Chapter 5 Natural Gas Sector

In this chapter, a present data analysis is conducted about natural gas policy, which is the main source of primary energy in Bangladesh, domestic fuel situation, future development trends, and the demand according to sector. It works on the policy geared towards future stable reservation including LNG imports. A promising point connected to future development is investigated from the viewpoint that domestic resources are utilized to their utmost with regards to the development of natural gas, and the available supplies which are in charge of optimum power development plan decision, which are clarified.

5.1 National development plan

5.1.1 Government policy and plan

The Government's development goals are;[1]

- to provide energy for sustainable economic growth and for maintaining energy security in the country
- to provide energy to all socio-economic groups in the country especially to the less developed areas
- to diversify use of indigenous energy; and
- to contribute towards protection of the environment.

In order to achieve the above goals, the Government is planning to take various measures for the petrochemical fuel sector including natural gas such as to increase the proven gas reserves by hastening survey, exploration, prospect drilling, evaluation and production optimization; to make an adequate assessment before the development; to introduce a method of the legal control of natural resources by the state owned companies; to make a comprehensive control by the state-owned companies, specially commercial applications; to reduce the gas demined by curtailment of system loss and improving the efficiency; to solve the regional development unbalance by extension of the pipeline toward western part of the country; to have strategic stock pile of petroleum fuel for minimum two months; to work privatization of liquefied fuel sector.

In recognition of the importance of natural gas in the socio-economic development of the country to support the poverty reduction strategy paper (PRSP), the Government would implement several measures to the gas sector, including hastening exploration and development of gas fields by the united efforts of government sector and private sector, facilitating foreign capital investments with giving incentives to them through Production Sharing Contract (PSC), privatization of the domestic gas sector, rationalizing the domestic gas price and making link with international gas price, making arrangements for environmental protection from the initial stage of development and evaluation.

5.1.2 Gas reserve estimation report 2003

The latest reserve estimation performed in 2003 by the Hydrocarbon Unit of Energy and Mineral Resources Division (HCU) and related parties, and published as then "Bangladesh Gas Reserve Estimation 2003". The work of the "Bangladesh Gas Reserve Estimation 2003" was started in May 2002 in order to update the existing gas reserve report titled "Bangladesh-Petroleum Potential and Resources Assessment 2001"by forming an expert team comprised of HCU, Petrobangla, Bangladesh Gas Fields Ltd. (BGFCL), Sylhet Gas Field Ltd. (SGFL), Bangladesh Petroleum Exploration & Production Company Limited (BAPEX) and the Norwegian Petroleum Directorate (NPD). In order to update the gas reserve, old reports were examined with the seismic data, well log data, production and other relevant data that was collected. The gas fields operated by the PSC members such as Jalalbad, Sangu, Bibiyana and Moulavi Bazar were not included for this

[1] National Energy Plan (Draft) 2008

re-evaluation work and the figures of the reserves of these fields provided by Petrobangla were kept unaltered and applied to this report.

The gas fields in the Bangladesh were divided into Developed Gas Fields and Undeveloped Gas Fields. And for the purpose of re-estimation, developed gas fields were divided into Producing Gas Fields and Suspended Gas Fields. Out of 22 discovered gas fields, 16 gas fields were included for re-assessment by volumetric method. The producing sand of 5 gas fields were analyzed by Material Balance method using Shut In and Flowing Well Head Pressure since enough Shut in Bottom Hole Pressure data required for this method were not available for the most producing wells. Therefore, the results of re-assessment by the Material Balance were not considered to be correct.

All of the previous reports relating to the gas reserves were described based on this "Bangladesh Gas Reserve Estimation 2003." In this MP, the latest preliminary reserve estimation which currently assessed by HCU is used. Since the latest estimation report has not published yet, the details are not clear at this stage, however, the accuracy of the estimation is expected to be improved by reflecting new material balance method and 3D seismic survey result.

GoB formulated the National Strategy for Accelerated Poverty Reduction II (revised) (NAARP-II(revised)) in which it emphasizes essential infrastructure development in the 3rd block out of the 5 strategic blocks, especially focusing on the power and energy sector as a priority matter. It requires that the National Energy Policy be updated to provide the guidelines for achieving the nation’s energy security.

5.1.3 Gas Sector Master Plan 2006

At present, the latest Gas Master Plan for the Bangladesh Government is Gas Sector Master Plan (GSMP 2006) published by Petrobangla/World Bank (Consultant: Wood Mackenzie) in 2006. The following issues are presented in the GSMP 2006;

(1) Current status in the Bangladesh gas sector

The GSMP 2006 indicated that the Gas Sector in the Bangladesh faces a very financially weak sector, as a result of low gas prices and recognized that insufficient funds were therefore available to undertake the level of investment required in both supply and transmission to meet demand growth, which continues to be strong.

The Bangladesh has only proved gas reserves to fully meet demand until 2011, although taking into account probable reserves this extent to 2015. For this reason, the GSMP 2006 suggested that there is an urgent need for radical reform measures to enable that gas demand can be met.

(2) Gas demand forecast up to 2025

Based on GDP growth assumptions, the gas demand forecast was made for the three cases.

- Case A: Essentially a continuation of the recent GDP growth trend in 2006.
- Case B: Consistent with the Bangladesh Government PRSP and MDG aspirations.
- Case C: 9% GDP growth until 2015, then decrease to 7% by 2025.

In comparison with actual gas demand (1,791mmcfd) at the end of fiscal year in 2009, it is nearly same as Case C (1,785mmcfd at the end of 2009) and the actual gas demand shows higher growth than Base Case (Case B) assumed by the GSMP2006. In Case C, the total demand as of 2025 is estimated 7,441mmcfd. In this case, there will be causing shortage of gas supply against gas demand in 2013 if the gas supply is only proved reserves (P1) plus probable reserves (P2).

(3) Gas network issue

Substantial expansion and modification of gas network system in the Bangladesh is inevitable to satisfy with increasing gas demand. Significant investment is essential to improve the infrastructure, and then of addition of compressor. In total an investment requirement of US$1.3 billon was identified in the transmission sector over period to 2025.

(4) Strategy and investment for the Bangladesh gas sector

The expected total addition of gas needed from new gas fields will be 16 to33 Tcf, or which will require an investment of about US$5 billion to 10 billion.

5.1.4 Gas Sector Reform Road Map (2009-2012)

The Bangladeshi Government dialogued with ADB to revise the Gas Sector Reform Road Map (GSRR) to address the various issues held in the Gas Sector. The GSRR forms the action plans to set concrete countermeasures, time frames, monitoring instruments etc, classified into following seven categories. By implementing these action plans, the GSRR aims to improve operational performance in the gas sector and reform the inadequate investment, uneconomic tariffs, inadequate investment resources, inefficient use of gas and inadequate capacity in the state-owned gas companies and government agents.

(1) Policy Framework

To update the road map on gas sector reforms covering 3 years, and outline the latest government's vision on the gas sector.

(2) Regulatory Instruments

To develop rules and regulations for private sector participation and to establish competitive and effective markets in terms of gas purchases, sales, and transmissions.

(3) Sector Planning

To update the gas master plan and disseminate investment options for the private sector.

(4) Increased Access to Natural Gas

To develop a strategy for the exploration and utilization of undiscovered reserves.

(5) Corporate Governance

To reduce the accounts receivables from public and private customers and minimize system losses in distribution and transmission in order to improve financial management.

(6) Gas Sector Restructuring

To establish TGTDCL as three separate companies and BGSL into two separate companies in order to improve management performance.

(7) Private Environment

To allow private financing in the gas sector in order to reduce dependence on government funds.

5.1.5 Natural Gas Access Improvement Project (2010）

In the face of impending gas shortage as well as the continued growth of Bangladesh's energy and natural gas requirements in recent years due to economic growth, the Bangladeshi Government has requested ADB financing for several priority projects in the sector that would help implement its Poverty Reduction Strategy (PRSP). In response to a request from the Government, the ADB in January 2008 engaged with Technoconsult International Limited (TCIL) who is a local technical consultant firm based in Bangladesh to undertake the Technical Assistant study for preparing a clean fuel sector development program (the Program). TCIL commenced its study for the Program from February 2008 and submitted a final report with its proposal after compiling investigation results to ADB on March 2009. Following the proposal by TCIL, ADB worked out a proposal for the Natural Gas Access Improvement Project (the Project) mainly to provide a loan to the People's Republic of Bangladesh, and the Board of ADB approved the Project on 26 March 2010. The outlines of this Project are as follows.

(1) Project cost and financial plan

The project is estimated to cost US$542 million equivalent, including tax and duties of US$ 101 million. ADB loan will be US$261 million equivalent from ordinary capital resources (OCR) and US$5 million equivalent from the Asian Development Fund (ADF). Korea Eximbank will provide US$45 million equivalent for construction of Ashuganj-Bakhrabad Gas transmission loop-line and installing interface metering as shown in Table 5-1. The Bangladesh Government will provide US$231 million equivalent through loan and equity contributions.

(2) Explanation of the program

The gas sector has been affected by inadequate investment, compounded by uneconomic tariffs, inadequate investment resources, inefficient gas usage, and a large number of system losses, so that it has not performed at its potential gas production capability yet. The project is to support the country's gross domestic product (GDP) growth and promote broad-based development across the country through improving the sector. This will be accomplished by improving the efficiency and expanding the gas transmission and distribution network in the targeted areas at the same time ensuring a sustainable gas production, and maximizing the utilization of natural gas.

(3) Impact and outcome

The impact of the project will be increased and more reliable access to natural gas for sustained economic growth, achieved by reinforcing and augmenting natural gas supply and addressing policy and institutional constraints. The main outcome of the project will be expanded capacity and improved efficiency in natural gas production, transmission, and distribution systems.

(4) Outline of the Project

Table 5-1 Project cost summary for Natural Gas Access Improvement Program

Cost by Project Component	(Million US$)
A. Base Cost 1. GTCL(Gas Transmission Company Ltd)- Transmission Capacity Expansion A-1: Ashuganj-Bakhrabad gas transmission loop-line. ➢ Construction of gas loop line: 30" OD 61km 400 mmcfd ➢ Installation of major transmission –distribution interface metering and regulating stations at Manohardi, Dewanbhog, Kutumbpur, Feni and Barabkund	81
A-2: Gas Compressor installation at Ashuganj and Elenga ➢ Ashuganj maximum throughput: 1,500mmcfd ➢ Elenga maximum throughput: 500mmcfd	173
2. Safety and supply efficiency improving in Titas gas field B-1: To improve safety at existing problematic wells in Titas field B-2: To improve supply efficiency through four additional appraisal-cum-development wells and install processing plants in Titas field to increase gas production by 120 mmcfd	9 103
3. Access improvement in southwestern region Construct 2" to 20" gas distribution pipeline of 845 km to provide gas to the districts of Kushtia, Jhenidah, Jessore, Khulna, and Bagerhat (including Mongla.)	73

Cost by Project Component	(Million US$)
4. Supply and demand management Establish gas metering at consumer connection of Titas Gas Transmission and Distribution Company Limited (TGTDCL) include installing prepaid Meter for domestic consumers and for industrial consumers replacing existing meters with remote sensing meters on a pilot basis.	8
2. Contingencies	54
3. Financing charge during implementation	41
Total (1 + 2 + 3)	542

Source: ADB, Natural Gas Access Improvement Project

(5) Estimated project completion date

31 March 2015

(6) Project benefits

The government’s ongoing reform program based on the GSRR will strengthen the financial position of sector entities, enhance public–private partnership, and improve sector and corporate governance. The project will create efficient and viable gas infrastructure to address priority supply and network constraints. These interventions will ensure sustained growth in the gas sector, which is critical to the country's economic development.

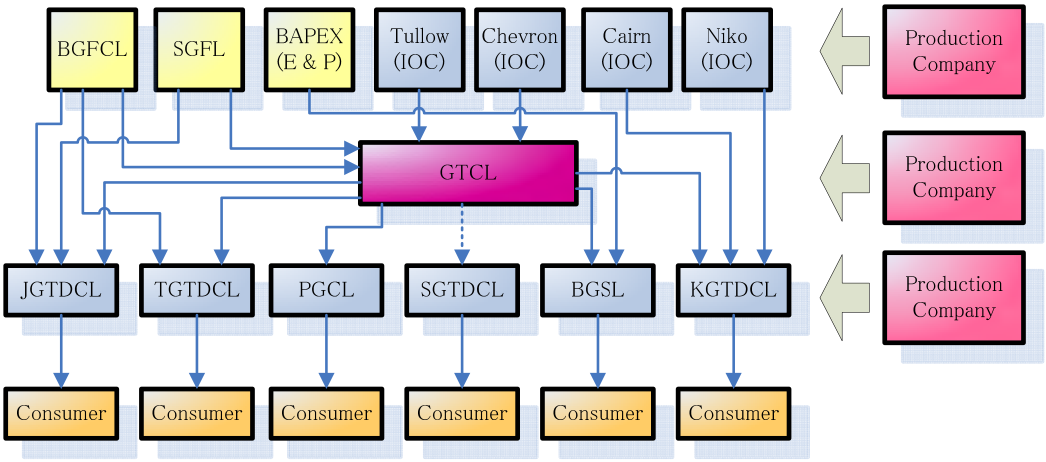
An estimated 200,000 households will gain access to gas through the new distribution network. The project will have a positive impact on environment and health, particularly of women and the poor, who are the most vulnerable to indoor air pollution from the use of biomass and fuel wood, which will be replaced with natural gas. An additional 1,400 industrial and commercial establishments and 35 compressed natural gas filling stations will have access to gas in the southwest. Industries such as jute mills, textile weaving factories, small cottage industries, and textile mills, and commercial entities such as restaurants and bakeries, will benefit, generating significant employment in the region and thus reducing poverty. The project will directly create 3,000 persons per month of job opportunities during implementation.

The perspective of gas demand-supply projection forecast is presented by TCIL in the Program and projections indicate that the gas demand will exceed the supply at the year of 2010. Gas supply will increase year by year up to 2017, however, the supply may not catch up the growth of demand. Therefore, the gap between gas demand and supply will be magnified increasingly since production supply will decrease gradually after 2017. Thereafter, production will decline if no new reserves have been found. This would be addressed by requiring the Government to encourage and accelerate exploration activities both in the public and the private sectors to ensure timely gas availability. The Program addresses these concerns by appropriate policy reforms to promote upstream investment.

5.1.6 Organizational structure

(1) Natural gas sector overview

The gas sector in Bangladesh is organized into distinct segments for exploration and production, gas transmission and gas distribution under Petrobangla. All of the installation and supervision of the pipelines are under control of Gas Transmission Co. Ltd. (GTCL).



Source: EMRD (2011)

Fig. 5-1 Organization structure of gas sector

(2) Formation of companies under Petrobangla

Since the gas was found for the first time in 1955, the gas-based petroleum industry in Bangladesh has grown active gradually. In 1974 after the independence, the national company Bangladesh Oil, Gas and Mineral Corporation (Petrobangla) for carrying out the exploration, the production, transportation, and the sales of natural gas and petroleum and the excavation of coal and granite was established under the Energy and Mineral Resources Division (EMRD) based on the petroleum law of Bangladesh. In 1976, the national company BPC for carrying out the petroleum refinery and the sales of petroleum products was established.

The activities of the Petrobangla group encompass the entire spectrum of the gas sector. The companies under Petrobangla are involved in each of the stages from the drill bit to burner tips. Petrobangla, through its companies, conducts geological and geophysical exploration by its own crew, drills exploration and development wells by its own rig, processes the raw gas, transports the processed gas through the network of high-pressure transmission lines and distributes gas to the consumers.

Bangladesh constitutes one of the largest deltas in the world and has proved its hydrocarbons potentiality through the discovery of 23 gas fields including one oil field during the course of drilling only 76 exploration wells over a period of the last 50 years of exploration. In spite of a slow exploration pace, the success ratio is 3:1. However, when offshore drilling is concerned a total of 17 gas fields have been drilled with only one commercial discovery i.e. Sangu Gas Field. Before emerging as an independent country in 1971, exploration was conducted under license by foreign companies and also by the state exploration wing. 1974 marked the year when the opportunity for the international petroleum industry to explore, develop and produce oil and gas under PSC in the offshore areas only arose

Currently, Petrobangla controls eleven companies divided in five departments

(3) Organization for production/exploitation

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

BAPEX was separated from Petrobangla in 1989 to be established as a development company. It has the exploration development capability only in Petrobangla-owned companies and assumes geology department, physical exploration department, and excavation and renovation department. The production department has three gas fields; Salda, Fenchuganj, and Shahbazpur and currently, these gas fields produce approximately 2% of whole gas quantity produced in

Bangladesh. BAPEX has 10% right of mine sites in blocks 5, 7, 9, and 10 and 100% right of mine sites in blocks 8 and 11. BAPEX also has a joint venture with Niko to develop two marginal gas fields Feni & Chattak. Currently, it operates two drilling rigs and one workover rig and orders new drilling rig to replace present one in order to replenish inefficient operation. Additionally, it has one seismic survey equipment, trained personnel and the analytical capability. The total number of employees is 1989. (As of June 2009)

(b) Bangladesh Gas Field Company Limited (BGFCL)

BGFCL is the largest gas production company in three Petrobangla-owned companies. It produces approximately 39 % of whole gas quantity produced in Bangladesh from four gas fields; Titas, Bakhrabad, Habiganj, and Narshingdi. The predecessor of BGFCL is Pakistan Shell Oil Company established in 1965 and it was acquired by the government in 1974 after the independence of Bangladesh, and the name was changed to BGFCL in 1975. Titas gas field produces the second largest gas production volume; 395mmcfd of gas after 527mmcfd of natural gas production volume of Chevron Bangladesh (Chevron), and it is planned to excavate two evaluation wells based on the result of recent seismic survey. It is also planned to excavate four production wells additionally depending on this result. The reserves are re-evaluated and it is expected that the production volume will increase dramatically. The number of employees is 1975. (As of June 2009)

(c) Sylhet Gas Field Limited (SGFL)

SGFL's predecessor is Burma Oil Company (BOC) established in the 1950s and after the nation's independence, it fell under the control of the Bangladeshi government. It produces 9 % of all of the gas produced in Bangladesh from four gas fields; Sylhet, Kailashtila, Rashidpur, and Beanibazar. It is planning to carry out the 3D seismic survey including Sylhet, Kailashtila, and Rashidpur gas fields from 2010 and re-evaluate the structure of each gas field and excavate five evaluation wells. The gas field of SGFL, especially Kailashtila gas field has a higher production ratio of condensate than that of other gas fields. The construction of the Petrochemical plant in the future is planned. The number of employees is 1982. (As of June 2009)

(d) International oil companies (IOC's)

Currently, five foreign companies; Chevron, Cairn Energy Plc. (Cairn), Tullow Oil Plc. (Tullow), Niko, Total E & P are evolved in exploration, development and production of natural gas and petroleum onshore and offshore under PSC with Bangladesh and the companies other than Total E & P are producing the gas at PSC gas field. The gas field activity of each PSC company and current activity are listed shown below based on the data of Petrobangla.

Table 5-2 Activity for each block of IOC companies

Operator	Block	Activities（Jun. 2009）
Cairn Energy Exploration（Bangladesh） Limited	5	So far conducted 69 LKM (line kilo meter) seismic surveys beyond the buffer zone of Sundarban forest. Not drilled any wells yet.
Chevron Bangladesh Block Seven limited	7	Has conducted 1,047 LKM seismic survey. Not drilled any wells yet.
Tullow Bangladesh Limited	9	Discovered Bangora-Lalmai gas field in 2004. Now producing from Bangora field at the rate of 87 mmcfd.
Cairn Energy Exploration (Bangladesh) Limited	10	Has conducted 1233 LKM seismic survey. Not drilled Any wells yet.
Chevron Bangladesh Block Twelve Limited	12	Discovered Bibiyana gas field in1998. Bibiyana has started production from 2007.Current production rate is about527 mmcfd as of June 2009.
Chevron Bangladesh Block Thirteen & Fourteen Limited	13 &14	Discovered Moulavibazar gas field in 1997. Currently producing 74 mmcfd. Chevron is also producing gas from previously discovered Jalalabad gas field at the rate of about 158 mmcfd as of June 2009.
Cairn Energy Sangu Field Limited	16	Discovered Sangu gas field in 1996. This is the first and only producing offshore gas field in the country. Now Producing 50 mmcfd as of June 2009.
Total E & P	17&18	An amendment agreement was signed on 2007 to Extend the exploration period up to 2010. But, they subsequently withdrew.

Source： Petrobangla

(4) Gas transmission organization

(a) Gas Transmission Company Limited (GTCL)

GTCL was established in 1993 and is eligible as a National Gas Transmission Company in Bangladesh. Since then GTCL is at present extending gas transmission network to the South-Western districts of the country.

It is responsible for transforming the produced gas and condensate via its owned transmission line from each gas field to the distribution line owned by a franchised gas distribution company. The total length of the pipeline is 930 km and the piping diameter is 20 to 30 inch and the Supervisory Control And Data Acquisition (SCADA) system is facilitated to monitor gas transportation conditions.

In recent years the development plans of the gas transportation capability has been studied with World Bank (WB) and ADB, where Ashuganj is marked as a hub station and some bypass lines to the south-western area and/or the western area next to Dhaka is under study by Gas distribution organization.

(5) Gas distribution organization

(a) Titas Gas Transmission and Distribution Company Limited (TGTDCL)

TGTDCL has been jointly founded by the former Pakistan Government and Pakistan Shell Oil in 1964 and has transformed natural gas in Dhaka and the surrounding areas. After the independence of Bangladesh, as a 100% government-owned corporation, it became a subsidiary company of Petrobangla under control of EMRD in 1975. It has the largest number of customers in Dhaka and its neighbor in Bangladesh.

