply of oil products in emergency, due to the difficulty of blending under such emergency situation. Alternatively, the robust oil product distribution infrastructure and local depots are now considered more important.

Under the low refining margin circumstances, following actions should be considered in parallel with a refinery development plan:

- Construct oil product storage facility,
- Reinforce/expand delivery infrastructure (road, local depots, product oil pipeline, etc.)
- Buy oil products from market,
- Construct refinery after confirming the improvement of refining margin

10.4 LPG

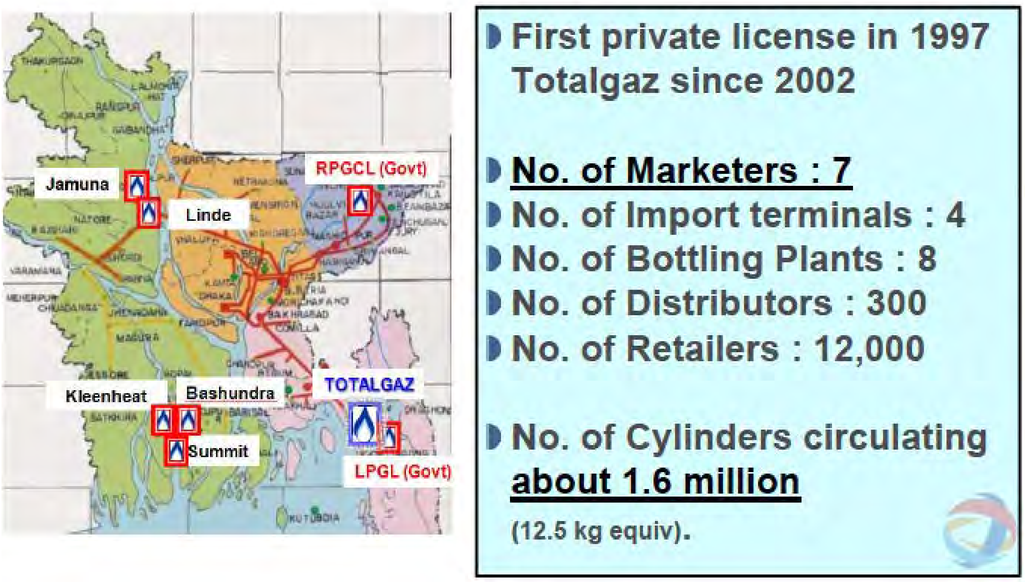
Alike other low and middle income countries, Bangladesh is increasing the reliance on LPG mainly as a proxy of modern household cooking fuel. It is in general a reasonable choice to convert to LPG from conventional solid biomass, because LPG is widely available, highly energy efficient, and less CO2 and air-polluting particles emission than combustion of conventional solid biomass and less risk of deforestation by overexploitation of forest resources[6].

In this section, the current LPG status, issues and countermeasures of LPG promotion are discussed.

10.4.1 LPG current status

The official holistic statistics on LPG is not available in Bangladesh; however, based on the publically available information, the LPG consumption in the last few years approximately 110,000 ton/year, where the private sector distributes 90,000 ton and public sector (i.e. BPC) sells 20,000 ton year[7]. This volume is still quite small 2% compared to the total oil demand in Bangladesh (110,000 ton out of 5.1 million ton mentioned in the previous Section).

In supply side, currently there are four import terminals and seven LPG private operators in Bangladesh, who deals with LPG import, shipping and distribution. Also the government has guaranteed to issue licenses to thirty new private operators[8]. For further downstream value chain, there are 12,000 retailers and about 1.6 million cylinders (12.5kg) in the market, which stands for only 4% household penetration[9].



Source: TotalGaz Presentation (ibid.)

Figure 10-10 LPG Status in Bangladesh

6 IEA World Energy Outlook 2006 Chapter 15, "Energy for Cooking in Developing Countries"
7 Ministry of Planning, "A Paradigm Shift in Bangladesh Energy Sector towards SDG-7: A Few Insights of Energy Statistics in Bangladesh", November 2015 (http://www.unosd.org/content/documents/14698_SDGs-Incheon-2015-Bangladesh.pdf)
8 Financial Express "Encouraging the use of LPG by households", April 28, 2016 (http://www.thefinancialexpressbd.com/2016/04/28/28116/EncouragingtheuseofLPGbyhouseholds)
9 TotalGaz Presentation in the World LPG Conference, February 2012 http://www.wlpga.org/wp-content/uploads/2015/09/Bangladesh_Renzo_Bee_Totalgaz.pdf

10.4.2 LPG policy

Since Bangladesh is facing a serious shortage of the domestic natural gas, the government has stipulated the pipelined gas access limit policy and encourages LPG alternatively (no new gas connections for new household and commercial buildings, and reducing hours for gas distribution). At the same time, Energy Division of GoB has developed the following fifteen items as part of "LPG Strategy Paper", which has obtained the approval of Prime Minister as an authorized policy[10].

1. Natural gas price should be raised to an appropriate level,
2. No further new connection for domestic (residential) customers,
3. LPG price should be at international market level,
4. Gas connection monitoring system should be developed,
5. Natural gas raiser at building should be utilized for LPG,
6. Import tax/duty for LPG cylinder material should be lowered,
7. Land acquisition for LPG business should be promoted,
8. Government's LPG storage capacity should secured and expanded,
9. Tax incentive for LPG import facilities (e.g. LPG road tanker) should be introduced,
10. LPG guideline for customer protection should be introduced (e.g. LPG quality standard, safety measures),
11. Conversion from CNG vehicle to LPG ones should be promoted (should be started from Gov't vehicle),
12. LPG business license fee for private enterprises should be lowered. Currently LPG storage tank development requires 50 lack taka for license,
13. Quality standard, regulation and monitoring for LPG cylinder. Currently poor quality of illegal cylinders caused many explosion accidents,
14. LPG statistics and database, and preceding survey should be implemented,
15. Customer awareness raising for LPG usage should be conducted

Out of above fifteen items, No. 1, 3 and 4 are consisted with the JICA Survey Team's recommendations (refer to Chapter 7 and Chapter 8.) In addition, the JICA Survey Team's assumptions employed in Chapter 6 are found to be consistent with GoB's policy on LPG (e.g. LPG will be mainly consumed in residential sector. For the assumption of the transport sector's LPG demand can be referred in 10.4.4).

It should be noted that BERC does not have explicit regulatory functions (including pricing) on LPG, while BERC Act 2003 does not deny it. Alternatively Energy Division currently takes regulatory roles on LPG. Energy Division may consider such function at BERC in future.

Other LPG regulations will also be defined or revised within the year 2016, such as LPG Rules (2014) to be revised, LPG Bottling Plant Guideline and LPG Conversion Workshop Establishment Guideline to also be developed.

[10] Interview with Energy Division and JICA Survey Team (June 2016). The Strategy Paper accompanies with Action Plan and Roadmap, which are yet approved as of June 2016 hence not disclosable.

10.4.3 LPG price

As mentioned earlier, Bangladesh has two groups of LPG distributors; one is private and the other one is public (BPC). Between these two groups, there is noticeable price difference: privately distributed price is about 1100～1400 Tk/cylinder (12kg/cylinder) , and publically distributed one is 750 Tk/cylinder (12.5kg/cylinder). While the Energy Division well recognizes the gap, they expects that the competition among private distributes drives the price down to somewhere around 800 Tk./cylinder, given the large market share of private distributors. JICA Survey team believes that there should be some corrective actions for this price gap.