The annual sales amount of gas is around 12,239 MMCM and the number or customer counts on 1,350 thousands including 28 power plants. As for the transportation ability, it has its own 613km transmission line and a 10,277km distribution line.[1].

[1] Source: annual report of TGTDCL, 2008

(b) Bakhrabad Gas Systems Limited (BGSL)

BGSL was established in 1980 and has transformed natural gas for the benefit of the customers concentrated mainly in the Chittagong area as a subsidiary company of Petrobangla under control of EMRD. In 1985 onwards the connection line to TGTDCL was settled between Bakhrabad and Demra to meet the Dhaka area's large demand.

The annual sales amount of gas is around 2,811 MMCM and the number of customers is in around the 430 thousands including five power plants. As for the transportation ability, it has its own 67km transmission line, a 246km lateral line, and a 5760km distribution line.[1].

(c) Jalalabad Gas Transmission & Distribution System limited (JGTDSL)

JGTDSL has been established in 1977 and has transformed natural gas to the customers mainly in Sylhet area (north-eastern area) as a subsidiary company of Petrobangla under control of EMRD. In the north-eastern area there exists a plenty of gas field like Sylhet, Bibiyana, and Kailashtila, so the stable gas supply can be achieved when compared to other franchised gas companies.

The annual sales amount of gas is around 885 MMCM and the number of customers is around 120 thousands including 4 power plants. As for the transportation ability, it owns transmission line of 2,831km in length[2].

(d) Pashchimanchal Gas Company Limited (PGCL)

PGCL has been established in 1999 and has transformed natural gas to the customers mainly in Rajshahi area (north-western area) as a subsidiary company of Petrobangla under control of EMRD.

The annual sales amount of gas is around 614 MMCM and the number of customers is around 40 thousands including 4 power plants. As for the transportation ability, it owns distribution line of 878km in length[3].

5.2 Gas reserves

Bangladesh has discovered so far twenty three gas fields with a total GIIP (Proven + Probable) of 28.8 Tcf of which 20.4 Tcf is recoverable. As of June 2009, seventeen gas fields are producing from 79 wells. The capacity of daily gas production is about 2000 mmcfd and cumulative production for 49 years from 1960 to June 2009 has reached to 8.4 Tcf. According to the Petrobangla , remaining recoverable reserves as of end of June 2009 is estimated to be 12.1 Tcf of which 6.7 Tcf is proven reserves (P1) and 5.4 Tcf is probable reserves (P2), and possible recoverable reserves (P3) is 7.9 Tcf. The amount of deposit announced is based on the works made by HCU in 2003, by establishing an evaluation team with experts of petroleum in Norway.

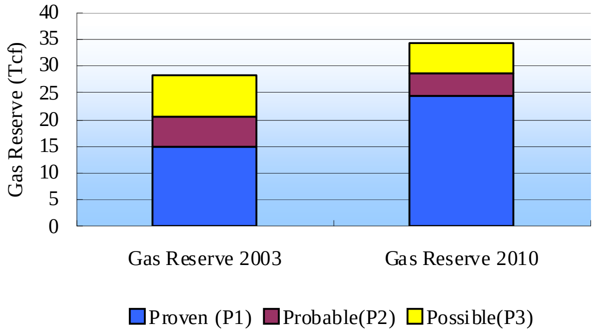
Meanwhile, HCU is re-evaluating the gas reserve by retaining Gustavson Associates as a consultant. The re-evaluation has still been under way as of October 2010. According to the interview with HCU, it is estimated that the overall remaining reserve will be increased. The gas reserves in 2003 and preliminary evaluation as of October 2010 is shown in Table 6-3. This MP uses the preliminary data as the latest information.

[1] Source: annual report of BGSL, 2008
[2] Source: annual report of JGTDSL, 2008, The annual gas sales amount was reviewed by PSMP Study Team
[3] Source: annual report of PGCL, 2008

Table 5-3 Gas reserve scenario

Category	Gas Reserve 2003	Gas Reserve 2010	difference
	(Tcf)	(Tcf)	(Tcf)
Proven Recoverable Reserve (P1)	15.0 (53%)	24.3 (71%)	9.3
Probable Recoverable Reserve (P2)	5.4 (19%)	4.5 (13%)	▲0.9
Possible Recoverable Reserve (P3)	7.9 (28%)	5.4 (16%)	▲2.4
Recoverable Reserve (P1+P2+P3)	28.3 (100%)	34.2 (100%)	5.9
Cumulative Production (Up to June 2009)	8.4	8.4	—
Net Recoverable (Proven +Probable) (Up to June 2009)	12.1	20.4	8.3

Source : Gas Reserve Estimation Report 2003, 2010 modified by PSMP Study Team (2010 data is preliminary basis)



Source: HCU Gas Reserve Estimation Report (2003, 2010 preliminary)

Fig. 5-2 Gas reserve comparison

The gas reserve estimate in 2010 is on a preliminary basis so that the details are not clear yet. However, it is estimated that the production from major gas fields such as Bibiyana, Rashidpur, Titas has increased up to 2.8Tcf, 1.9Tcf, 1.7Tcf respectively, while that from Habiganj has decreased to 1.1Tcf. It is supposed that the reasons for the increase are due to the accuracy of the evaluation by using 3D seismic survey improved and the recovery factor improved via renovated drilling technology, as a result the probable and possible reserves were upgraded to a proven one. The PSMP Study Team recognized this reserve estimation is as reasonable.

5.3 Current status and the future forecast of gas demand

5.3.1 The present situation of gas demand

(1) Area wise and sector wise demand in the present and future

This study is implemented with reference to the operating data from the annual report of Petrobangla and four major distribution and marketing companies. Sectors such as Power, Fertilizer, Industry, CNG, Captive Power, Commercial, Domestic, and Tea Estate are examined in this study.

The data of Petrobangla report are those from 1981 onward, in which the gas for the power is both for power stations and captive powers, and the gas for CNG is combined with that for Tea Estate.

As the purpose of this report is to clarify the future fuel source of power stations, it is needed to extract the real gas demand for power stations. CNG should also be analyzed independently from that for Tea Estate with different market. The data of four major distributors are those from 2004 onward and their demand groupings are same as Petrobangla's. Their total sale meets the Petrobangla wholesale to them. The following table shows the wholesales of Petrobangla from 1981 to 2003 and sales of four distributors from 2004 onward. The data is used as the base data to forecast the future gas demand.

Table 5-4 Present situation of gas demand

(Unit: mmcfd)

F.Year	Power/Captive Power		Fertilizer	Industry	Commercial	Domestic	CNG/Tea		Brick Field	Total	Gas Production	System Loss	Loss Ratio
	Power	Captive P.					CNG	Tea					
1981	36		49	22	4	9	0	0	0	121	137	16	12
1982	49		73	25	5	12	0	0	0	163	178	14	8
1983	60		71	27	5	14	0	0	0	177	198	20	10
1984	63		81	28	6	16	0	0	0	193	228	35	15
1985	105		75	35	6	17	0	0	0	237	259	22	8
1986	109		92	45	7	19	0	0	0	272	288	16	5
1987	142		96	51	9	19	0	0	0	317	331	14	4
1988	170		140	46	10	21	0	0	0	386	404	17	4
1989	179		146	41	9	25	0	0	0	401	444	43	10
1990	207		153	39	8	28	0	0	0	436	459	23	5
1991	226		148	36	8	29	0	2	0	450	473	24	5
1992	241		169	37	8	32	0	2	1	489	516	27	5
1993	256		190	42	7	37	0	2	1	533	578	45	8
1994	267		204	56	8	42	0	2	3	581	613	32	5
1995	294		221	66	8	52	0	2	3	645	677	32	5
1996	304		249	75	8	57	0	2	3	698	728	30	4
1997	304		213	78	12	63	0	2	1	673	715	41	6
1998	338		219	89	13	68	0	2	1	730	772	42	5
1999	386		227	98	13	74	0	2	1	800	844	43	5
2000	404		228	114	11	81	0	2	1	841	911	70	8
2001	480		242	131	11	87	0	2	1	955	1,023	68	7
2002	521		216	147	12	101	0	2	1	999	1,073	74	7
2003	522		263	175	12	123	0	2	1	1,098	1,154	56	5
2004	549	85	254	127	13	135	5	2	0	1,172	1,240	69	6
2005	578	105	257	143	13	144	10	2	0	1,254	1,333	79	6
2006	615	133	244	173	14	155	19	2	0	1,356	1,460	104	7
2007	606	172	256	212	15	173	33	2	0	1,469	1,542	73	5
2008	642	220	216	253	18	189	63	2	0	1,601	1,646	45	3
2009	704	260	205	287	21	207	85	2	0	1,770	1,791	21	1

Source： Annual report in 2008 of Petrobangla and four major distribution and marketing companies

(a) Power and captive power

The gas demand ratio of the Power sector to all sectors was slightly over than 45% in 2004, but after that it has been decreased yearly to its present 40%. This trend is shown below.

Table 5-5 Gas demand ratio of the power sector for all sectors

F. Year	Power/Total Gas (%)
2004	46.8
2005	46.1
2006	45.3
2007	41.3
2008	40.1
2009	39.8

Source: PSMP Study Team

(b) Fertilizer

In general, the gas demands of fertilizer plant are met to the extent possible during the peak season of production by adjustment with supplies to power stations.

PSMP Study Team interviewed to KAFCO Japan which is a parent company of KAFCO of a major Fertilizer company. Chittagong where KAFCO located is in the supply franchise area of distribution gas company BGSL. In 2009, there is in chronic gas shortage, while demand for the gas within the supply area is about 400 mmcfd on an average, actual supply was at about 300 mmcfd, with shortage about 100 mmcfd, though KAFCO as a foreign company is generally given priority in terms of gas supply over government owned other fertilizer plants. As for the fertilizer sector, while demand is about 120 mmcfd, gas supplies are only about 70 mmcfd with the shortage about 50 mmcfd.

For this reason, CUFL, another major Fertilizer company in Chittagong is obliged to suspended operation temporarily. Although the government guaranteed KAFCO to enough gas supply for operation. KAFCO reduced production by 20 to 30% from the scheduled quantity of production due to the shortage of gas supply, which appears big influence in revenue.

The cause of the gas shortage is the decrease in production of a Sangu gas field. Installation of the line compressor in April, 2009 does not help the situation completely. For the time being, although the production increase from Bakhrabad gas field, Semutang gas field and Feni gas field is expected, it is projected that restrictions of gas will continue until about 2013.

As a national energy policy, gas supply to Fertilizer sector has been restricted until 2013 and then will be expected to be increased due to the update of the facility according to the gas task team meeting on Feb.4, 2010. This view will be applied for the network analysis described later.

(c) Industry

The gas demand for Industry has increased steadily after 1981 and the share has reached to 16% of the total gas demand in 2009.

(d) Commercial

The gas for commercial use is only 1% of the total gas demand in 2009. However, it has been increasing steadily after 1981, the earliest year the data are available.

(e) Domestic

The gas for domestic use is slightly below12% of the total gas demand in 2009. It has also been increasing steadily after 1981.

(f) CNG

The gas demand for CNG suddenly appeared in 2004 and is increasing rapidly.

(g) Tea estate

The gas demand for Tea Estate appeared in 1991. The demand is stagnant and little.

(h) System loss

The system loss was more than 10% in 1980s, but has been improved to 1 % dramatically after 2009.

(2) Current status of area wise and sector wise gas demand

Four distribution and marketing companies are responsible for gas retail in Bangladesh. The amount of gas sales from 2004 to 2009 was calculated utilizing each annual report and local interview. The results are shown below.

Table 5-6 Gas sales amount by sector

（Unit : mmcfd）

	Fiscal Year	Power	Captive P.	Fertilizer	Industry	Commercial	Domestic	CNG	Tea Estate	Total
TGTDCL	2004	400	73	135	103	8	95	5	0	820
	2005	417	88	140	119	8	101	9	0	882
	2006	460	111	133	146	9	109	15	0	983
	2007	469	146	139	176	10	121	25	0	1084
	2008	495	186	107	211	12	130	44	0	1184
	2009	537	219	97	234	13	142	58	0	1301
BGSL	2004	64	12	103	20	4	31	0	0	234
	2005	71	14	101	20	4	34	1	0	245
	2006	77	18	95	23	4	36	3	0	256
	2007	68	21	102	29	4	39	7	0	270
	2008	56	28	93	32	5	44	13	0	272
	2009	42	32	92	37	6	48	21	0	278
JGFA	2004	32	0	16	4	1	8	0	2	63
	2005	32	3	16	4	1	9	0	2	67
	2006	32	3	16	4	1	10	0	2	68
	2007	26	4	16	7	1	10	1	2	68
	2008	40	5	15	8	1	11	3	2	86
	2009	62	7	15	14	1	12	1	2	115
PGCL	2004	53	0	0	1	0	0	0	0	54
	2005	58	0	0	1	0	1	0	0	60
	2006	46	0	0	1	0	1	0	0	49
	2007	43	1	0	1	0	3	0	0	48
	2008	50	1	0	1	0	4	2	0	59
	2009	62	2	0	2	0	5	5	0	76
Total	2004	549	85	254	128	13	134	5	2	1171
	2005	578	105	257	144	13	145	10	2	1254
	2006	615	132	244	174	14	156	18	2	1356
	2007	606	172	257	213	15	173	33	2	1470
	2008	641	220	215	252	18	189	62	2	1601
	2009	703	260	204	287	20	207	85	2	1770

Source： Annual Report, Titas Gas、Annual Report, BGSL、Annual Report, JGFA、Annual Report, PGCL

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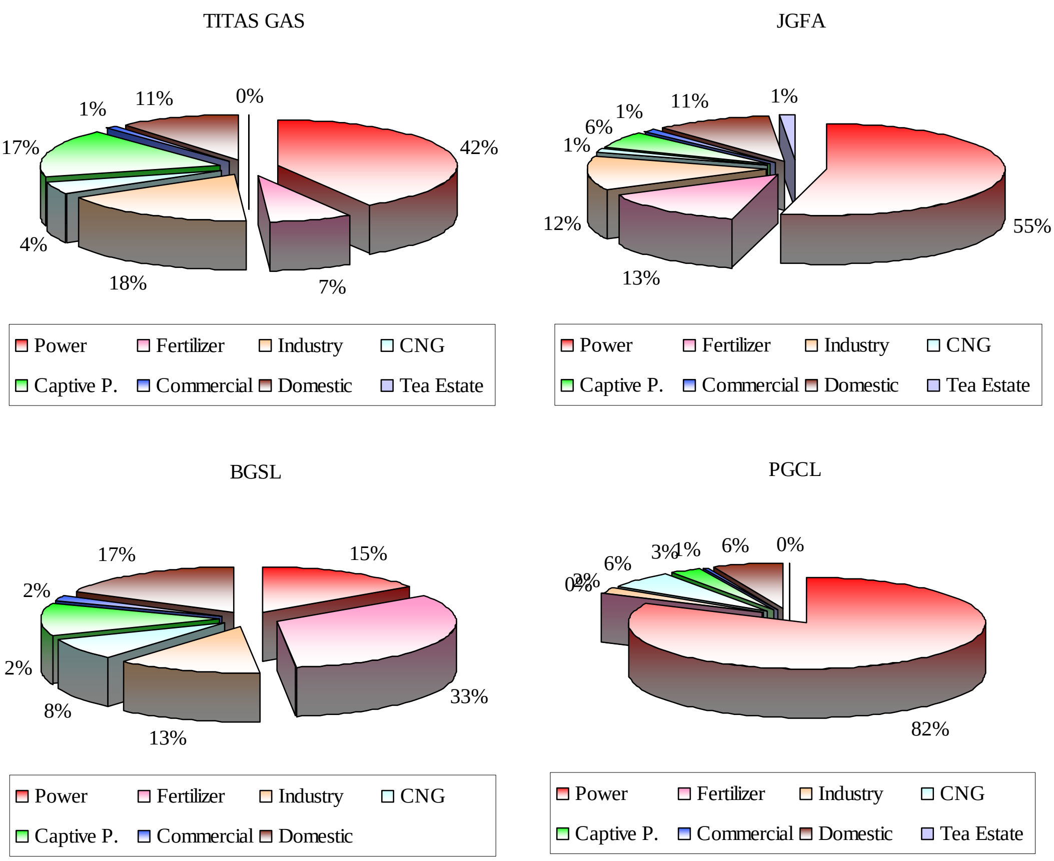


Source： PSMP Study Team

Fig. 5-3 Sector wise gas sales amount of 4 retailers (FY 2009)

(3) Gas demand-supply management

Petrobangla and the EMRD have involved taking some policy decisions on allocating and sharing the available gas among the power and fertilizer sectors to obtain maximum socio-benefit. For better gas management, especially for the power sector, a committee jointly headed by the Director (Operation) of Petrobangla and the Member (Generation) of BPDB is working since 2006 for gas allocation to different power stations considering the availability of gas. Gas allocations and sharing among the fertilizer and power sectors were carried out by Petrobangla, BPDB and BCIC. In Bangladesh, February to April being the irrigation season of the agricultural sector for which it is essential to supply more electricity for irrigation purposes, and each time, for the last couple of years, more gas is supplied to power sector even reducing gas supply to fertilizer plants.

5.3.2 Gas demand forecast

(1) Methodology

The annual gas demand up to 2030 can be forecasted by using the actual demand data in 2009 as foundational data. Generally speaking, the gas demand and the real GDP are correlated. However it is not universal. Some sectors never depend on real GDP and the newly generated sector has not had enough data for this statistic analysis. Therefore in a strongly correlated sector with a real GDP, a regression analysis can be conducted and for the other sectors, the demand can be forecasted utilizing the materials and local interviews.

(2) Analysis of the correlation between GDP and gas sales by each sector

Demand function is expressed with this equation. D=a*(GDP) ^b

This equation is developed. Log (D) =b*Log (GDP) +Log (a)

And Log (a) and b are found. The magnitude of correlation is checked by R^2.
Where y is log (mmcfd) and x is log (GDP).
Sensibility analyses were also done in forecasting gas demand by GDP correlation.

Table 5-7 Analysis of the correlation and data selection

Group	Sector	Correlation	Principle of demand forecast
Bulk	Power	y=0.9331x-3.2508 R^2=0.9387	The gas demand has a strong correlation with GDP. But it is strongly influenced by government policy, so the statistic analysis will not be appropriate for demand forecast. As the lead time for constructing new plant is long, the forecast will be conducted by investigating the mid-to-long term power plant development program.
	Fertilizer	y=-0.1361+3.2491 R^2=0.0736	The demand has no correlation with GDP. The market itself has not been activated and has gradually shrunken. There are only seven fertilizer plants and no new construction plan in Bangladesh. The demand forecast will be conducted through the interview with the task team of the gas sector.
Non-bulk	Industry	y=1.5649x-7.8163 R^2＝0.8083	The gas demand has a considerable correlation, but not sufficient. The demand forecast will be conducted through the interview with Petrobangla and calculated using the market growth rate in each area reported in Gas Evacuation Plan (2010-2015).
	Captive Power	y=3.6887x-21.681 R^2=0.9961	The gas demand has a strong correlation with GDP. But it is easily influenced by the national policy and it has a trade off relation with the stability of electricity supply, so a statistic analysis is not appropriate in this sector. The demand forecast will be conducted in accordance with the diesel shift scenario obtained from Petrobangla.
	Domestic	y=1.7953x-9.3976 R^2=0.9892	As the gas demand has a strong correlation with GDP and the customer's number is statistically meaningful, the demand forecast will be conducted by regression analysis. As SGCL is a new area, the demand forecast will be conducted in accordance with the Gas Evacuation Plan.
	Commercial	y=0.9321x-4.8255 R^2=0.8537	As the gas demand has a strong correlation with GDP and the customer's number is statistically meaningful, the demand forecast will be conducted by regression analysis.
	CNG	y=9.1048x-57.515 R^2=0.9892	The gas demand has a strong correlation with GDP. But the task team of gas sector indicated that the demand might be different by area. So, the demand forecast will be conducted through the interview with Petrobangla and calculated using the market growth rate in each area reported in Gas Evacuation Plan.
	Tea Estate	y=0.0703x-0.1521 R^2=0.0122	The gas demand has no correlation with GDP. The market remains stagnant. The demand will continue the same level of 2009 up to 2030.

Source: PSMP Study Team

(3) Gas demand forecast by each sector

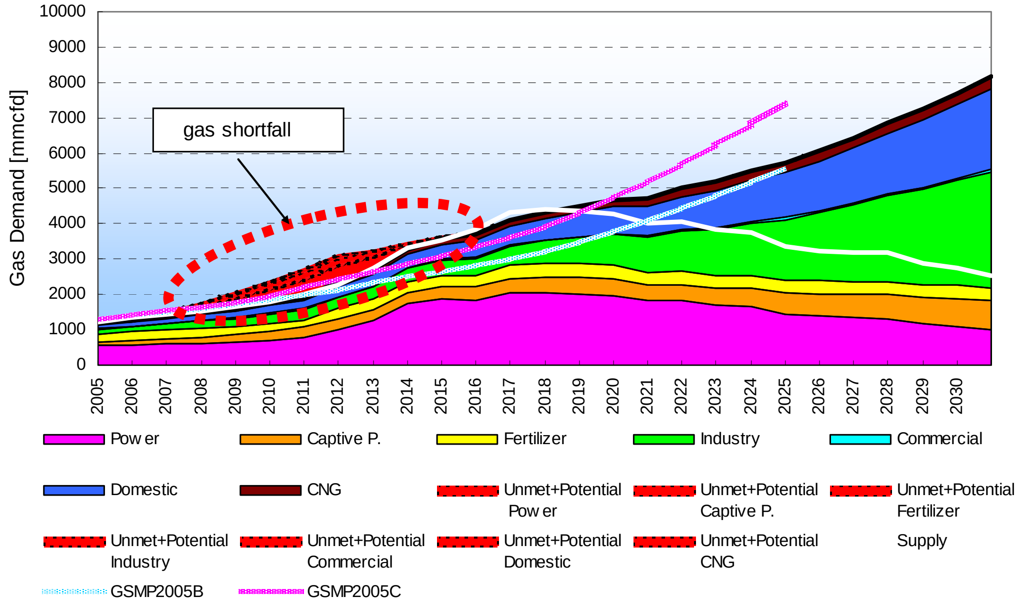
Gas demand forecast by each sector is shown in below table and figure.

Table 5-8 Gas demand forecast by each sector

(Unit : mmcfd)

Fiscal Year	Power	Captive P.	Fertilizer	Industry	Commercial	Domestic	CNG	Tea Estate	unmet + Potential	Total
2004	549	85	254	127	13	135	5	2		1,170
2005	578	105	257	143	13	144	10	2	0	1,252
2006	615	133	244	173	14	155	19	2	160	1,515
2007	606	172	256	212	15	173	33	2	320	1,789
2008	642	220	216	253	18	189	63	2	480	2,083
2009	704	260	205	287	21	207	85	2	640	2,411
2010	776	309	177	326	22	220	102	2	800	2,733
2011	1,023	284	290	320	21	289	109	2	800	3,138
2012	1,265	303	290	356	22	326	125	2	600	3,289
2013	1,734	324	290	396	24	367	142	2	200	3,477
2014	1,863	347	320	440	25	414	158	2	100	3,669
2015	1,841	372	320	489	27	467	174	2	100	3,792
2016	2,050	400	370	562	29	527	183	2	0	4,122
2017	2,068	431	370	647	31	593	192	2		4,334
2018	2,030	465	370	744	33	669	202	2		4,514
2019	1,962	503	370	855	35	755	212	2		4,693
2020	1,819	441	370	983	37	851	222	2		4,726
2021	1,820	465	370	1,131	39	943	234	2		5,004
2022	1,692	490	370	1,301	41	1,046	245	2		5,188
2023	1,641	532	370	1,496	44	1,160	257	2		5,501
2024	1,460	576	370	1,720	46	1,286	270	2		5,731
2025	1,386	625	370	1,926	49	1,427	284	2		6,068
2026	1,352	650	370	2,158	51	1,569	290	2		6,441
2027	1,322	675	370	2,417	54	1,725	295	2		6,860
2028	1,177	722	370	2,707	56	1,898	301	2		7,233
2029	1,113	773	370	2,977	59	2,087	307	2		7,689
2030	1,007	827	370	3,275	62	2,296	313	2		8,152

Source: Gas Evacuation Plan (2010-15) modified by PSMP Study Team



Source: Petrobangla, GSMP2006, Gas Evacuation Plan, modified by PSMP Study Team

Fig. 5-4 Gas demand forecast

As of June 2010, there exists a gas shortfall, breakdown of which is shown in the below table. The total gas shortfall was about 800 mmcfd, in which about 500 mmcfd was unmet demand, i.e. the amount was not delivered to the existing gas customer, and about 300 mmcfd was potential demand, i.e. the amount was wanted from the potential customer who had already applied for a gas contract but it was not executed yet. This gas shortfall arose continuously from around 2005. In order to project the gas demand forecast, the shortfall amount as of June 2010 was incorporated into the forecast as unmet/potential demand, then extrapolated to 2005. The gas shortfall will be alleviated due to the Gas Evacuation Plan (2010-2015) including the introduction of LNG, and the Government incentive plan for switching from gas to other fuels to gas potential customers. Via these measures, the gas shortfall is expected to be dissolved by 2016.

Table 5-9 Breakdown of unmet demand and potential demand as of June 2010 (mmcfd)

Category	Demand	Supply	Balance
Power	1076	760	316
Captive	370	330	40
Fertilizer	289	170	119
Industry	415	375	40
Domestic	245	235	10
CNG	115	100	15
Others	35	30	5
Sub Total	2545	2000	545
Potential	300	0	300
Grand Total	2845	2000	845

Source: Petrobangla

5.4 Current status of natural gas development and production

5.4.1 Current status of natural gas production

Since the development of Chattak gas field, 23 gas fields have been discovered until now and currently (June 2009), 17 gas field are producing the gas. The gas fields are operated by three National companies and four IOC companies. The gas fields of Titas, Bakhrabad, Habiganj, Narsingdi, and Meghna are possessed by BGFCL, the gas fields of Sylhet, Kailastila, Rashidpur, and Beanibazar are possessed by SGFL Company, and the gas fields of Salda, Fenchuganj, and Shahbazpur are possessed by BAPEX. The gas fields of Jalalabad, Moulavi Bazar, Bibiyana (Chevron), Sangu (Cairn), Bangura (Tullow) and Feni (Niko) are operated by IOCs with PSC. The average gas production volume is 1,791 mmcfd (2008/09) in all, and the production volume of IOC makes up 50%. The production capability for each gas field is shown in the following tables. Natural gas chemical properties are tabled in Appendix.

Table 5-10 Production capacity of each gas field

(Bcf)

	Company	Sl. No	Gas field	Discovery	Number of gas well		Production Capacity (mmcfd) (as of June 2009)			Recoverable (Proven+Probable) 2003 basis	Recoverable (Proven+Probable) 2010prelim.	Cumulative (June 2009)	Remaining Reserve (2003 basis)	Remaining Reserve（2010 prelim.）
National	BGFCL	1	Titas	1962	14	30	395	697	41%	5,128	7,582	2,996	2,132	4,586
		2	Bakhrabad	1969	4		33			1,049	1,322	692	357	630
		3	Habiganj	1963	9		236			3,852	2,787	1,617	2,235	1,170
		4	Narsingdi	1990	2		33			215	217	99	116	118
		5	Meghna	1990	1		0			120	49	36	84	13
		6	Begumganj	1977			0			33	33	0	33	33
		7	Kamta	1981			0			50	50	21	29	29
	SGFL	8	Sylhet	1955	1	14	2	157	9%	479	372	189	290	183
		9	Kailastila	1962	6		91			1,904	2,654	466	1,438	2,188
		10	Rashidpur	1960	5		50			1,402	3,149	448	954	2,701
		11	Beanibazar	1981	2		15			170	137	57	113	80
	BAPEX	12	Saldanadi	1996	2	4	10	38	2%	116	267	59	57	208
		13	Fenchuganj	1988	1		27			283	281	60	223	221
		14	Shahbazpur	1995	1		0			466	269	0	466	269
		15	Semutang	1995			0			150	318	0	150	318
IOC	Chevron	16	Jalalabad	1989	4	31	158	811	48%	837	1,245	509	328	736
		17	Moulavi Bazar	1997	4		74			360	889	140	220	749
		18	Bibiyana	1998	12		527			2,401	5,199	361	2,040	4,838
	Cairn	19	Sangu	1996	6		50			500	695	458	42	237
	Tullow	20	Bangura	2004	2		0			309	0	0	309	0
	Niko	21	Feni	1981	3		3			129	130	62	67	68
		22	Chattack	1959			0			474	474	26	448	448
		23	Kutubdia	1977						--	--	--	--	--
Total					79	79	1,70	1,70	100	20,427	36,761	8,376	12,130	19,822

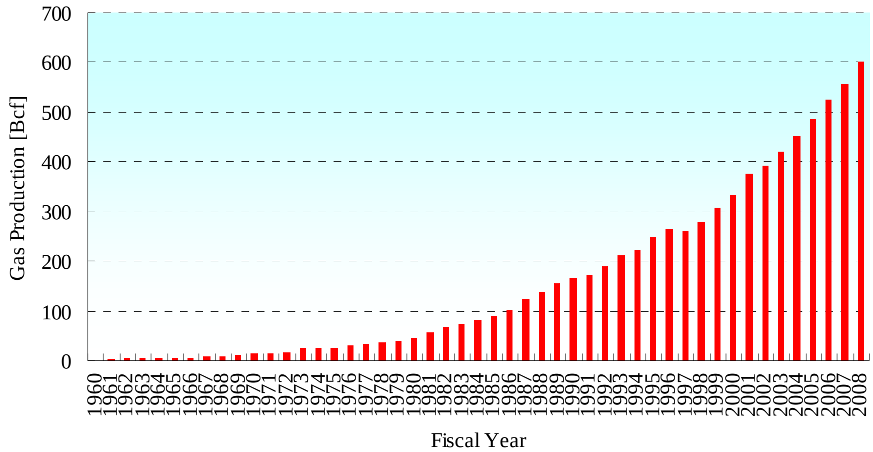
Source: Petrobangla Annual Report 2008 modified by PSMP Study Team

5.4.2 History of gas production

Production history of the country dates back to 1959 when Chattak Gas Field started commercial production and supplying gas to the then Assam Bengal Cement Factory. In 1960 Sylhet Gas Field started commercial production and the only consumer was Fenchuganj Natural Gas Fertilizer Factory. Titas Gas Field which started production in 1968 and in the following year Habiganj Gas Field went into production. Till 1983 these four fields supplied gas to the consumers. Average daily production during 1982-83 was 197 mmcfd. In 1984 Kailastila was added to the list of producing fields. Next year Bakhrabad and Kamta went into production. During the year 1991-92 Feni started production. During 1992-93 daily average production was 577 mmcfd.

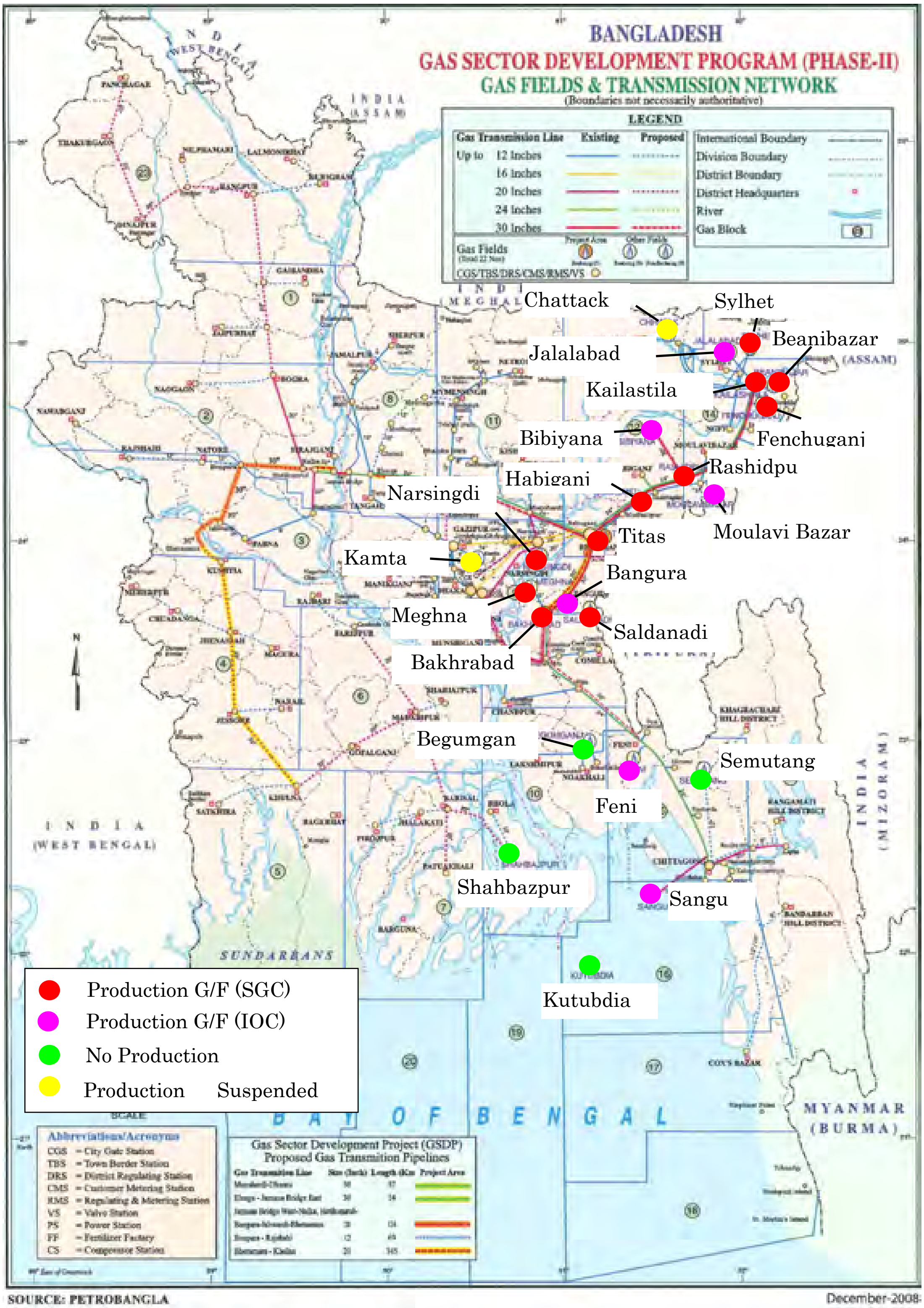
Currently, out of 23 gas fields so far discovered, seventeen are producing. Production from two fields i.e. Chattak and Kamta were suspended in 1985 and 1998 respectively due to excessive water production from different wells. First offshore gas production of the country started in June, 1998 from Sangu Gas Field operated by Cairn Energy Bangladesh Ltd.

At present gas is being produced from 17 fields and operated by three national and four international companies under PSC & JVA. The cumulative production of natural gas in Bangladesh for last 49 years is 8.4 Tcf. The volume of gas production has been increasing substantially from 2000 and onwards. The average annual gas production since inception is given as below:



Source: Clean Fuel Development Program, TCIL (2009)

Fig. 5-5 History of gas production in Bangladesh



Source: Petrobangla

Fig. 5-6 Location map of gas fields

TEPCO

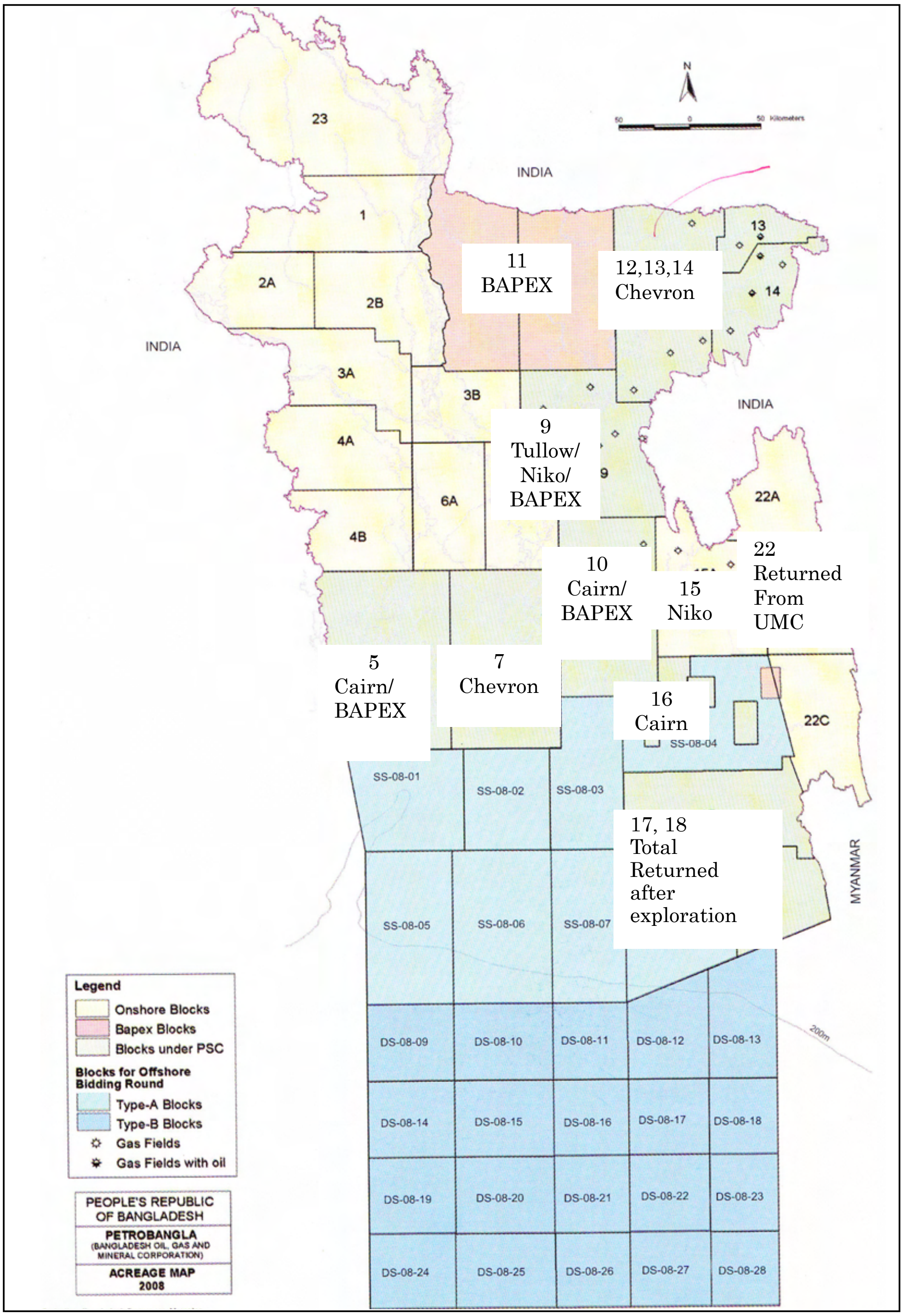
5.4.3 International bidding for newly opened offshore blocks

Before the independence in 1971, the exploration activities were mainly carried out by foreign companies, however, since the effect of petroleum law in 1974, the PSC (Production Sharing Contract) was introduced to exploration, development and production of petroleum and the international bidding of mine site were carried out. In 1993/1994, the first bidding was carried out and eight blocks were awarded a contract. The block 11 was given to BAPEX preferentially. Occidental carried out total five exploratory excavations in three blocks; 12, 13, and 14 under the PSC agreement and confirmed the gas at two places. However, a blast was generated in a well and the accident occurred that destroyed the gas field structure itself and the facility on land surface. On the other hand, for Jalalabad gas field that had been discovered, the production was started in 1998 and it was finally sold to Chevron via Unocal. In blocks 15 and 16, Cairn Energy carried out six exploratory excavations and discovered Sangu gas field at ocean location. The production was started in 1998, however, the gas production volume comes down currently and only 30 to 40 mmcfd of gas is produced. In 2000, Shell/Cairn discovered a new gas field South Sangu 1, however, the production is not carried out until now. In blocks 17 and 18, the exploratory excavation was also carried out, however, the commercial gas was not discovered. The block 22 is not practically investigated yet. Almost all of three blocks; 17, 18, and 22 were returned to Bangladesh following the PSC agreement.

At the second bidding carried out in 1998/1999, four blocks were awarded a contract. With this bidding, BAPEX ensured 10% right of each block. The block 7 and blocks 5 and 10 were awarded a contract by Unocal (Chevron) and JV of Shell/Cairn, respectively. The block 9 was awarded a contract by Tullow Oil and Chevron Texaco. In August and September 2003, ChevronTexaco and Shell made the sellout of mine sites known to public. The reason is that the export of gas was not allowed and the domestic market had a limitation. In 2004, Niko Resources purchased the area possessed by Chevron Texaco (60%) in the block 9. In the block 9, the drastic seismic survey including 3D was carried out and after five test wells were excavated, a large-scale gas field was discovered in Bangora-Lalmai. The production was started in August 2006 and the production volume of 60mmcfd at first increased to 120 mmcfd currently. On the other hand, in the block 12, Chevron finished the development of the first phase in Bibiyana gas field and the gas production accomplished 290 mmcfd, and after the development of the second phase was terminated, the production volume accomplished 500 mmcfd. Bibiyana gas field currently produces 600 mmcfd or more of gas and it seems to have a capability of 700 mmcfd. It is said that the capability can reach 1,000 mmcfd in the future.

Bangladesh divided the offshore mine site into 28 blocks in February 2008 and carried out PSC Offshore Bidding Round- 2008. The recent news report said that seven IOC companies bid for 15 blocks and after the review, ConocoPhillips won a bid for deep sea block (water depth 200m or more) and Tullow won a bid for shallow sea (water depth 200m or less) block. However, the agreements have been suspended and the gas production prospect is not yet clear due to an international border dispute with Myanmar and India.

A new acreage map has been prepared for Bangladesh Offshore Bidding Round -2008 in Fig. 5-7.



Source : Petrobangla

Fig. 5-7 Bangladesh PSC Blocks Status-2008

Box 5.1 What is Production Sharing Contract（PSC）?

PSC is an exploration development contract, a type of service contract which became common in Indonesia from early 1960s, and was adopted by other oil-producing countries. Indonesian president issued a decree to nationalize oil industry in 1960. However, as a result of search for a contract to adopt fund and technology from foreign companies, a series of development contract and PSC were adopted the 1960s.

Different from traditional profit sharing exploration development contract, PSC allows oil-producing countries and foreign oil companies to share products. Foreign oil companies act as contractors for oil-producing countries or crown companies of oil-producing countries, and also provide necessary funds and technology. If commercial-scale product is discovered by exploration, the cost is recovered in kind. The contract allows to recover actual cost in advance as a production cost and to share crude oil after collecting cost between oil-producing countries and oil-producing companies.