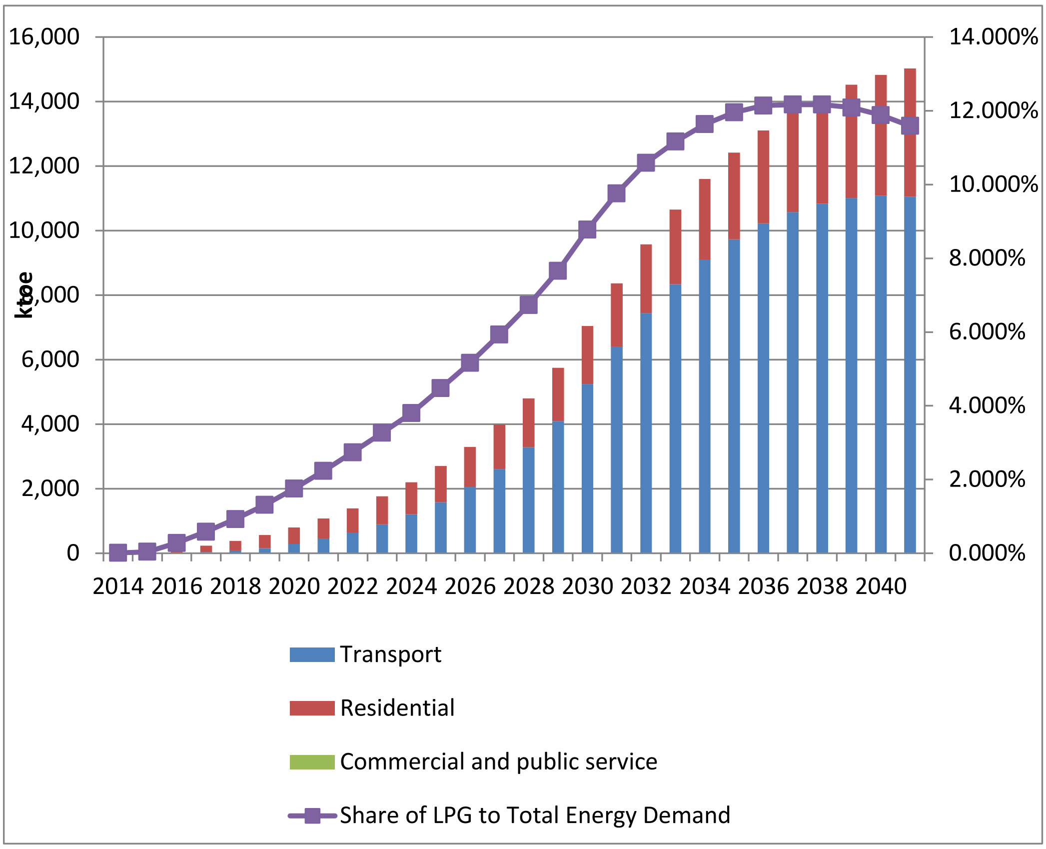
Energy Division also points out that the current difference of one unit of LPG cylinder between private and public (private cylinder is 12kg and public cylinder is 12.5kg) will be standardized to 12kg per cylinder.

10.4.4 LPG future demand

It should be pointed out that, although the government has policy to encourage LPG for household use, there is still no articulated policy or direction on LPG in the holistic picture of energy supply. This means that, in face of the decline of domestic natural gas and prospected sharp LNG import increase, the position of LPG to meet the growing energy demand, not only from the household but demand of all consumer sectors (especially transport sector), is yet clear.

Alternatively, for the purpose of the demand projection, the JICA Survey Team assumes that LPC will be used mainly in the household and transport sector to meet the energy demand-supply gap. More precisely, the team has taken the following assumptions; 1) as for the residential sector, the study team assumed that the natural gas supply will be maintained only for the existing customers and that new houses and apartments are obliged to use LPG instead, and 2) as for the transport sector, the current final consumption amount ratio of oil products and natural gas is roughly 2 to 1. The sharp increase of transportation fuel demand is met by oil products and natural gas (including LNG) at the same ratio (2-to-1), and the transportation fuel demand on gasoline will increase at higher pace than in the past, and the LPG meets the demand-supply gap.

As a result, the demand on LPG is projected to increase drastically at the growth rate almost 35% p.a., 15 times higher in 2041 than in 2016, as shown in the below figure.



Source: JICA Survey Team

Figure 10-11 LPG Demand Projection (Household + Transport) from 2014 to 2041

This demand projection is merely the Survey team's assumption and it could largely vary depending on the policy making; however, it is still noticeable that the oil demand from transport sector – regardless of it would be gasoline, LPG or other oil products, will grow radically.

10.4.5 LPG supply future plan

In order to respond to the anticipated future LPG demand growth, the Government has taken initiative to cooperate with India. It is reported that BPC and Indian Oil Corporation Limited (IOCL) had an MOU in April 2016 for a future LPG plant in Chittagong, which will be the largest plan in Bangladesh[11]. The details of the project (e.g. capacity of the terminal, or construction schedule) are yet disclosed. However, it is reported that the LPG received or produced in Chittagong will be transferred to Tripura, in the northeast India, thorough a pipeline to be developed in the Bangladesh territory. In exchange for this, oil products from a refinery in Numaligarh, Assam India will be received at Parbatipur in the northwest Bangladesh (there is some 700km distance in between).

However, in fact, in Bangladesh, some 80% of LPG is produced and delivered by private companies, including international oil companies. The government role can be, not to invest the capital intensive projects, but appropriate LPG regulation to accommodate healthy market competition and protect consumers.