Generally, there is a “limit for cost recovery,” and only cost for certain percentage of annual production volume is recovered （Unrecovered part is rolled over from year to year）. Since adaptation of the PSC in Egypt in 1970, many countries had adopted PSC. It is now the most common system in developing oil-producing countries. This is because the system allows oil companies to have (1) advantage in terms of cash flow by preferential recovery of funds, and increased possibility for development of smaller oil mines and (2) relatively large profit by minimizing cost. (3) In the meantime, oil-producing countries can benefit from a control over oil resources and exclusive mining rights to nation for nation or crown oil company to operate oil mines and the business, and maintain direct control over crude oil.

5.4.4 Gas Evacuation Plan

A production plan has been drawn up to meet the demand by augmenting supply from national gas companies and increasing gas purchases from the IOCs, There would be about 15 new exploration and development drilling and the five workover together with the necessary process capacity in the public sector supported by necessary process plants which will be installed. The upcoming drilling and workover programme of Petrobangla under the short, mid and long term are furnished below (GEP: Gas Evacuation Plan 2010-15). According to the GEP, the production rate as of 2015 will be double of current one, including 500 mmcfd LNG import. This production plan is indicative/development wells drilling results and reservoir conditions, therefore it could be achievable from technical view points. As it is based on high success rate of exploration and depending on IOC’s development more than half, PSMP Study Team assumes the production plan will be ambitious/opportunistic or high case scenario.

Table 5-11 Short/Mid/Long term development and workover

I. Short Term Program (Up to December 2010)					
SL No.	Name of Well	Type of Program Well	Owner of Field/ Structure	Expected Completion Time	Expected Production Augmentation (mmcfd)
1	Sylhet # 7	Workover	SGFL	Jan'10	8
2	Meghna #1	Workover	BGFCL	Jun'10	15
3	Habiganj # 11	Workover	BGFCL	Jun'10	20
4	Titas # 12	Workover	BGFCL	Jun'10	20
5	Semtang # 1, 5	Workover	BAPEX	Dec'10	15
6	Sundalpur # 1	Exploration	BAPEX	Oct'10	15
7	Fenchuganj # 4	Appraisal	BAPEX	Oct'10	20
8	Saldanadi # 3	Appraisal	BAPEX	Jul'10	15
9	Sangu (South)	Exp/Dev	Cairn	Dec'10	30
	Sub Total				158

II. Mid Term Program (Up to Dec 2013)					
SL No.	Name of Well	Type of Program Well	Owner of Field/ Structure	Expected Completion Time	Expected Production Augmentation (mmcfd)
A. Petrobangla Companies					
1	Kapasia # 1	Exploration	BAPEX	Mar'11	15
2	Srikail # 2	Exploration	BAPEX	Fev'11	15
3	Mubarakpur # 1	Exploration	BAPEX	Jun'11	15
4	Saldanadi # 4	Appr/Dev	BAPEX	Mar'11	15
5	Fenchuganj # 5	Appr/Dev	BAPEX	Aug'11	20
6	Titas # 17	Appr/Dev	BGFCL	Jun'11	25
7	Titas # 18	Appr/Dev	BGFCL	Nov'11	25
8	Bakhrabad # 9	Development	BGFCL	Apr'12	20
9	Titas # 19, 20, 21, 22	Development	BGFCL	Jun'12	100
10	Rashidpur # 5	Development	SGFL	Jun'12	15
11	Rashidpur # 8	Development	SGFL	Jun'12	20
12	LNG	Import		Dec'12	500
	Total (I)				785
B. IOC's					
1	Moulavibazar	Development	Chevron	Jun'12	100
2	Kajol	Exploration	Chevron	-	-
3	Bibiyana	Development	Chevron	Dec '13	200
4	Manama	Exploration	Cairn	-	-
	Sub Total				300
	Total (II)				1085

III. Long Term Program (Up to 2015)					
SL No.	Name of Well	Type of Program Well	Owner of Field/ Structure	Expected Completion Time	Expected Production Augmentation (mmcfd)
A. Petrobangla Companies					
1	Titas #23,24,25,26	Appraisal	BGFCL	2015	100
2	Sylhet, Kailashtila & Rashidpur	Appraisal	SGFL	2015	80
	Sub Total				180
B. IOC's					
1	Magnama	Development	Cairn	2015	-
2	Kajol	Development	Chevron	2015	-
3	Moulavibazar	Development	Chevron	2015	200
4	Bibiyana	Development	Chevron	2015	250
5	Jalalabad	Development	Chevron	2015	250
6	Offshore bidding round 2008	Exploration		2015	200
	Sub Total				900
	Total (III)				1080
	Grand total (I +II + III)				2323

Source: Gas Evacuation Plan (2010-2015)

5.5 Examination for marginal production capacity of natural gas

5.5.1 Possibility of increasing production at existing gas fields

As of November 2009, Bangladesh produces gas equivalent to approx. 1,950 mmcfd at 79 gas wells in 17 gas fields. Among them, 11 wells have been suspended of production due to a certain reason. Except for 2 or 3 wells that stopped production due to mechanical reasons, most of the suspension in production is attributable to gas layer itself. When a well cannot produce gas due to inclusion of formation water, a refurbishment work is necessary by filling the lower layer and newly completion the upper layer. How to refurbish varies well by well. Even a tentative blocking of formation water inflow can secure production volume of 5 to 10 mmcfd per well. However, if stereoscopic structure of gas layers, distribution of gas and formation water using a 3D seismic survey can be identified, more effective refurbishment plan can be formed. It is necessary to shape methods of increasing gas production by introducing a latest completion technology. It is also essential to pay efforts to reduce cost for refurbishment works as well as to enhance speed of the works by using a coil tubing unit. Among the existing gas fields, Begumganj, Shahbazpur and Semutang Gas Fields have been left unattended after confirmation of gas layers exist. Past data should be reviewed and re-development works should be examined by referring to the latest seismic survey data. Besides them, Chattack Gas Field and Kamta Gas Field have hefty amount of deposit still now but production hasn't been resumed yet. These gas fields must be surveyed so that production can be resumed as soon as possible. As broad seismic surveys have been conducted to existing gas fields, depending on the outcome, there is still room of drilling fair number of wells additionally. Like Titas Gas Field, a half of the structure on the southern part of it is left underdeveloped. It seems that there is still room of developing gas fields in the country.

5.5.2 Possibility of increasing production from new gas field development

In Bangladesh, total 75 trial wells have been drilled so far during the history of about 50 years. Speaking of 2001 and thereafter, the number of trial wells drilled remains 5 on the land and 4 under the sea. This level is quite low from the world standard. So far, 23 inland gas fields and 2 sea gas fields have been discovered including two petroleum layers. The ratio of successful trial drilling is about 30%. In this sense the ratio of discovery is quite high suggesting that the country is blessed with abundant natural gas reserves. BAPEX conducted a series of geological survey from 2007 to 2008 for 183 km extended from the eastern end of the Julji Structure to the western end of the Banderban Basin. 77 rock specimens as well as gas specimens from two locations were collected for analysis as to whether they contain hydrocarbon or not. Additionally, gas specimens were collected and analyzed from 14 gas leakage sites. The locations include Sylhet, Chittagong, Khulna and Moulavibazar. In addition to the geological surveys, seismic surveys were also conducted. A 3D seismic survey will be conducted by BAPEX covering the area of 1,250km^2 where Titas Gas Field and Bakhrabad Gas Field controlled by BGFCL and Sylhet Gas Field, Kailashtila Gas Field and Rashidpur Gas Field controlled by SGFL exist. In addition, similar seismic surveys will be conducted in Mubarakupur, Kapasia and Sundalpur as candidates for trial drilling. As to IOC, the Block-7 Chevron is being focused. It is reported that at Chevron, a seismic survey was conducted in 2006 extending to 1,000 km that as a result, hydrocarbon structures were found at three places and that detailed survey of the structure is ongoing now. Cairn Energy discovered the Magnama Structure in the vicinity of Sangu Gas Field in Block-16 Mine Area and it is said that a 3D seismic survey is being conducted. There are many underdeveloped areas both inland and sea areas According to a joint survey conducted in 2001 by United States Geological Survey (USGS) and Petrobangla, gas equivalent to 32 Tcf exists with the probability of 50%. It is highly likely that new structures will be discovered.

5.6 Possibility of importing natural gas by pipeline

In Bangladesh, where there is a growing and urgent demand of natural gas, there seems to various arguments on import of natural gas. In the past, there was a plan to supply gas from Bibiyana Gas Field to the gas market in northern India but was suspended due to the assertion of the Government of Bangladesh that it would not export gas unless strategic volume of reserves enough to support domestic demand of gas for at least 50 years be secured. After then, there was a sudden change in conditions and people in Bangladesh argued against the possibility that supply of natural gas doesn’t meet its demand and importing natural gas was on the table of argument. The possible importing route via pipeline is from India or Myanmar. In India, Reliance, a conglomerate discovered a large-sized gas field, Dhirubhai, at KG-DWN-98/3 (D6) mining area located at the KG sedimentation basin in the east of the Bay of Bengal in 2002. The success of discovering the gas field stimulated investment to the upstream function of the area, which led to discovery of other large-sized gas fields. Consuming the period of 7 years, the gas field started production in April 2009. It is expected that this will further lead to uplifting Indian economy and securing energy. Under such circumstances, Bangladesh seems to have had several times of meetings with India over importing natural gas from the country, but the result of the meeting is unknown. On the other hand, in Myanmar, Daewoo in South Korea discovered Shwe Gas Field at A-1/3 mining area off the western coast of the country in 2004. According to Daewoo, available gas reserve combining 3 gas fields in the vicinity amounting to 4.8 to 8.6 Tcf. Bangladesh seems to have had a negotiation with Myanmar in February 2002 to import natural gas from the country via pipelines, but Myanmar seems to have announced that it would prioritize export of natural gas to China and India, first. The Myanmar side disclosed that it would examine export of natural gas to Bangladesh provided that there is room of doing so after exporting to China and India. The trend surrounding importation of natural gas seems to be a very complex and sensitive issue with a mixture of speculations of related countries.

5.7 Feasibility of LNG imports

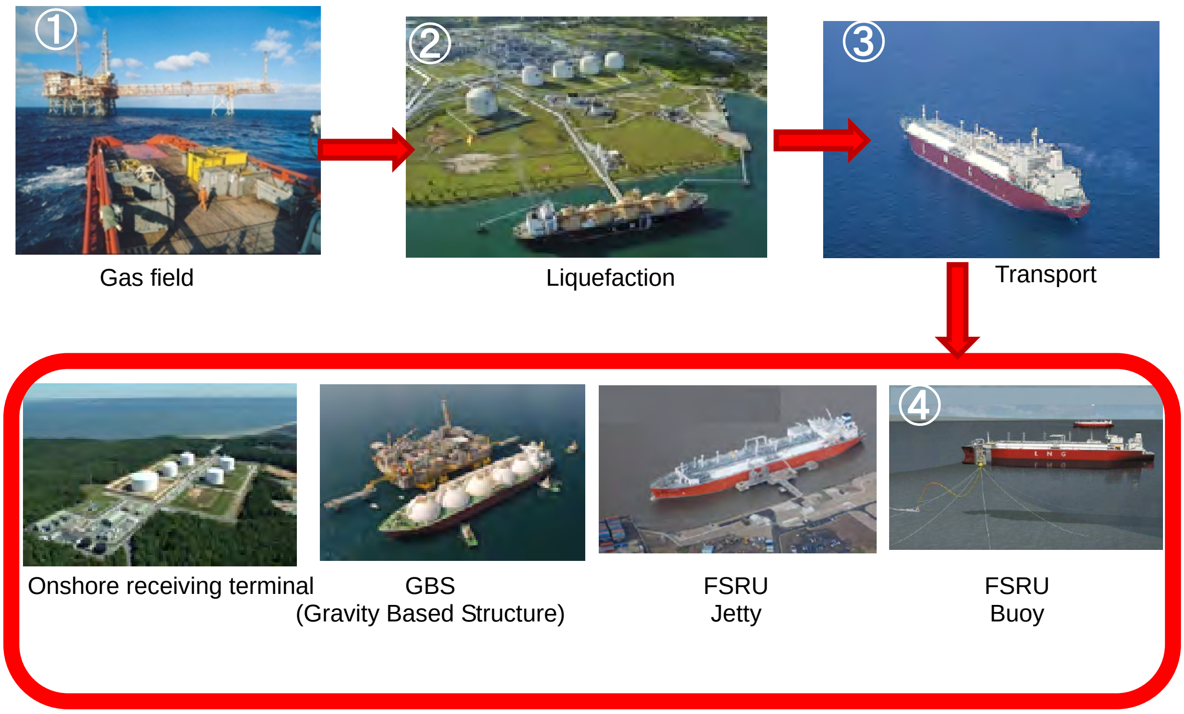
In consideration of the excess demand versus the supply of natural gas in Bangladesh, the shortage should be resolved by LNG imports.

Taking into account of the above situation, a feasibility study of the offshore regasification system should be taken up in view of availability of a new technology in the LNG world.

5.7.1 LNG chain

The LNG chain from production in the gas field up to consumption at the user level is described below.

(1) Production in gas field
(2) Liquefaction.
(3) Natural gas is liquefied with its volume approximately 1/600, temperature -162 degree C.
(4) Transportation from the liquefaction plant to a user by a special cargo ship. Regasified at the regasification system, then supply natural gas to the user.



Source: NIKKISO CO., LTD. study data (2010)

Fig. 5-8 LNG chain and receiving terminal

5.7.2 Offshore regasification system outline

Floating Storage Regasification Unit (FSRU) is one of the technologies developed as an offshore LNG regasification system.

The advantage of FSRU is that LNG storage, transportation and regasification are available with low costs and short delivery instead of a huge and complicated plant onshore.

All regasification processes which encompass storage, transportation and regasification can be completed by the FSRU itself.

RV (regasification vessel) developed by the Excelerate as well belongs to category of FSRU.

Currently, following the two types of mooring systems have been established as shown below.

Jetty

-Enough depth of water for voyage is required
-Convenient of human access
-All types of FSRU are available

Buoy

-Anchored in the offing. Hence no special attention is required regarding to the depth of water.
-Type of FSRU which can be connected to buoy is restricted.

Source: NIKKISO CO., LTD. study data (2010)

Fig. 5-9 Type of mooring system

5.7.3 Comparison of LNG receiving terminal

GBS (Gravity Based Structure) and FSRU have been categorized as offshore receiving terminals. Furthermore, 2 types of LNG loading systems which are the Jetty mooring and the Buoy mooring systems have been developed as FSRU.

The onshore receiving terminal and the GBS have an advantage in supplying bigger gas capacity, however, the construction lead time is long and the cost is high compared with FSRU as shown in the below table.

Table 5-12 Comparison of LNG receiving terminal[6]

	Onshore Receiving Terminal	Offshore Receiving Terminal		
		GBS	FSRU	
			Jetty mooring	Buoy mooring
Operating history since development	50 years	2 years	3 years	5 years
Construction Cost Note-1	US$500M to 1000M	US$ 1500M	Pipe line US$80M FSRU US$100M-250M	Buoy US$80M FSRU US$100M-250M
Lead time	4 years	4 years	0.5 years 1.5 years	1.5 years 1.5 years
Capacity	>1000 mmcfd	775mmcfd	500 mmcfd	500 mmcfd
Miscellaneous	Expansion is possible	Expansion is impossible	Both shuttle/fix operation is possible Enough water depth for voyage is required	Both shuttle/fix operation is possible
Evaluation	△	△	○	◎

Source: NIKKISO CO., LTD. study data (2010)

[6]Costs shown on the table is a reference value, because it depends on the location, design etc.

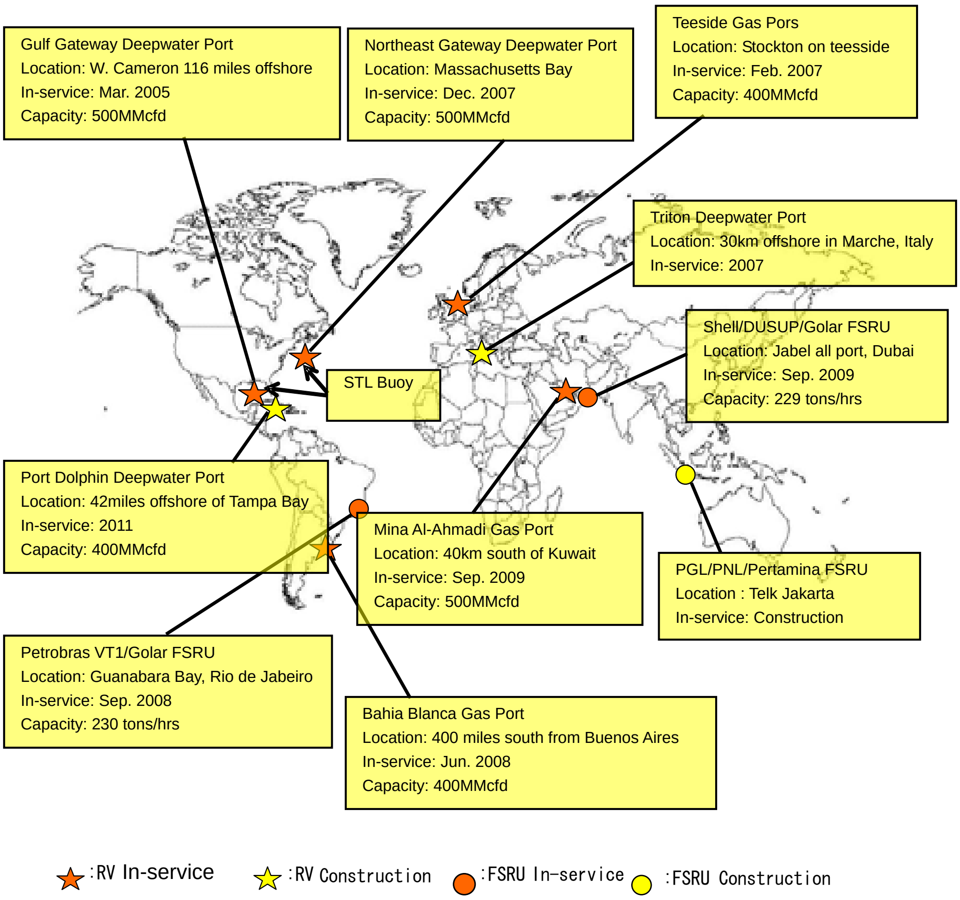
5.7.4 FSRU/RV installation list

Number of FSRU in Table 5-13 are now working in the world.

Table 5-13 FSRU/RV in the world

Project	Energy Bridge	Suez Neptune	Petrobras Guanabara Brazil	Shell DUSUP Dubai	Livorno offshore Italy
Ship owner	Exmar Excelerate energy	Hoegh LNG	Golar LNG	Golar LNG	OLT Offshore LNG
RV/FSRU	RV	RV	FSRU/RV	FSRU	FSRU
Nos.	8	2	2	1	1
Ship name	Excelsior Excellence Excelerate Explorer Express Exquisite Expedient Exemplar	GDF Suez Neptune GDF Suez CAPE ANN	Golar Spirit (FSRU) Golar Winter (RV)	Golar Freeze	Golar Frost
Operation start at	3 ships 2005～2006 5 ships 2008～2010	2009	Golar Spirit 2008 Golar Winter 2009	2010	2010
Storage capacity	3 ships 138,000 m3 （4.87Mcf） 5 ships 150,900 m3 （5.33Mcf）	145,000 m3 （5.12Mcf）	Golar Spirit 129,000 m3 （4.56 Mcf） Golar Winter 138,000 m3 （4.87 Mcf）	125,000 m3 （4.41 Mcf）	137,000 m3 （4.84 Mcf）
Sendout capacity	500 mmcfd	500 mmcfd	Golar Spirit 250 mmcfd Golar Winter 500 mmcfd	400 mmcfd	500 mmcfd
Voyage	Possible	Possible	Possible	Impossible	Impossible
Jetty/Buoy	Both available	Both available	Jetty	Jetty	Buoy

Source: NIKKISO CO., LTD. study data (2010)



Source: NIKKISO CO., LTD. study data (2010)

Fig. 5-10 Location of FSRU/RV

5.7.5 Subjects to be considered for offshore regasification unit

List of expected problems and an evaluation is described as below.

Table 5-14 List of expected problem and evaluation

	Subject	Evaluation
1	Access of FSRU/LNG Cargo	Generally, the necessity of the water depth under 100% LNG loading condition is approximately 20m. It is possible to adopt the FSRU system in case the water depth around the receiving system is deeper than 20m.
2	Evaluation for rolling and pitching	1) Mechanical strength of LNG tank Mechanical strength of LNG tank in FSRU must be considered in order to withstand the hydraulic force due to movement of LNG during voyage. (sloshing) Old cargo ships were designed based on only 2 typical cases such as LNG fully loaded or completely emptied in the tank during voyage. 2) Limitation of wave height in operation STL（Submerged Turret Loading）system is designed up to 11m of wave height, corresponding to a 100 year storm. It was confirmed that the operation was performed without any problems at the Hurricane Katrina attack (category 5) in 2005 at Mexico bay.

	Subject	Evaluation
		*Wave height at "category 5" is categorized as 5.8m or greater. 3) Restriction while the LNG is loaded to FSRU from the cargo ship Loading is possible under the wave height below 2.5m. It can be concluded that LNG loading within "category 2" is possible.
3	Influence to environment	Influence to the environment of FSRU is lower than the onshore regasification system. 1) Consideration to NIMBY (Not In My Back Yard) campaign Influence to the environment can be minimized by the establishment of the FSRU in the offing. 2) Consideration of the cooled water used after vaporizing Influence to the marine ecological system around the FSRU due to draining the cold water used after the LNG vaporizing is concerned. This problem can be solved by using the Vaporizer except for the Open-Rack type. Although the running cost is higher than the Open-Rack vaporizer.

Source: NIKKISO CO., LTD. study data (2010)

5.8 Underground coal gasification

Recently, each country conducts experimental test of underground coal gasification (UCG) technology. It seems that the UCG technology is being developed for the purpose of effective utilization of coal resources located deep under the ground or in complex geological structure. It is pointed out that the merit of gasification of coal under the ground includes there is no need of constructing a gasification furnace above ground and cost can be curtailed. It is reported that Bangladesh has five coal fields in the northwestern area. Among them, however, Barapukuria Coal Field is only the one that is in operation now, and for others coal mining hasn't been started yet. Among them, Jamalganj Coal Field has a coal layer at 640m to 1,000m under the ground and hence, normal method of mining cannot be applied. In order to effectively use the coal reserves and due to the shortage in gas supply, it seems necessary for the country to examine whether the UCG technology can be applied to Jammalganj Coal Field or not. The coal reserve at Jammalganj Coal Field is said to be approx., 1 billion ton. The UCG technology has been among the topic for a long time and each country seems to be involved in the study of it. However, a new and more effective technology may be discovered that is environmentally friendly at the same time, by merging new technologies to UCG technology. Russia is advanced in terms of UCG and it is said that a practical plant has been in operation after the World War II. There is also a report that India and Vietnam are involved in an experimental development project. Bangladesh should start examination of the possibility by requesting experts for investigation of it and establish pilot test for it as far as possible.

5.9 Long and mid term production forecast of natural gas

5.9.1 Long-term production forecast scenario setting

Long-term production forecast was investigated by setting with three scenario cases; Government Plan (high), PSMP Study Team Plan-1 (base), and PSMP Study Team Plan-2 (low). The element of each case is shown in Table 5-15 for natural gas supply scenario basic chart.

Table 5-15 Natural gas supply scenario basic chart

Case	Government	Study Team 1	Study Team 2
(National Company)			
Existing gas field (Petrobangla) Proven reserve(P1)	●	●	●
Existing gas field (Petrobangla) Probable reserve (P2)	●	●	●
Existing gas field (Petrobangla) Possible reserve (P3)			
Kamta gas field re-development	●	●	●
Chattack gas field re-development (East)			
New discovery 1（Petrobangla）Srikail, Sundalpur, Kapasia, Mubarakpur	●	●	●
Block 11 (Netrokona)	●		
(IOC)			
Existing gas field (IOC 1) Proven reserve (P1)	●	●	●
Existing gas field (IOC 1) Probable reserve (P2)	●	●	●
Existing gas field (IOC 1) Possible reserve (P3)			
Chattack gas field re-development (West)	●		
New discovery (IOC 2)			
Block 7 (Kajal)	●	●	●
Block 16 (Magnama, Hatia, Manpura)	●	●	●
Block 17 & 18			
New discovery (IOC 3)			
Offshore Bidding 2008 #1	●	●	
Offshore Bidding 2008 #2	●		
(Imported Natural Gas)			
LNG	●	●	●

Source: PSMP Study Team

5.9.2 Concept for each case

The gas production forecast is composed of development and work-over from existing gas fields as well as development from new gas fields. According to the expectation level of success, the PSMP Study Team with Petrobangla and the member of the Task Team investigated three cases; Government Plan (high case), PSMP Study Team Case 1 (middle case) and PSMP Study Team Case 2 (low case).

In the long-term forecast, the PSMP Study Team reviewed the “Clean Fuel Sector Development Program (consultant: Technoconsult International Limited) which ADB carried out in March, 2009” (ADB program) as base and modified it according to the results of an investigation, the field survey and discussion with Task Team. The long-term forecast is based on the sum total of the proved reserves (P1) of the existing gas field (the gas production company affiliated with Petrobangla plus the existing IOC) and probable reserves (P2).

As for field survey, it was conducted from the end of October, 2009 to early in November during a visit to Petrobangla, three subsidiary gas production companies (BAPEX, BGFCL, SGFL) and an interviews with two companies (Chevron, Cairn) of IOC were held. Further, a field survey in the Titas gas field of BGFCL, the Kailashtila gas field of SGFL, and the Bibiyana gas field of Chevron was conducted.

According to the information acquired from Titas gas field, the southern part of the area which occupies a space of 30 percent or more of the gas field is underdeveloped. However, it seems to be promising based on the 3D survey with the financial support of ADB. Such a situation has been taken into consideration and the Titas Prediction of the ADB investigation which has set the maximum production size of the gas field to 565 mmcfd by 2020 is revised upward to 678 mmcfd.

The production of the Kailashtila gas field was interrupted due to the decreased pressure of the No.5 well which began production as a new layer in 2006 with the permeation of the stratum water. Since the upper part had thick unproduced sand layers according to SGFL, it was scheduled to be finished with this repair work. Concerning the production of this gas field, it gradually increased from 115 mmcfd in 2010 via an ADB investigation. Then the production was increased as predicted to 325 mmcfd in 2020. Based on the production increase plans of SGFL, the production history of this gas field, it was judged that there is more potential so that production forecast may go up to 500 mmcfd in 2023 in the Government case.

At the field survey of the Bibiyana gas field, the amount of gas production during the investigation period exceeded original expectations of 640 mmcfd. According to Chevron’s explanation, the potential production capacity of the gas field was able to reach more than 1,000 mmcfd if the results of the 3D prospecting were taken into consideration. Since the maximum production size was predicted to be 500 mmcfd in the ADB investigation. However, the current production rate is already exceeding the ADB’ prediction. The forecast was revised upwards to 1166 mmcfd in the Government case.

In addition to the aforementioned results of the investigation, the production increase prospects from the new offshore sites were considered and a prediction evaluation was conducted.

Reflecting the aforementioned site survey and the prospects form the new discovery, a natural gas prediction was conducted.

Government case (high case):
The gas reserve is derived from the HCU preliminary reserve report 2010, including proven and probable reserves. In terms of the new discovery, New discovery 1 (Srikail, Sundalpur, Kapasia, Mubarakpur), New discovery 2 (Block 7 (Kajal), Block 16 (Magnama, Hatia, Manpura), Block 11 (Netrokona) and New offshore bidding site (200mmcfd) have been taken into account as gas production. The Government case fully reflects the “Gas Evacuation Plan (2010-15)” up to 2015 as the fast track augmentation program where Petrobangla, GTCL et al formulated. In the Government case, the gas production will reach to plateau around the year 2018, at a 4,000mmcfd production rate, and then decrease gradually thereafter.

PSMP Study Team Case 1 (middle case):
The gas reserve is derived from the HCU preliminary reserve report as well. New discovery 1 (Srikail, Sundalpur, Kapasia, Mubarakpur), New discovery 2 (Block 7 (Kajal), Block 16 (Magnama, Hatia, Manpura) and New offshore bidding site (100mmcfd) are taken into account, however, Block 11 (Netrokona) is not taken.

PSMP Study Team Case 2 (low case):
The gas reserve is derived from the HCU preliminary reserve report as well. Only New discovery 1 (Srikail, Sundalpur, Kapasia, Mubarakpur), New discovery 2 (Block 7 (Kajal), Block 16 (Magnama, Hatia, Manpura) have been taken into account.

Chattack East re-development, New Discovery 2 (Block 5, 10, 17, 18) are not included in any cases, as it is judged difficult to commence production by 2030 in consideration of the current development situation.

In addition, the Bangladeshi Government has set forward the introduction of LNG by 2013 for the measures of serious gas shortfall. As mentioned previously, the PSMP Study Team independently researched the feasibility of LNG facilities, there already exists several offshore LNG terminals to be practically used. Therefore, the PSMP Study Team believes the offshore LNG terminal is technically possible as a provisional case until the permanent terminal is constructed. In this MP, LNG is included as a complement to domestic gas production.

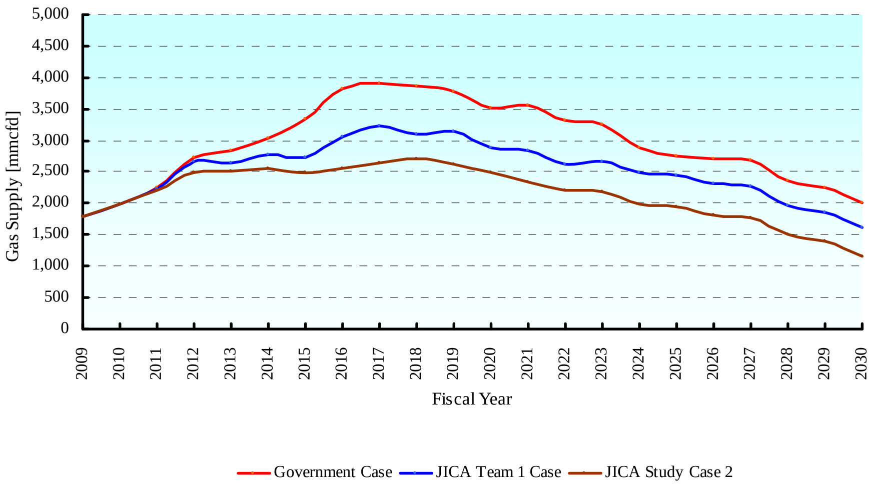
5.9.3 Results of long-term production forecast

Estimated resuls of long term production forecast is shown I Table 5-16 and its graphical view is shown in.Fig. 5-11

Table 5-16 Long term production forecast (without LNG)

Cases	Government Case		PSMP Study Case 1		PSMP Study Case 2	
	(mmcfd)	(Bcf)	(mmcfd)	(Bcf)	(mmcfd)	(Bcf)
2008 – 2009	1,791	654	1,791	654	1,791	654
2009 – 2010	1,995	728	1,995	728	1,995	728
2010 - 2011	2,253	822	2,225	812	2,208	806
2011 - 2012	2,738	999	2,673	976	2,479	905
2012 - 2013	2,838	1,036	2,636	962	2,512	917
2013 - 2014	3,038	1,109	2,765	1,009	2,563	935
2014 - 2015	3,348	1,222	2,730	996	2,498	912
2015 – 2016	3,818	1,394	3,062	1,118	2,554	932
2016 – 2017	3,907	1,426	3,230	1,179	2,647	966
2017 – 2018	3,874	1,414	3,108	1,134	2,698	985
2018 – 2019	3,778	1,379	3,148	1,149	2,618	956
2019 – 2020	3,513	1,282	2,888	1,054	2,488	908
2020 – 2021	3,563	1,300	2,838	1,036	2,328	850
2021 – 2022	3,323	1,213	2,623	957	2,203	804
2022 – 2023	3,253	1,187	2,653	968	2,173	793
2023 – 2024	2,879	1,051	2,479	905	1,979	722
2024 – 2025	2,749	1,003	2,449	894	1,949	711
2025 – 2026	2,709	989	2,309	843	1,809	660
2026 – 2027	2,679	978	2,279	832	1,779	649
2027 – 2028	2,367	864	1,967	718	1,517	554
2028 – 2029	2,247	820	1,847	674	1,397	510
2029 – 2030	2,017	736	1,617	590	1,167	426

Source: Petrobangla modified by PSMP Study Team



Source: Petrobangla modified by PSMP Study Team

Fig. 5-11 Long term production forecast (without LNG)

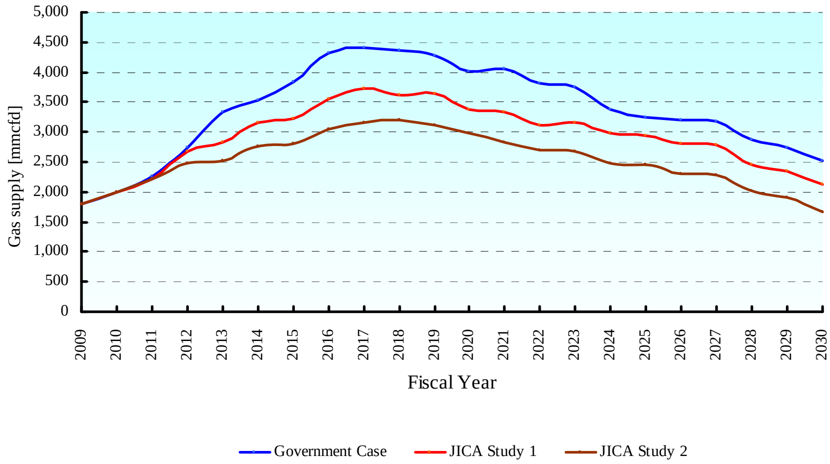
In each case, in addition to the production from the existing gas fields, the increased production is expected from a new gas field via the discovery of a new structure in the future and the production amount will be increased till 2017. In case of the PSMP Study Case 1, the production amount will peak out at 3,320 mmcfd in 2017 and gradually decline thereafter. Even in the Government Case, the production amount will peak out at 3,907 mmcfd in 2017 and begin its decline thereafter and the PSMP Study Case 1 also indicates the same trend. In case of the PSMP Study Case 2, it also indicates the same trend but the peak production amount is steady at 2,698mmcfd.

As a measure of gas shortage, the Bangladeshi Government plans to introduce LNG by 2013. The table and figure shows the total gas supply with LNG below.

Table 5-17 Long term gas production forecast (with LNG)

Cases	Government Case		PSMP Study Case 1		PSMP Study Case 2	
	(mmcfd)	(Bcf)	(mmcfd)	(Bcf)	(mmcfd)	(Bcf)
2008 – 2009	1,791	654	1,791	654	1,791	654
2009 – 2010	1,995	728	1,995	728	1,995	728
2010 - 2011	2,253	822	2,225	812	2,208	806
2011 - 2012	2,738	999	2,673	976	2,479	905
2012 - 2013	3,338	1,218	2,836	1,035	2,512	917
2013 - 2014	3,538	1,291	3,165	1,155	2,763	1,008
2014 - 2015	3,848	1,405	3,230	1,179	2,798	1,021
2015 – 2016	4,318	1,576	3,562	1,300	3,054	1,115
2016 – 2017	4,407	1,609	3,730	1,361	3,147	1,149
2017 – 2018	4,374	1,597	3,608	1,317	3,198	1,167
2018 – 2019	4,278	1,561	3,648	1,332	3,118	1,138
2019 – 2020	4,013	1,465	3,388	1,237	2,988	1,091
2020 – 2021	4,063	1,483	3,338	1,218	2,828	1,032
2021 – 2022	3,823	1,395	3,123	1,140	2,703	987
2022 – 2023	3,753	1,370	3,153	1,151	2,673	976
2023 – 2024	3,379	1,233	2,979	1,087	2,479	905
2024 – 2025	3,249	1,186	2,949	1,076	2,449	894
2025 – 2026	3,209	1,171	2,809	1,025	2,309	843
2026 – 2027	3,179	1,160	2,779	1,014	2,279	832
2027 – 2028	2,867	1,046	2,467	900	2,017	736
2028 – 2029	2,747	1,003	2,347	857	1,897	692
2029 – 2030	2,517	919	2,117	773	1,667	608

Source: Petrobangla modified by PSMP Study Team



Source: Petrobangla modified by PSMP Study Team

Fig. 5-12 Long term production forecast (with LNG)

In the table below, it indicates the comparison with the predicted gas supply assumed in this MP and the previous Gas Sector Master Plan 2006 (GSMP2006).

Comparison with GSMP2006 and this master plan is shown in following table.

Table 5-18 Comparison with GSMP2006

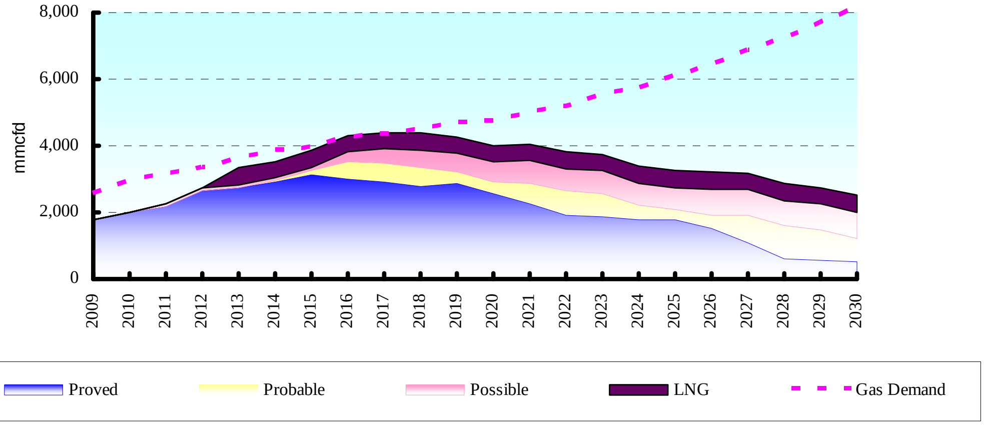
	Gas Sector Master Plan 2006	PSMP2010	
	PSMP Study Case1	Case B	difference
	(mmcfd)	(mmcfd)	(mmcfd)
2009 – 2010	1,896	1,995	99
2010 – 2011	2,022	2,225	203
2011 – 2012	2,158	2,673	515
2012 – 2013	2,340	2,636	296
2013 – 2014	2,518	2,765	247
2014 – 2015	2,669	2,730	61
2015 – 2016	2,852	3,062	210
2016 – 2017	3,030	3,230	200
2017 – 2018	3,240	3,108	-132
2018 – 2019	3,509	3,148	-361
2019 – 2020	3,818	2,888	-930
2020 – 2021	4,112	2,838	-1,274
2021 – 2022	4,439	2,623	-1,816
2022 – 2023	3,992	2,653	-1,339
2023 – 2024	3,636	2,479	-1,157
2024 – 2025	3,324	2,449	-875

Source: GSMP2006, PSMP Study Team

When comparing case B of GSMP2006 with the PSMP Study Case 1 of this MP, the production amount of the MP is greater than that of GSMP2006 until 2017, while the production amount of GSMP 2006 is greater than that of the MP after 2018. The reason for this difference is derived from the GSMP2006 which assumes 1600mmcfd a large amount of YTF (Yet to Find) in the later years. The production of GSMP 2006 without YTF is max 3424 mmcfd in 2010, which is almost the same as max production 3230 mmcfd in 2007 of this MP. In any case, unless a large scale gas field is discovered soon, it will be difficult for domestic gas to maintain a stable supply over the long term.

5.9.4 Government Target Case

In the Government Target Case, the gas production is derived from the "Gas Evacuation Plan (2010-15)" and expected gas production from each gas field extrapolated up to 2030. The gas demand supply balance of the Government case is shown in the below figure.



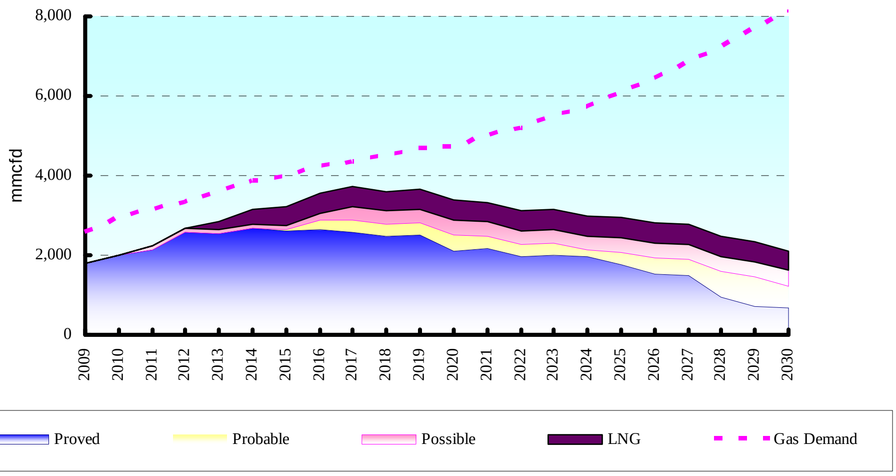
Source: Petrobangla and modified by PSMP Study Team

Fig. 5-13 Gas demand supply balance (Government Target Case)

The amount of gas production all included Proven (P1), Probable (P2), possible reserve (P3) and LNG will be increased until 2017, then gradually decreased thereafter. In 2016 and 2017, the production will be greater than the demand and the demand supply gap will be dissolved for a short period of time. However, the gap will be split again after 2019. The gap would reach 6,000 mmcfd as of 2030, if the demand supply forecast drastically changes.

5.9.5 PSMP Study Case 1

The gas demand supply balance of the PSMP Study Case 1 is shown in the below figure.



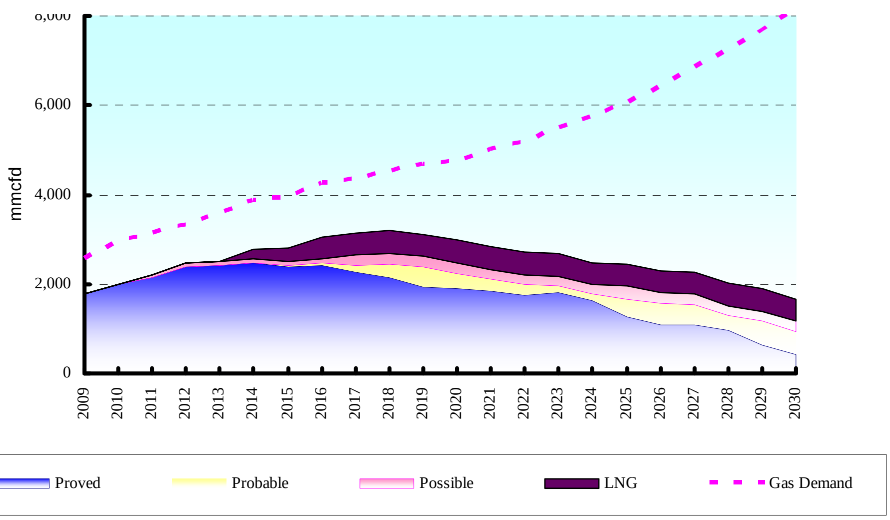
Source: Petrobangla and modified by PSMP Study Team

Fig. 5-14 Gas demand supply balance (PSMP Study Case 1)

In the case of the PSMP Study Case 1, the gas demand and supply will not be balanced and the gap will not be dissolved. The gas production will be increased up to 2019. However, without meeting the demand and supply gap, the gap will be expanded after 2019. The gap is 955mmcfd in 2010, and will be expanded to 722 mmcfd and 1,338 mmcfd in 2015 and 2020 respectively.