[11] Financial Express, "BPC, Indian corpn sign MoU on LPG plant today", April 18, 2016 (http://www.thefinancialexpress-bd.com/2016/04/17/26591/BPC,-Indian-corpn-sign-MoU-on-LPG-plant-today)

10.4.6 Issue of LPG

(1) Absence of strategic position of LPG in the energy policy

As pointed out earlier (10.4.2), Bangladesh government has indicated a direction of LPG usage in Household (Domestic) sector and Transport Sector; however, it is yet enough. In fact, the strategic positioning of LPG calls for the strategic positioning of LNG, which will also meet the deficient domestic natural gas supply. The new energy policy should clearly define how LNG and LPG will meet the supply shortage of domestic natural gas, and which sector should be a main consumer of each import fuel.

Simultaneously, pricing policy of LPG and LNG also needs be established.

(2) The gap between household fixed gas tariff

As mentioned earlier, private dealers offer for one 12kg cylinder, ranging from some 1050 Taka to 1300 Taka, while public dealer offers only 750 Taka. Although the GoB (Energy Division) expects the market competition among private dealers drive down the price, it is recommendable to take corrective actions, if GoB wishes to disseminate LPG.

Furthermore, there are striking difference between the LPG marketed price and the current pipelined natural gas (fixed tariff, 450 Taka for one burner for month)- approximately 8 to 1 as seen the below Table 10-4 . GoB has well recognized this issue and will take corrective actions (10.4.2).

Table 10-4 Per MJ Price Difference between LPG Marketed Price and Pipelined Gas for Household

	Fixe Price for one burner		Unit Sales Price		Heat Value per Unit		Unit Price per MJ	
Natural Gas	Tk 600	Tk/month	Tk 8.33	/m3	39.59	MJ/m3	Tk 0.21	/MJ
LPG	Tk 1,050	Tk/12 kg (1 cylinder)	Tk 87.50	/kg	50.80	MJ/kg	Tk 1.72	/MJ

Source: JICA Survey Team

As mentioned in the Chapter 7, Bangladesh's pipeline gas tariff for household itself has long been an issue for energy sector, which has been pointed out in many studies including JICA's, to improve energy efficiency in Bangladesh. In fact, the Government has taken initiatives to improve the situation, and pre-paid gas meter installment supported by JICA and other development partners.

(3) Affordability for households

Even though the government intends to encourage LPG for household as an alternative of pipeline natural gas, the substantial deployment of LPG would be difficult without corrective actions for this price difference. Also, the actually expensive LPG may not be affordable for low income families, especially for the rural ones.

Assuming that one household consumes two cylinders a month, the fuel cost for cooking would be some 2,100 to 2,600 Taka. As per BBS's survey in 2010, the national average monthly income is

11,479 Taka, while the rural one is 9,648 Taka[12]. According to the World Bank's study using 2005 data, Bangladesh rural households spend some 2 to 6 % of their monthly income for biomass fuels[13]. If this expenditure pattern remains almost equal today, the LPG fuel cost would be about 25 % to an average rural household, and give a big pressure to the household expenditure compared to the conventional solid biomass, and LPG dissemination to the rural area would be very difficult. As mentioned in the Chapter 13, Bangladesh's access to modern energy is quite limited (the only 8% of pipelined gas consumers are urban centric, especially in Dhaka area). According to the BBS statistics in 2014, more than 94% of the rural population in Bangladesh uses traditional solid biomass for cooking. However, LPG cannot be affordable to rural household nor contribute to the improvement of the access of the modern energy for all.

This LPG affordability issue must be addressed, not only the LPG tariff or household gas tariff issue, but also from the national energy strategy viewpoint. "LPG subsidy" maybe an easy solution to address the price issue, but should be analyzed carefully.

At the same time, in order to address the LPG affordability issue, biogas should be considered as a domestically and richly available resource. For detailed discussion of potential of biogas and its economic competitiveness over LPG is discussed in Chapter 13 [14].

10.4.7 Pressure to the national coffer

Despite efforts of JICA Survey Team to collect information on LPG subsidies, no GoB official information was provided. However, it is clear that GoB intends to shrink the oil subsidy including LPG in future. Given the LPG future demand projection, this oil subsidy policy is quite important and valuable decision.

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[12] BBS, "Report of the household income & expenditure survey 2010"

[13] World Bank, "Expenditure of Low-Income Households on Energy", June 2010, Figure E.2 Monthly Urban Household Expenditure on Biomass.

[14] In the interview with Energy Division in June 2016, they replied that the biogas potential in rural areas is worth for further consideration.