5.9.6 PSMP Study Case 2

The figure below indicates the PSMP Study Case 2 Gas Supply-Demand Balance.



Source: Petrobangla and modified by PSMP Study Team

Fig. 5-15 Gas Supply-demand Balance（PSMP Study Case 2）

It is obvious that the PSMP Study Case 2 will not balance and follows the same trend as PSMP Study Case 1. The production amount will be increased until 2017 when it begins to declining thereafter. The Supply-Demand Gap in 2010, 2015 and 2020 will be expanded to 955mmcfd, 1154 mmcfd, and 1,738 mmcfd respectively.

5.10 Gas pipeline network analysis

The demand side issues regarding gas in Bangladesh have been discussed in the foregoing sections.

The supply side issues include the development of new gas fields in the upstream, improvement of gas transmission capacity of the GTCL-owned pipeline network as well as the feeding networks of the retail companies.

In this section, the PSMP Study Team conduct a network analysis based on the on-site data to evaluate the transport capacity of the pipeline network at present and in the future.

5.10.1 Calculation results and considerations

Transportation ability of a network can be judged by checking if required pressures are secured at each gas consumption node. In case gas is supplied to a gas turbine without a fuel gas compressor, the supply pressure should be higher than 1.7MPa (250psi).

(1) Calibration

As mentioned previously, the efficiency factor of each pipeline was adjusted so as to match the measured flow and pressure to the calculated results. The measured data are shown in Fig. 5-16. It should be noted that the total supply to the network is not consistent with the total consumption from the network. It is due to the unsteady local behavior. Whatever the reason is, it contradicts the law of conservation of mass. Therefore, complete conformance between the measured and the calculated is impossible.

In this study, a node of gas supply from a gas field was identified as a pressure designated point, at which the calculated gas supply differs from the measured data. Fig. 5-16 shows measured /calculated gas pressures at major nodes and measured /calculated gas supplies at supply nodes.

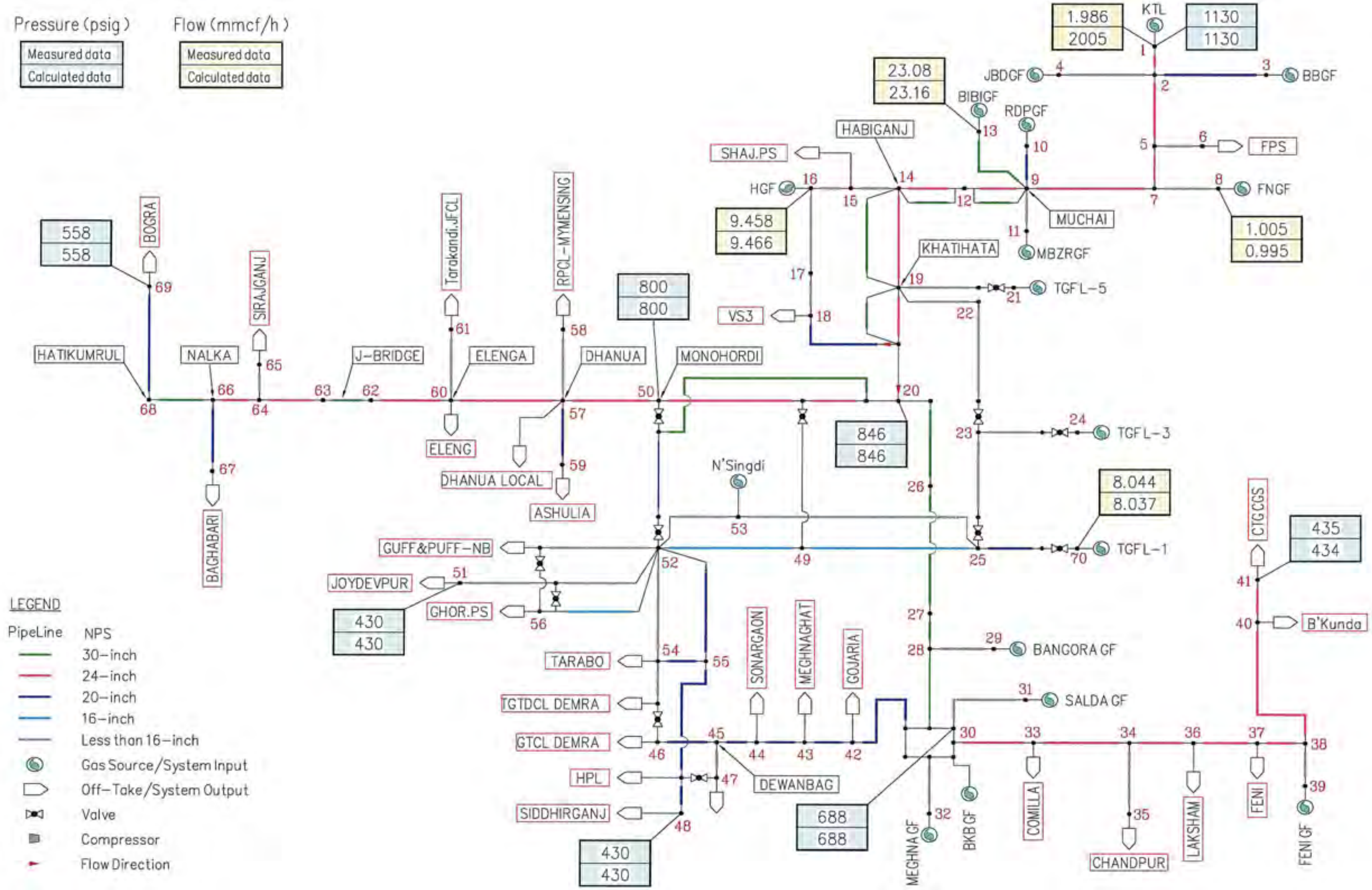
Generally speaking, the efficiency factor of a pipeline in Japan is about 0.93. However, many factors are below 0.8 in this study. There is a possibility that the pipelines are acting up. Sediment deposits may have accumulated inside.

(2) The study results on fiscal year 2009

In the case of average load, the transport capabilities are enough. When the load is increased to 1.2 times of the average load, troubles in the transport appear at around node40 and node41 (Chittagong), at node51, and in the region of node 61 and its downstream in the east-west line. Even if the pressure of node30 is changed from the current 688psi to 960psi (maximum operation pressure) the situation does not change. To circumvent this supply shortage, the gas supply from Feni (node of 39) should be increased to meet the total demand at No.40 and No.41 or additional pipelines parallel to the lines between No.30 and No.40 should be installed. However, there is no problem in the case of a conventional load. Generally speaking, a big pressure drop occurs in the branch lines from the east-west trunk line and lines around Dhaka. It implies the lack of transport margin in those areas; careful maintenances including pigging are desirable.

At other nodes, the gas supply pressures are more than 250 psi, where the supplies are secured. The flow velocities are not shown in the tables, but they are less than the 15 m/sec, reasonable value.

The tendency of locations where the transport trouble appears conforms to the real tendency. Although the actual peak load is bigger than 1.2 times average, the actual flow is unsteady and the holder effect of the pipelines can be expected. The aforementioned result supports the rationality of using the value of the 1.2 in the analysis. In the study on 2015 and 2030 hereafter, the PSMP Study Team used 1.2 times of the average loads to analyze the transport ability.



Source: PSMP Study Team

Fig. 5-16 Gas pressure at measure nodes and supply from gas fields (Calibration)

(3) The study results on fiscal year 2015

It is assumed that the line from Hatikumrul (Node68) to Bola (Node85) through Khulna (Node 83) and the line from Bakhrabad (Node30) to Siddhirganj (Node73) are completed and the new gas demands appear before 2015. It is also assumed that new gas supply sources like LNG (connected to Node41, Chittagong), Semutang (Connected to Node41), New Discovery (connected to 38) appear.

(a) Case study: Existing network.

In this case study, reinforcements like the installment of compressor stations (Node12.Node20, and Node60), in addition of loop lines (from Node20 to Node41, from Node50 to Node66 from Node12 to Node20, and from Node9 to Node11), and bypass line from Node50 to Node51 are not applied. The calculation used the gas load of1.2 times of the average. The results are shown in Fig. 5-17. As already explained, the 'Unable' in the pressure columns means 'unable to calculate the flow', i.e. inability in supplying gas through the pipeline there. The red figure means low pressure (＜250psi).

The transport troubles appear in the circular line from Bakhrabad (Node30) to Monohordi (Node50) through Demra (Node46), which surrounds Dhaka. They also appear in the down stream trunk/branch line of Dhanua in the east-west trunk line. Despite their location far from the northern gas fields, many new power stations are planning to get gas from those nodes. The pressure at Bahkrabad (Node30) is 688psi; the outlet pressure of Bahkrabad gas fields is controlled at the value. If the capacity is not enough and the pressure decreases below 688psi, the situation will be worse. The transport troubles do not appear in the lines between Bakhrabad and Chittagong. This is because LNG is introduced to Chittagong.

(b) Case study: Effect of compressors and additional loop lines

The effect of the aforementioned compressors as well as the loop lines is analyzed.

The outlet pressure of the compressors is set at 1,000psi. As enough pressure is secured in the area from the northern gas fields to Ashuganj, the compressor at Node12 has been eliminated. However, if the outlet pressures of the gas fields are not secured or the compressor at Node20 requires a lower pressure ratio, a re-examination would be necessary. Pressure designations to Bahkrabad (Node30), Salda (Node31), and Narsingdi (Node53) are changed to Supply designations. It is because reverse flow occurs if set pressures in preceding calculations are used, which means the gas fields can not feed gas to a high pressure network. 1.2 times of production rates are used for setting the above supply rate. At those nodes, calculated results will be pressures, which must be secured to feed the set value of supply.

The pressures at the major nodes in the pipeline are shown in Fig. 5-18. 1.2 times of the average gas load is used in the calculation. Fig. 5-18 shows that gas transport is secured except Node61.The supply problem to Node61 can be overcome by one of following countermeasures.

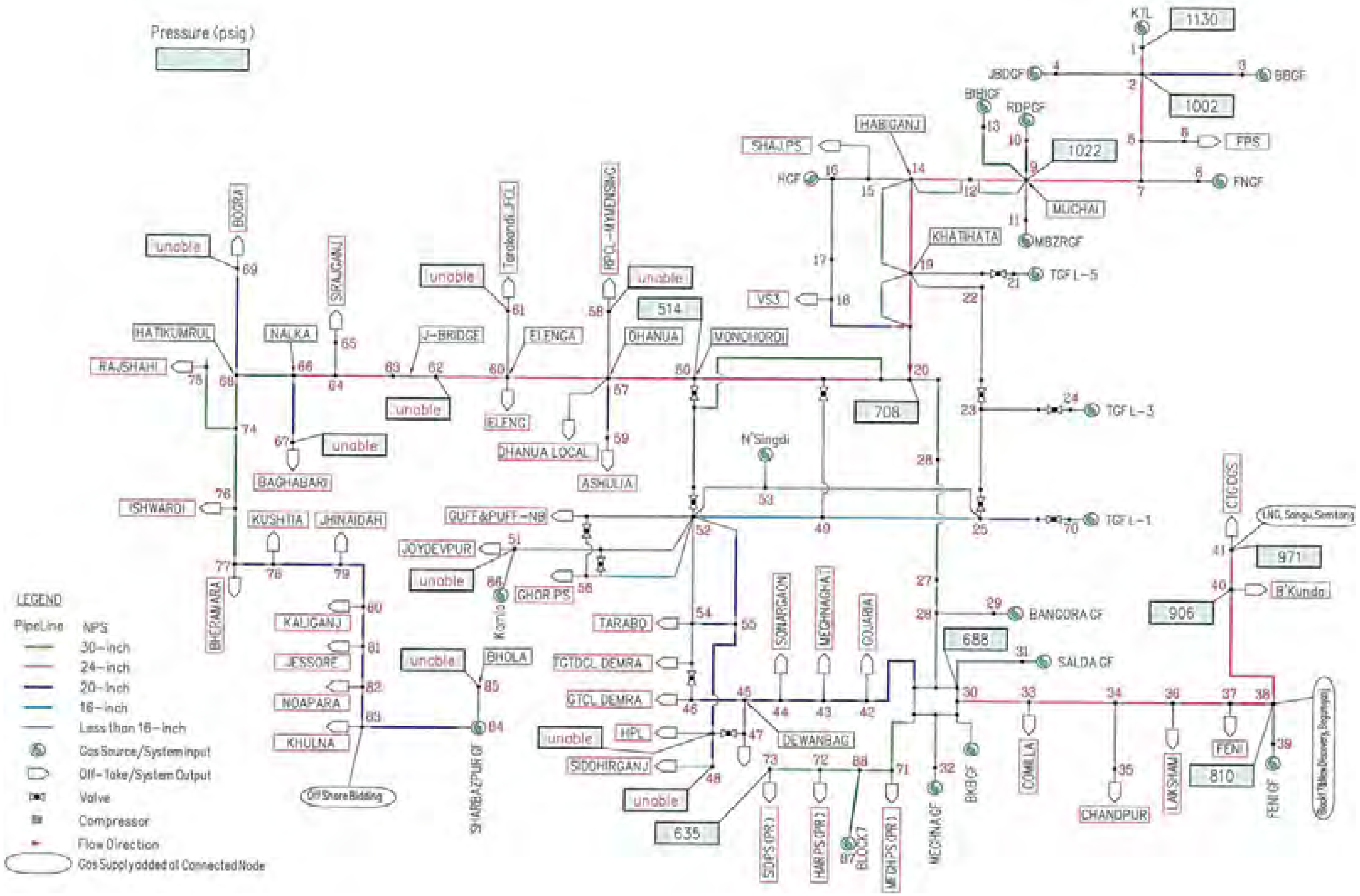
- Introduction of new gas fields like Block11 to this area
- Installation of bypass line from Node13 to Node57 (described later)
- Change of the connecting point of the branch line to the discharge of the compressor

(c) Case study: Effect of bypass line

The effect of the bypass line between Node13 and Node57 is analyzed. The pressure distribution in the area between the two compressors (Node20 and Node60) is shown in Fig. 5-19. This bypass line has been proposed in the Gas Evacuation Plan (2010-15) and the primary purpose is to reduce the flow duty on the compressor (Node20). However this bypass line improves the transport around Node61. It also contributes to reducing the compression related running cost as well as the plant cost. However, the following problems may appear.

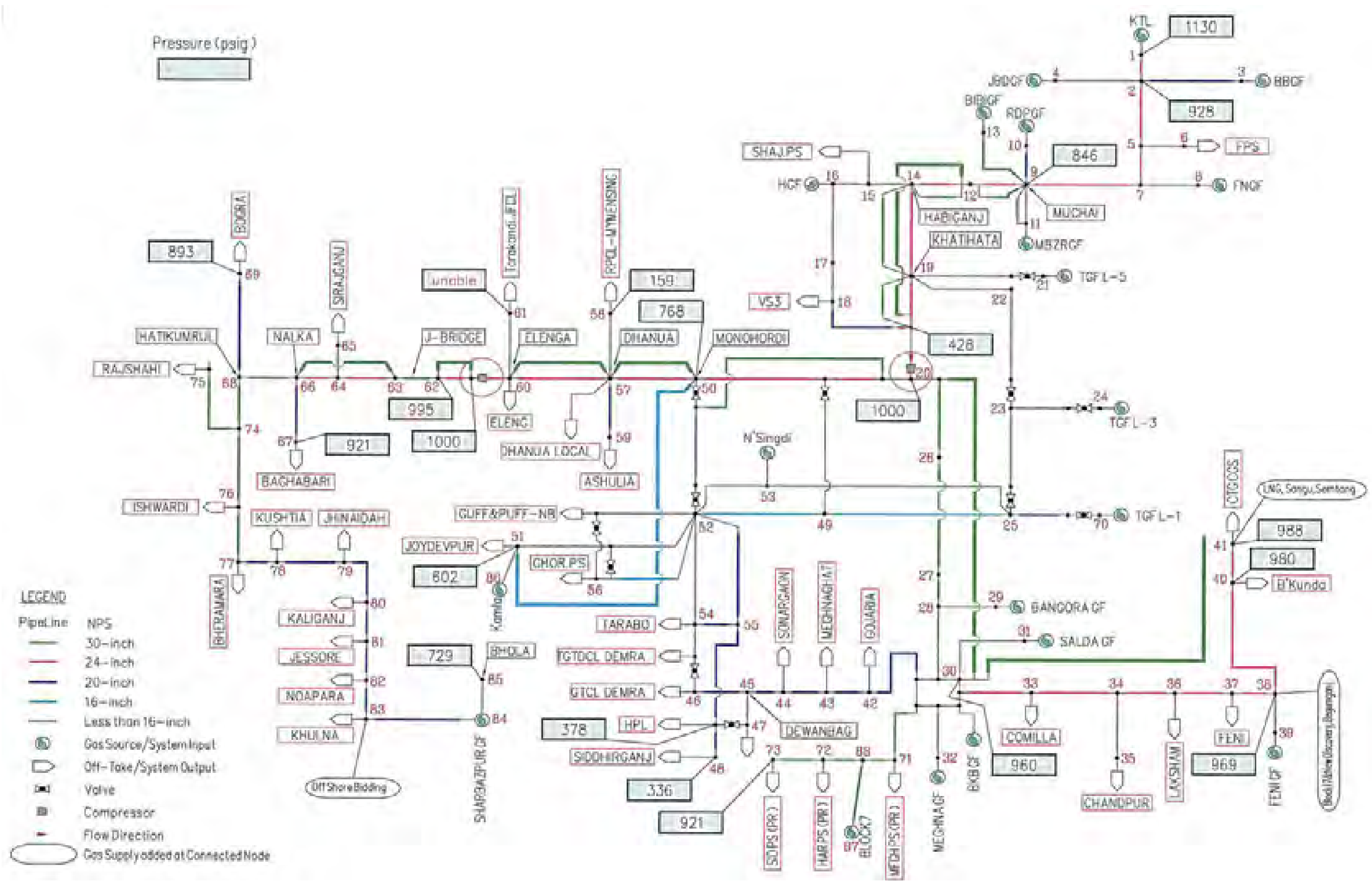
- The network becomes complex as a whole. So does the control.
- Pressures upstream from Node57 also increase. Difficulty in feeding from some gas fields may occur.

Careful and detailed analysis is required before start of the installation.



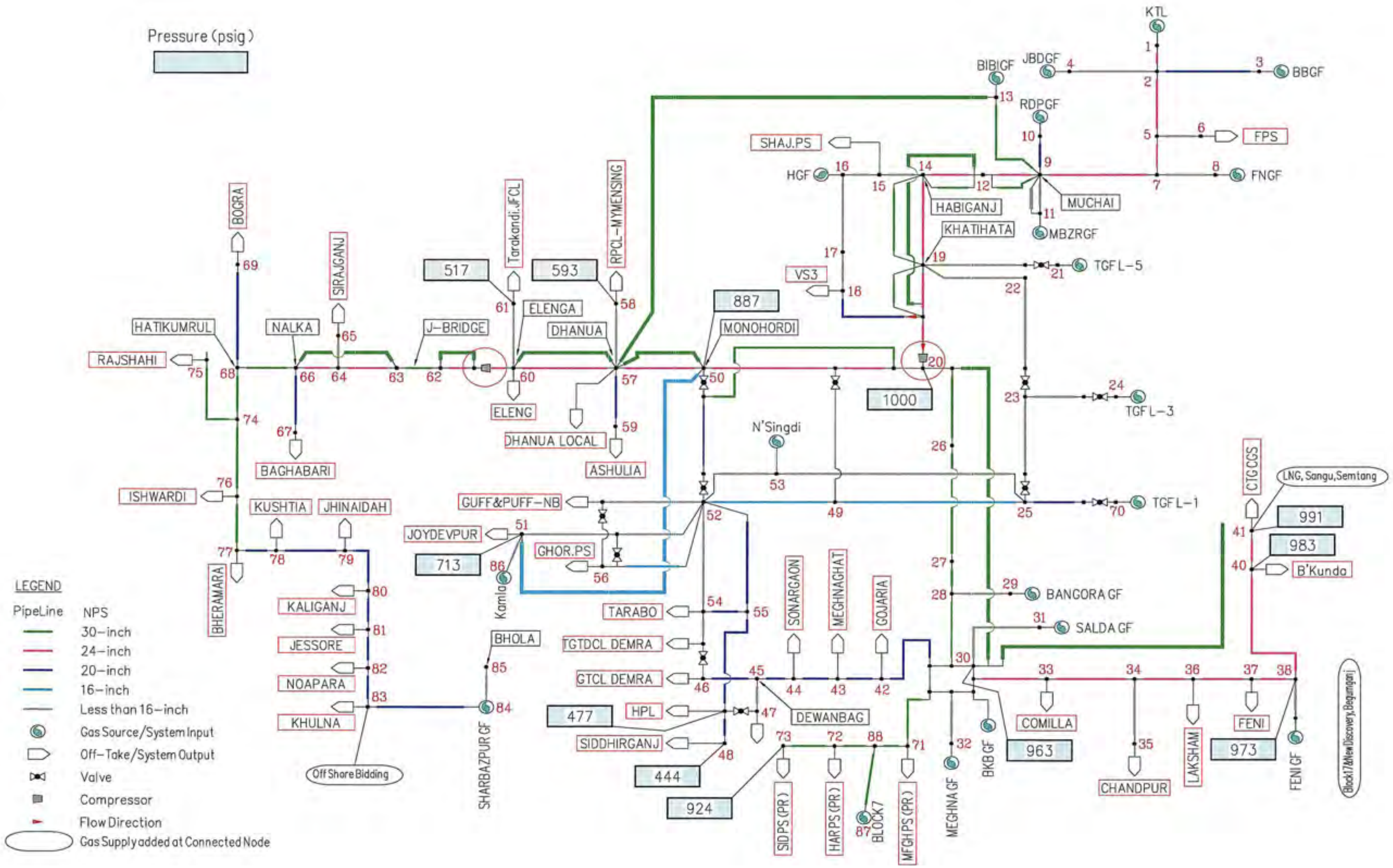
Source: PSMP Study Team

Fig. 5-17 Pressures at measure nodes (2015, Ave. Gas Demand×1.2)



Source: PSMP Study Team

Fig. 5-18 Pressures at measure nodes (2015, Ave. Gas Demand × 1.2, Network Reinforced)



Source: PSMP Study Team

Fig. 5-19 Pressures at measure nodes (2015, Ave. Gas Demand × 1.2, Bypass btwn.Node13 and Node57 Added)

(4) The study results on fiscal year 2030

1.2 times of the average load in fiscal year 2030 is used in the calculation. The network is the same as that mentioned in (3) except additional new gas fields. It has compressor stations at Ashuganj (Node20) and Elenga (Node60). The new gas fields are Off Shore Bidding (connected to Node83), Block7 (connected to Node88), and Kamta (connected to Node51).

The necessary pressure is secured in the PGCL area and the SGCL area (downstream of Elenga Compressor Station, Node60) except at Bogra (Node69). However, almost all nodes in the TGTDCL area and the BGSL area (up-stream of Elenga Compressor Station, Node60) fall into 'Unable'. As the flow through, Node20 can not be gained, pressure in JGTDSL (upstream of Node20) can not be calculated.

In the year 2030, the total gas demand is 7,909mmcfd and the total gas supply is 2,117mmcfd. There is a big discrepancy between demand and supply, which means the flow calculation, is intrinsically impossible. As all new gas fields are dealt as the supply designated node, most of the gas demand must be supplied from old gas fields in calculation. This fact may have brought many 'Unable' throughout the TGTDCL area and the BGSL area. To check this possibility, the PSMP Study Team made additional calculations by setting pressure to all nodes representing gas fields. The result is shown in Table 5-19.

According to Table 5-19, pressure is secured in the BGSL area, the PGCL area, and the SGCL area except Node35 and Node69. As these two nodes are in the branch lines, it can be overcome easily by adding a parallel line. Many nodes in the TGTDCL area still have trouble. It means the capacity of the pipelines is not enough.

Under such circumstances, it is difficult to overcome the trouble without sweeping measures.

Such measures include

(a) Reinforcement of pipeline by construction of loop lines with a focus on Padma Bridge

Padma Bridge, multipurpose bridge of 6km length to connect Maowa on the east bank of the Padma river (35km from Dhaka) to Zajira on the west bank, is being considered. Pipe lines on the bridge to connect Khulna, Shariapurin, etc. in the SGCL gas distribution area to Munshiganj, Narayangonj, etc. in the TGTDCl gas distribution area, bridge attribute to exchange gas between two areas. Additional loop lines around Dhaka such as lines parallel to the East-west & North-South trunk line, line from Bakhrabad to Monohordi would be necessary to secure pressure at the peripheral of the network.

(b) Pressure boost by turbo-compressors

The pressure boost by compressors is effective. They should be installed just before or somewhat upstream by a margin from the line where a big pressure drop takes place.

(c) Acceleration in exploiting domestic gas fields, introduction of foreign gas/LNG

The discrepancy between supply and demand would be filled by exploiting new gas field, by purchases from Myanmar, and by the introduction of LNG. Those gases should be injected from the southern part of the Dhaka area .to smooth out the pressure distribution.

(d) Promotion of energy saving and/or direct demand cut

In the rapidly growing industry sector, the promotion of energy conservation will curtail gas consumption. It includes the introduction of efficient equipment, the effective use of exhaust heat, and the use of unharnessed energy. Government measures such as various incentives are desirable.

In the domestic sector of the second largest gas demand, adding to the dissemination of efficient appliances, awareness campaigns toward the people through, for example, the development of charging methods or the introduction of prepaid cards are desirable.

In the power sector, the levelizing of demand is important. As the peak duration time is very short during the day and the remnant demand shape is flat, the use of prime movers like an oil-fired diesel engine during peak hours will cut down the peak load considerably.

(e) Introduction of SCADA

The introduction of the SCADA system is desirable in order to operate the network soundly. It can control pressures and flows throughout the network. With the help of SCADA, the staffs can create an improvement plan in a timely manner for the areas suffering from transport difficulty. They can adjust the gas flow by controlling valves so that power plants or other important facilities can secure a sufficient gas supply.

(f) Reduction of flow resistance in the network through maintenances like pigging

Many pipelines around Dhaka are old. The resistance of those pipelines tends to increase due to scales. It is possible to keep the transport capacity high by keeping the inner wall smooth.

Table 5-19 Gas demand/supply and pressure distribution (2030, Ave.x1.2, pressure designated)

	Node	Demand	P/S	Supply	Pressure		Node	Demand	P/S	Supply	Pressure
		mmcf/h		mmcf/h	psi			mmcf/h		mmcf/h	psi
TGTDCL	20		C	214.754	1,000	BGSL	33	12.368			848
	23				845		34	0.603			896
	24		P	8.486	900		35	1.865			Unable
	25				398		36	0.829			938
	26				890		37	4.678			983
	27				889		38		P	47.804	1,000
	28				889		40	9.458			990
	29				889		41		P		990
	30				837	PGCL	62				998
	31				837		63	2.701			980
	32				837		64				978
	42	6.486			Unable		65	1.626			911
	43	1.359			Unable		66				979
	44	1.733			Unable		67				979
	45				Unable		68				979
	46	28.723			Unable		69	4.647			Unable
	47				Unable	SGCL	74				981
	48	50.377			Unable		75				981
	49				Unable		76				983
	50				Unable		77	1.489			983
	51	46.389			Unable		78				986
	52	5.624			Unable		79				990
	53				Unable		80				991
	54	27.331			Unable		81				994
	55	5.733			Unable		82				996
	56	1.362			Unable		83		P	6.361	1,000
	57	32.741			Unable		84				981
	58	17.300			Unable		85	1.483			906
	59	43.496			Unable						
	60	16.250	C		* Unable						
	61	4.289			Unable						
	70		P	27.225	900						
	71	8.957			842						
	72	1.489			904						
	73	3.227			903						
	86		P	20.078	1,000						
	87		P	19.905	1,000						
	88				912						

P/S:P=Pressure set point S=Supply rate set point
C=compressor
* Pressure at compressor inlet

Source: PSMP Study Team

5.10.2 Conclusions

(1) Analysis on present network

Network analysis was done for Year 2009, Year 2015, and Year 2030.
It has confirmed that the numerical simulation results in Year 2009 conforms well with actual state.
In Year 2015, transport trouble takes place in PGCL, SGCL, and the southern part of TGTDCL.
In Year 2030, transport trouble takes place in almost all areas.

(2) Analysis on reinforced network for Year 2015

If reinforcements in accordance with ‘GSMP/PB/2006 (Wood Mackenzie) are applied to the network, almost all transport troubles will disappear except Node61, located in the branch line from the compressor inlet. The trouble at Node61 is overcome by additional reinforcements presented in the 'Gas Evacuation Plan'. The reinforcement is useful.

(3) Analysis on reinforced network for Year 2030

With increased demand in 2030, the reinforced network mentioned above (GSMP/PB/2006, Gas Evacuation Plan) can not avoid trouble.

(4) Recommendations for Year 2030

Bulk gas demand for power stations stays almost constant; it changes from 704 mmcfd in 2009 (40% of total demand) to 742 mmcfd in 2030 (less than 10% of the total demand). That for fertilizers also stays constant. The lack of supply is mainly due to the rapid increase of Non-bulk gas demand.

The gas demand is quite large especially in the area of TGTDCL, which comprises 78 % of the total nationwide demand. It is why most transport trouble manifests itself in this distribution area. The transport reinforcement plan should be focused on the area of capital Dhaka.

On the other hand, according to the forecast, gas production in 2030 is supposed to be 1,617mmcfd. Even with the addition of 500mmcfd LNG, the total supply will be 2,117mmcfd. By contrast, the total gas demand will be 7,909mmcfd. The discrepancy is 5,792mmcfd. Adding to the exploitation of new gas fields, measures such as the import of gas from Myanmar and the import of LNG should be considered.

As the demand in the capital area is huge, LNG stations should be located as near as possible to Dhaka and the gas should be introduced into the circular lines surrounding Dhaka.

5.11 Price scenario

For a reliable information or data to predict a natural gas price, World Energy Outlook (WEO) by IEA. is utilized. According to WEO2009, the prospect of gas market in North America and other regions has been changing due to the rapid development of unconventional natural gas in the US and Canada during recent years. Because shale gas, remained untouched for its development due to the high cost, can particularly become possible to be produced with low cost by technological innovation, the oversupply is predicted in the future and there is a possibility to influence on the pricing system in Asia-Pacific region.

On the other hand, the natural gas price in Bangladesh is suppressed largely as lower price by the government subsidy, compared to the international price. Because the demand cannot be fulfilled only by the domestic natural gas, the LNG import and the import through interconnected international pipelines are predicted and it is considered that the natural gas price could be linked with the international price soon or later. In addition, for supplying natural gas stably and continuously, the dependency of spot market has a high risk of price fluctuation and is inappropriate; therefore, it is considered that it is necessary to conclude the long-term contract with gas suppliers for 10 years or more.

It is assumed in this study that the natural gas price scenario will be raised in incremental steps after 2010 and linked with the international price by 2020. In addition, for the linked international price, the long-term contract for natural gas (Japan price for JCC link) described in WEO2009 is adopted as a reference value. However, as discussed previously, the LNG import price can be largely changed depending on the negotiation between Bangladesh and gas suppliers in consideration with the production trend of unconventional gas and the gas price scenario might need to be re-examined with rolling base every year. The detail of the natural gas scenario is described in Chapter 8.

5.12 Assessment of risks

5.12.1 Risk for existing gas field production

Summary of risk associated with the production of gas from existing gas field is provided below.

Table 5-20 Summary of production impediments in existing gas fields

Risk Factor		Cause of Impediment	Phenomenon during production	Occurrence of the Risk	Related Problems	Significance of the Risk		Measures	
						Frequency %	Damages	Hard	Soft
(1)	Formation Water	Inappropriate gas well control	Early increase of formation water level	Generation of formation water	- Decrease in production - Suspension of production - refurbishment works	30	Serious	- Periodical check of pressure at the bottom of wells - 3D earthquake survey - Collect gas at the place farther from the boundary of gas and water as much as possible	Establishing an optimum production model
(2)	Sand	Fragile sandstone layers	- Inflow of sand into a well - Occurrence of erosion	Damages to gas collection pipe due to erosion (perforation)	- Decrease in production - Suspension of production - Refurbishment works	10	Serious	- Use of a gravel packing (filled with sands and gravels) for completion - Fixing sand by injecting plastic materials	Analysis of sand grain size
(3)	Scale generation	Deposition of salts in formation water into a well	Deposition of scales inside of pipes in a well Clogging of gas pathway	- Closure and clogging of gas collection pipe - Creation of cracks at the upper parts of open holes	- Reduced production - Suspension of production - Leakage of as to above ground and fire due to cracks	10	Serious	- Periodical measurement of inner diameter of gas collection pipes - Periodical removal of scales - Removal of scales using a coil tubing unit	Identification of inhibitors appropriately by water quality analysis
(4)	Clogging of gas layers Clogging of drilled holes	- Clogging of gas layers due to clay minerals and other solid substances - Insufficient drilling	Failure of gas passing through gas layers	Production impediment	Reduced production volume	20	Large	- Reducing difference in pressure between oil/gas layers and mud column pressure in completion - Drilling using a through tubing - Re-drilling	- Understand production impediment factors quantitatively using the results of periodical high-low pressure measurements
(5)	Freezing	Generation of gas hydrates near the well mouth or in flow lines	Under a certain temperature and pressure condition, gas and water reacts chemically to generate gas hydrates causing a freeze.	Generation and freezing of hydrates	- Clogging of the well mouth and flow line pipes - Temporary suspension of production	5	Small	- Heating - Use of an agent that inhibit generation of hydrates (methanol/glycol)	Reducing gas pressure within pipes

Source: PSMP Study Team

5.12.2 Risks involved in developing new gas fields

(1) Risks associated with drilling of abnormally high pressure layers

Bangladesh has experienced several times of gas explosion accidents in the history of gas field development projects. All of them are associated with unexpected blowout of gas in trial drilling. This is not limited to Bangladesh only, but is observed every corner of the world. By using the recent advancement of well drilling technology, existence of gas under a shallow layer can be detected beforehand. Blowout accidents haven't been eliminated, however.

More recently gas leaked out from the Titas-3 well, which is an offending issue in the country. The leakage started from the well mouth in March 2003 and stopped in January 2008. However, due to cracks generated in the well, gas is leaking out at various locations around the well. In order to stop the leakage, BGFCL, operator of the well plans to invite an expert team through a bidding process to eliminate the gas leakage. The gas leakage from gas production fields greatly impedes gas production. Causal analysis and thorough measures to prevent occurrence of it are wanted.

(2) Risks associated with developing new gas fields at marine mining areas

Demand for natural gas is ever increasing year by year in Bangladesh. In order to fill the demand-supply gap, development of new gas fields is urgently required. The country recently conducted 2D and 3D seismic surveys to review the volume of gas reserves in existing gas fields and to examine whether or not new gas deposits should be explored. In response to the gas field discovery works in the Bay of Bengal by India, Myanmar and other neighboring countries, in 2008, the GoB chose 28 new marine mining areas to invite a tender by overseas corporations to take part in development of these marine gas fields. Even if a new and potential gas deposits be found in a seismic survey under the sea at the depth of more than several hundred meters, huge amount of cost will be required for drilling test and delineation wells, completion of the sea bottom, laying pipelines under the sea and construction of above-ground production and treatment facilities. Moreover, 6 to 7 years will be required from exploration to start of production, from the example of Dhirubhai Gas Field in India.

5.12.3 Risks related to the policy

Although the necessity of domestic gas exploration development business and pipeline maintenance is described in the national policy and project, it is hard to say that the plan has been preceded as scheduled in the existing circumstances. Because the natural gas development has been exposed to various risks for a long time, it is necessary for the government to lead or precede the development. If the change of power happens or the political situation become fluid, the implementation of the national development plan, such as LNG import or pipeline project, may be significantly changed and/or delayed.

(1) Risk related to changes in political administration

Since Bangladesh became independent in 1971, several severe changes in political administration have occurred between ruling and opposition parties in the country. The general election (every five years) had not been held as scheduled. The general election in January, 2007 was delayed for two years due to struggles between the ruling and opposition parties, so it was held in December, 2008, and the current administration was inaugurated in January, 2009. In the meantime, the interim government ruled the country. At the PSC international bidding of offshore area in 2008, Petrobangla and EMRD recommended Conoco Phillips and Tullow to the interim government as successful bidders of PSC. As for IOC's, the former made a bid for Block 10, 11, 12, 15, 16, 17, 20 and 21, and the latter for Block 5. Nevertheless, the administration postponed the decision by regarding it as a matter for the next government. Petrobangla and EMRD asked the current administration to consent the bidding result, but the government considered that it would not be wise to give the nine blocks of PSC to the two companies. Thus, the government decided to allocate Block 10 and 11 to Conoco Phillips and Block 5 to Tullow, respectively. Petrobangla and EMRD have had the contract negotiation with Conoco Phillips and Tullow, but it is still unsettled at present. The delay in political decisions by changes in administration has become a big obstacle to invite investment for Bangladesh and had a tremendous impact on the promising project on gas mining development in the Bay of Bengal.

Furthermore, it is required to have a political solution regarding oceanic boundary issue with Myanmar and India so that the offshore new gas fields are developed by IOCs. Otherwise, the international oceanic boundary issue takes very long time to solve, then the offshore bidding could not be succeed within the expected time line.

(2) Risk of delay in the project due to slow bidding process

In Bangladesh, it takes quite a long time to start and implement a project after preparing a draft plan. According to the BAPEX's Annual Report (FY 2007-2008), for example, there was an project on procurement of drilling rigs (5,000m+) to strengthen the operation capability of oil/gas exploration. The aim was to improve efficiency of the exploration work by replacing the old rigs with new ones (the old rigs need extra time for maintenance and repair) and to cut down on drilling expenses. This project – its budget amount was 815.8 million taka - was authorized by the Executive Committee of the National Economic Council (ECNEC) on June 8, 2003. The first bidding ran over the budget by 31%, and the best bid at the second bidding also exceeded the budget by 90%. Thus, it was modified to 1.42 billion taka. Likewise, Development Project Proposal (DPP) was revised in that the project completion would be June, 2008. The third and fourth bidding were also not successful, but there were six bids in March, 2006. Two of them satisfied the bidding requirements. The winning bid has been approved by the board of directors in BAPEX, and the PSMP Study Team is told that the prescribed process is now under way. DDP was modified according to a result of the winning bid, so the cost is now 2.565 billion taka and the date of acceptance/receiving inspection has been changed to December, 2011. After the approval of ECNEC, this project will take eight and half years to finish the receiving inspection. In addition, the cost is three times higher than the predicted cost, which was approved by ECNEC in 2003. On afterthought, something seems to have been wrong with the bidding system. The delay in the main bid had a tremendous impact on the gas field development. As countermeasures against gas shortage, the short-term, medium-term and long-term plans on increased production have been considered, but there is some possibility that the gas production will not implemented in a timely manner if these plans will not work out as scheduled.

5.12.4 Risks related to finance

The requirements or conditions surrounding the natural gas exploration/development are becoming more difficult and the maintaining of economic efficiency is also becoming more difficult with an increase of necessary investment amount. In addition to the national conditions in the exploited regions targeted for deeper and complicated stratification, the costs for infrastructure maintenance such as roads could be increased. Furthermore, because of the increased interest for environment, a requirement of environment assessment becomes general by severely being asked for environmental attention.

The depletion of domestic natural gas would be timing issue, therefore, importing natural gas by LNG and/or pipeline will be inevitable. As gas price is exposed to international gas demand-supply situation, in order to secure the stable natural gas supply, the government should revised the current gas tariff, which is currently regulated significantly low price from the political reason, to link to international market price. It is desired to make the gas price system more appropriate for collecting those increased costs.

Chapter 6 Other Primary Energy

6.1 Petroleum sector

In this chapter, a present data analysis is conducted of oil regarding policy, domestic reserve situation, future development, import trends, etc. as sources of primary energy other than coal and natural gas. The basic information was collected for the optimum power development plan. To establish domestic transportation and storage system is a matter of urgent for the recent fast track project of oil fired power stations.

6.1.1 Petroleum policy

(1) Basic policy and plan

From 1997 to 2007, the demand for oil is increasing by 2.6% as an annual average. Under the present circumstances, the demand of oil refinery productions and around one third of the petroleum products was refined by the Eastern Refinery Limited (ERL: subsidiary of BPC), with the remains imported outside the country. In order to correspond to the demand growth of petroleum products, the procurement of energy security and storage for 60 days, the basic plan for the petroleum sector is as follows;[1]

- To undertake by ERL to increase its present processing capability from 1.5 million metric tons to 4.5 million metric tons per annum,
- To construct deep sea unloading facilities with sub sea pipe line linkage to ERL for crude oil and refined petroleum products to facilitate a quick and safe discharge,
- To construct pipe lines including the ancillary facilities for the transportation of petroleum products from Chittagong to Dhaka to ensure the safe and smooth transportation of petroleum products. The pipe line may be gradually extended to the northern region of the country.
- To increase storage facilities at ERL, Oil Marketing Companies main installation and other different strategic points especially the Southern and Northern regions to maintain the inventory of petroleum products in accordance with the 60 days requirement.
- To establish 2nd Main Installations (MI) at the Mongla port for discharging imported petroleum products as an alternative arrangement to meet emergency requirements.
- To modernize river transportation and the custody transfer system of petroleum products from MI to secondary and territory depots to minimize the transit loss & pilferage during transportation.
- To develop railways facilities for the transportation of petroleum products via tanker.

As for liquefied petroleum gas (LPG), priority has been placed on marketing LPG for domestic use. After meeting the domestic requirements, the surplus may be used as commercial fuel. To meet the demand for cooking fuel in non-gas areas, the establishment of an LPG bottling plant in the west zone may be encouraged. So far, there are no existing power generation plans that utilize LPG or a mixture of LPG with other natural gases.

For environmental prevention in the urban areas, utilizing diesel as fuel for transportation is restricted, and the promotion of CNG utilization is underway.
The promotion of CNG utilization will be extended to the western area and the eastern part of the county.

[1] National Energy Policy (Draft), MPEMR (2008)

6.1.2 Current status and subject concerning supply and demand

The demand for whole petroleum in Bangladesh is 3.8 million tons per annum, in which 1.2 million tons of crude oil was refined in ERL and 2.6 million tons of petroleum products were imported in the fiscal year 2006/07.

The oil-refining equipment in Bangladesh is located only in ERL in Chittagong. The design installed capacity of ERL is 1.5 million tons per annum, while the 1.2-1.4 million tons per annum was actually refined crude-oil, on average annual 330 day operation.

Imported crude oil is comprised of mainly two kinds, the Murban crude oil of Abu Dhabi, and the Arabian light (ALC) of Saudi Arabia. In ERL, 15 kinds of oil-refining products, such as HSD (High Speed Diesel), FO (Furnace Oil), and LPG (Liquefied Petroleum Gas), are manufactured.

In 2009, HSD 139,000 ton/year, and FO 116,000 ton/year were refined for the electric power supply, which was 7.7% of the total amount refined in ERL. In the near future, ERL will supply HSD 310,000 ton/year and FO 810,000 ton/year for Rental power (eight sites) and Small oil fired power stations (ten sites) in the year 2011. The supply from ERL will be assumed to be HSD 440,000 ton/year and FO1,500,000 ton/year with the addition of 3 IPPs in 2013, which will be 8 times larger than the current capacity. In response to these rapid demand increases, BPC is prepared to reinforce capacity in ERL, which includes the construction of deep sea unloading facilities in Matarbari Island from the mother ship via a single point mooring (SPM) with a sub sea pipe line linkage to ERL. After the construction of SPM, which forecasts that the operation will start in the year 2012 and the capacity will be increased to a total of 4.5 million tons/year.

The supply into these electric power sectors is called fast-track projects. Urgent installation for fulfilling electricity demand will result in a temporary 30 percent of the total oil supply. It is assumed that it will eventually settles down to about 5% of the total supply.

From May 13, 2010, in responding to the aggravating electric power shortage, BPDB announced plans to urgently install power generation plants.

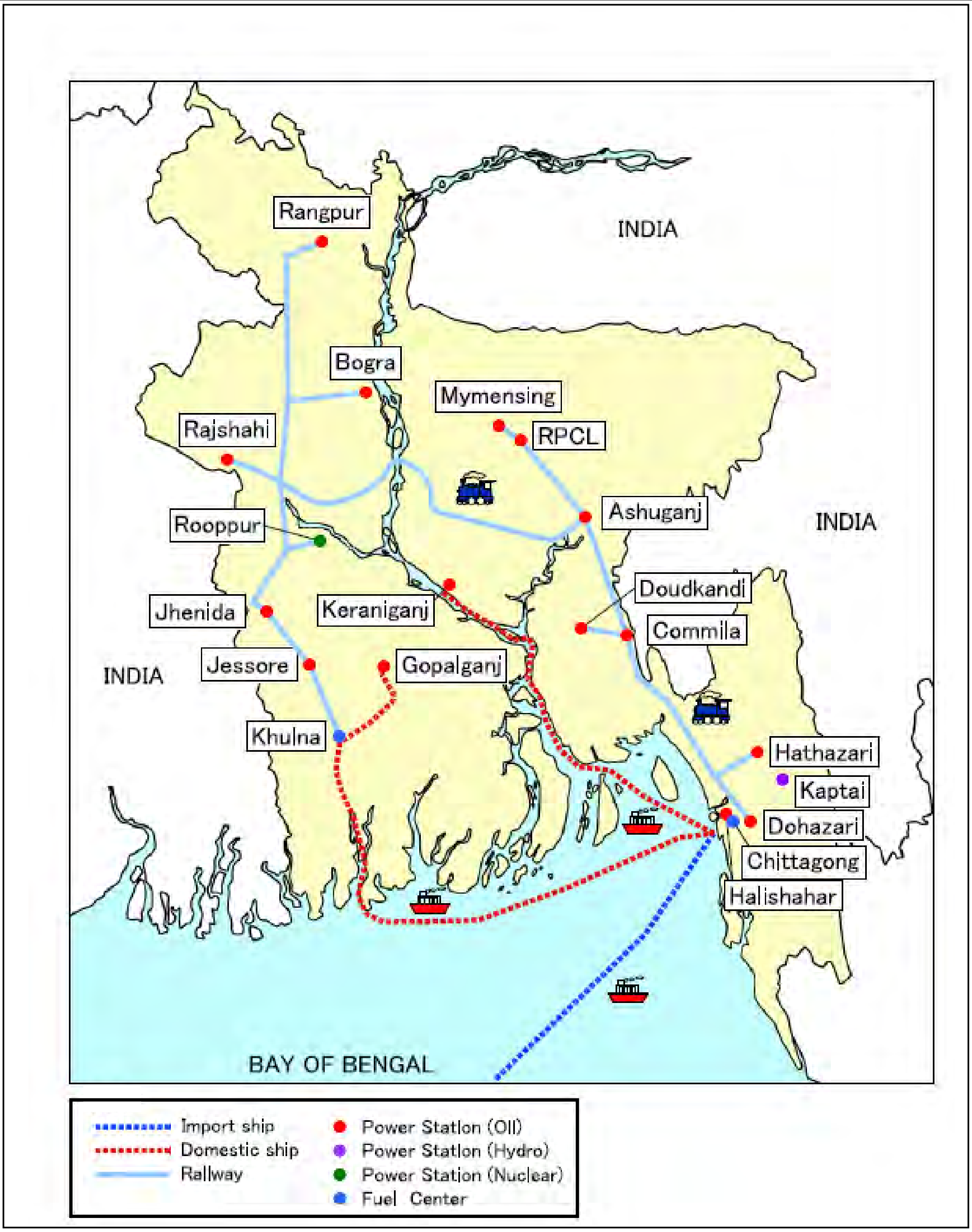
According to the BPDB's new plan, a total of 1200-1500MW introduction of the oil (HSD, FO) fired rental plant is due to be carried out by 2015 (the original plan was 530 MW).

It has been estimated that 200,000 tons of additional storage capacity will be newly required by 2012 with additional imports of 190,000-tons of HSD and 46,000-tons of FO by the end of 2010 in order that the oil supply capability in Bangladesh will not be affected.

6.1.3 Situation and subject of fuel infrastructure

As for the oil transportation organization inside Bangladesh, the BPC is a single managing body. After the products are refined by ERL, which is a subsidiary of BPC, and the imported products are collected to MI in Chittagong, they are distributed to many parts of Bangladesh. There are five large-scale oil depots in MI Chittagong, Godenail, Futullah, Daulatpur, Baghabari, six medium depots in Srimangal, Bhairab, Chandpur, Parbatipur, Barishal, Jhalakathi, and other small-scale depots in Sylhet, Rangpur, Natore, Rashahi, Harian, Ashuganj, Balashi, Chilamari, etc. Petroleum products are delivered to places by demand all over the country directly or via these depots from MI.

As a domestic carriage measure, transportation by river ships is 90%, railroads 8%, and the tracks has become 2%. There are two kinds of river transportation by ships; the Coastal Tanker (1000-5000t) and the Shallow Draft Tanker (700-800t). These tankers have been selected according to the demand of oil and the characteristic of the inland waterway, etc. Although traffic increases in connection with future increased demand, the enlargement of a domestic tanker is needed in order to improve transport efficiency and transportation cost reductions. For that purpose, the deep-dredging of a waterway is required, and the dredge method, frequency, and cost are issues that must eventually be dealt with.. Large scale inland water transportation is also needed in line with the first-track installation plan of the aforementioned power generation equipment.



Source: PSMP Study Team

Fig. 6-1 Petroleum transportation by ship and railway in Bangladesh

6.1.4 Price scenario

According to the National Energy Policy, the oil price of domestic production will be determined by market prices, after making a comparison with the Asia Pacific Petroleum Index (APPI). Moreover, the price of imported oil will be decided based on the Import Parity Price (IPP).

6.1.5 Risk evaluation

(1) Technical risk

Petroleum power station is introduced as a rental. Hence it is constructed in a short time. The term of contract is limited to 3 to 5 years. At the power plant, electricity is generated by a diesel engine. Its technique is almost established. The risk is low unless the fuel is continually provided.

(2) Political risk

Petroleum is imported for more than 10 years. Relationships with other countries concerning petroleum exports are well. Political risks are low, unless the policy regarding petroleum is vastly changed.

(3) Economic risk

Petroleum fired power station will be operated until the coal fired power stations start operation. If the start of operations of coal fired power stations becomes delayed, the petroleum fired power station may be continually operated. Since the petroleum cost is higher than other primary energy, there is the possibility that the operating cost becomes high, if the shift from petroleum to coal is late.

6.2 Renewable Energy Sector

6.2.1 Current status and issue

(1) Current status

Table 6-1shows the status of renewable energy currently developed in Bangladesh. As the table indicates, development of renewable energy is not progressing very much in Bangladesh.

Table 6-1 capacity of Renewable Energy Developed (as of June 2010)

Resources	Present status
Solar	30 MW
Wind	2 MW
Biomass based electricity	< 1 MW
Biogas based electricity	< 1 MW
Hydro	230 MW
Others	< 1 MW
Total	265 MW (about)

Source: Power Division

(2) Organizations

Renewable Energy Policy indicates that an independent organization, Sustainable Energy Development Authority (SEDA) will be established to promote the development of renewable energy and the utilization of energy effectively.

More precisely, SEDA is involved in promoting the use of renewable energy by managing trust funds collected from entire power generation sectors.

(3) Promotion measures

Renewable Energy Policy proposes the following incentive schemes.

- Exemption of customs duty and VATs
- Grant to public corporative bodies who will install a renewable energy system
- Exemption of corporate tax for 15 years
- Purchase electricity at high prices (1.25 times of the maximum purchase price from private electricity companies)
- Accelerated depreciation of up to 80% in the initial year
- Others

6.2.2 Target and future estimation

(1) Target of developing renewable energy

According to "Renewable Energy Policy of Bangladesh" released by the Power Division in November 2008, Bangladesh sets a target that 5% of total electricity demand will be fulfilled by renewable energy by 2015 and 10% by 2020.

The government estimates that electricity demand will reach approx. 10,283 MW in 2015. This means approx. 510 MW will be generated by renewable energy to cover 5% of the demand. Similarly, it estimates that electricity demand in 2020 will reach approx. 17,600 MW and 1,760 MW should be generated by renewable energy to cover 10% of the demand. (Assuming that electricity demand defined by Renewable Energy Policy is equivalent to actual electricity demand, renewable energy power generation facilities must be developed to cover more than double of the above power generation volume, because the ratio of utilizing renewable energy is low i.e. less than approx. 30%.)

As for the use of renewable energy, the country promotes the introduction of SHS (solar home system) using solar panels, in order to increase the ratio of electrification (currently 48.5 % in terms of population) as a priority basis as of now.

(2) Renewable energy

The renewable energy such as photovoltaic, solar thermal and wind power will be incorporated as power supply if their generation cost is reasonably dropped due to technical and/or economical breakthrough. If the renewable energy becomes feasible, other power supply such as oil and imported coal, imported LNG will be reduced accordingly. Renewable energy is important especially for isolated rural area with technical difficulty of connection to the grid system. However, the promotion for such renewable energy needs to be undertaken by programs other than this Master Plan.

(3) Future estimation

Although solar power generation (photovoltaic, solar thermal) is estimated to have enormous potential, the solar power generation cost at this point in time is more than five times higher than the power generation cost of conventional thermal power generation. In the future, the large-scale introduction of solar power generation cannot be expected unless the cost of solar panels becomes significantly lower or government provides large amount of subsidies.

In terms of wind power generation, past surveys have identified several candidate sites with an average wind speed of 6 m/s, which is a generally accepted borderline level of profitability for wind-power generation. At this moment, however, wind power generation is poor in profitability because the purchase price of electric power generated by wind power generation is low, and is not in an environment where active introduction by private power producers is expected. If the purchase price increases and such preferential measures as tax reductions are continuously taken in the future, private power producers may introduce wind power generation at some sites. Given the average wind speed on the borderline level of profitability, extensive introduction cannot be expected.

In terms of biomass, although Bangladesh has abundant agricultural residues, almost all of them are effectively used for fuels, fertilizers, feed and other commodities and the amount of biomass applicable to power generation is estimated to be extremely small.

In terms of waste, waste power generation has some potential chiefly in urban areas but much cannot be expected in light of the amount of electricity.

In terms of hydropower, while there are a few sites suitable for power generation within Bangladesh, there is much potential in the surrounding areas along national boundaries.

Judging from the above conditions, it is quite unlikely that domestic renewable energy will be greatly advanced by 2030, the last year of this MP. It is also assumed that the target values shown in the Renewable Energy Policy would unlikely be achieved. On the other hand, some projects which develop potential of hydro-energy in neighboring countries and export to Bangladesh are considered. If the imported electricity from such projects is also counted in the supplied electricity in Bangladesh from the renewable energy, it will be possible to supply 10% of total electricity demand by renewable energy by 2030.

6.2.3 Risk evaluation

Until 2030, which is the last year of this study, it is unlikely that the capacity of renewable energy in Bangladesh increases dramatically. Therefore, it is hard to hold excessive expectations of additional power capacity via renewable energy development in Bangladesh. On the other hand, there is the risk that recent major donor's willing support for renewable energy development makes it more difficult to secure the development fund required for the implementation of the master plan. In this study, imported electricity from hydropower plants in neighboring countries, such as Myanmar, Bhutan and Nepal etc., counted in the electricity from renewable energy. Bilateral meeting for the project of the hydropower development in Myanmar and interconnection with Bangladesh has been implemented and specific project sites (Lemro area: approximately 500MW) are considering in the meeting. Therefore the project is likely to be implemented and accomplished by 2030. The projects to inter connect hydropower plants in Bhutan and Nepal to Bangladesh's power grid, which interconnection should pass through India, will be discussed under the framework of the South Asia Association for Regional Cooperation (SAARC). Therefore it is possible but requires much time to implement these projects, which means the risk not to realize the condition in this study by 2030.

Chapter 7 Power Demand Forecasts

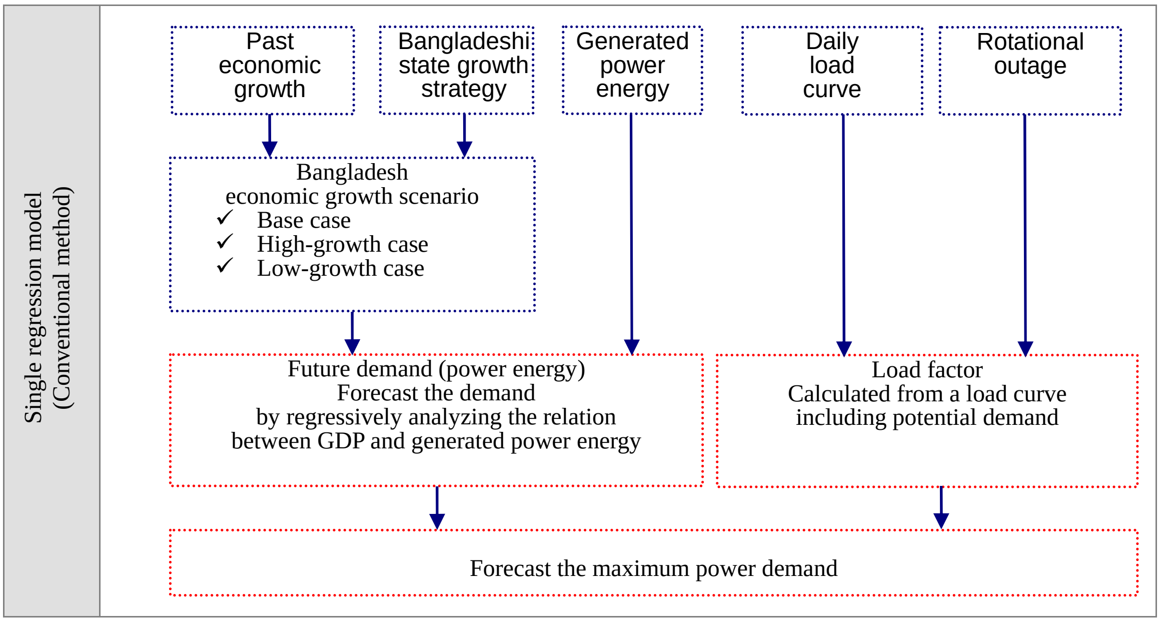
7.1 Objective

This section provides power demand forecasts until 2030, including assumed annual and daily load curves, while taking into account the economic growth rate of Bangladesh, degree of promotion of heavily energy consuming industries in the country, growth of the electrification rate in the country, etc. In making assumptions, PSMP Study Team first review PSMP 2006, which is the latest power system master plan of Bangladesh, to verify the forecast method adopted in the PSMP and then validate it from a macroscopic point of view through the formulation of a counterproposal.

7.2 Current states and evaluation of the power demand forecasts

7.2.1 Evaluation method

In Bangladesh, the Power System Master Plan (SPMP) is reviewed every 10 years, and its latest version is PSMP 2006, which was conducted in 2005. Power demand forecasts in Bangladesh have been performed by the System Planning Directorate of BPDB. The basic method used is to calculate the power usages of all systems by adding up the power usages of consumers by categories (e.g., household use, industrial use, and commercial use). Then, the annual maximum power is forecast by performing back calculation based on the annual load factor.

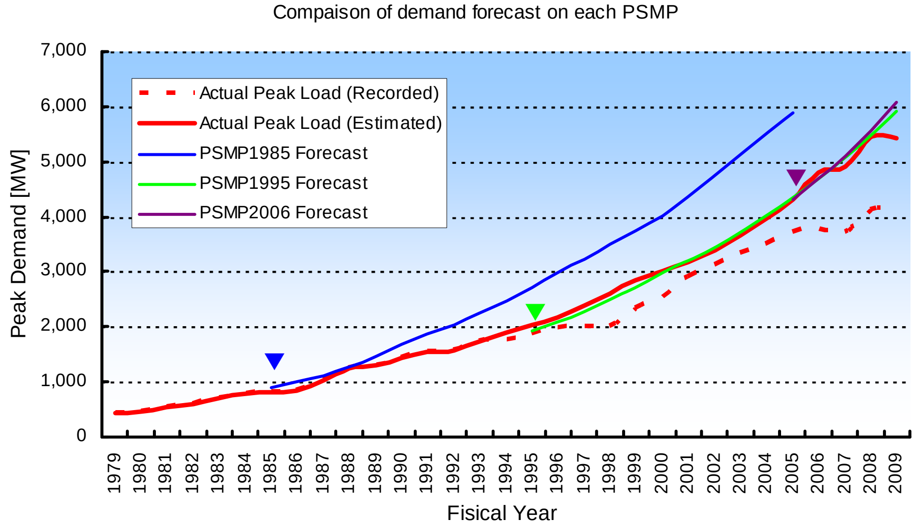


Source: PSMP Study Team

Fig. 7-1 Flow of forecasting/examining the demand in Bangladesh

7.2.2 Demand forecast by past PSMP

The following figure shows the comparison between the demand forecast scenario by past Power System Master Plan (PSMP1985,1995 and 2006) and actual peak demand.



Source: PSMP1985, PSMP1995, PSMP2006, PSMP Study Team

Fig. 7-2 Comparison of demand forecast by past PSMP

The demand forecast scenario by past PSMP shows a tendency to be higher than actual recorded data. However the data which is estimated with potential demand shown in 7.3.3 are close to the scenario by PSMP 1995 and 2005.

7.2.3 Economic growth scenarios of PSMP 2006

In 2006, when PSMP was formulated, the average economic growth rate for the approximate 10-year period from 1994 to 2004 was 5.2%. Given the past record of economic growth, PSMP 2006 forecasts demands based on the assumption of three scenarios: 5.2% on average in the base case, 8.0% in the high-growth case, and 4.5% in the low-growth case.

Table 7-1 PSMP 2006 economic growth scenarios

	Base Case		High Case		Low Case	
Fiscal Year	GDP (million Taka)	Growth Rate	GDP (million Taka)	Growth Rate	GDP (million Taka)	Growth Rate
2005	2,634,409	5.3%	2,664,431	6.5%	2,634,409	5.3%
2006	2,792,474	6.0%	2,850,941	7.0%	2,766,130	5.0%
2007	2,960,022	6.0%	3,050,507	7.0%	2,904,436	5.0%
2008	3,137,623	6.0%	3,264,043	7.0%	3,049,658	5.0%
2009	3,325,881	6.0%	3,508,846	7.5%	3,202,141	5.0%
2010	3,525,434	6.0%	3,789,553	8.0%	3,362,248	5.0%
2011	3,719,332	5.5%	4,092,718	8.0%	3,513,549	4.5%
2012	3,923,896	5.5%	4,440,599	8.5%	3,671,659	4.5%
2013	4,139,710	5.5%	4,818,050	8.5%	3,836,883	4.5%
2014	4,367,394	5.5%	5,227,584	8.5%	4,009,543	4.5%
2015	4,607,601	5.5%	5,698,066	9.0%	4,189,972	4.5%
2016	4,837,981	5.0%	6,210,892	9.0%	4,378,521	4.5%
2017	5,079,880	5.0%	6,738,818	8.5%	4,575,555	4.5%
2018	5,333,874	5.0%	7,311,618	8.5%	4,781,455	4.5%
2019	5,600,568	5.0%	7,933,105	8.5%	4,996,620	4.5%
2020	5,880,596	5.0%	8,567,754	8.0%	5,221,468	4.5%
2021	6,145,223	4.5%	9,253,174	8.0%	5,430,327	4.0%
2022	6,421,758	4.5%	9,993,428	8.0%	5,647,540	4.0%
2023	6,710,737	4.5%	10,742,935	7.5%	5,873,441	4.0%
2024	7,012,720	4.5%	11,548,655	7.5%	6,108,379	4.0%
2025	7,328,292	4.5%	12,357,061	7.0%	6,352,714	4.0%
Average		5.2%		8.0%		4.5%

Source: PSMP 2006, Bangladesh

7.2.4 Estimation of the maximum power that includes potential demands

In Bangladesh, the power supply has constantly remained strained in peak hours. Potential demands have not been met, and rotational outage has frequently occurred. The actual recorded maximum power has not included these potential demands. To estimate the maximum power that includes potential demands, PSMP 2006 adopts a method for calculating the generated power energy with which a compound daily load curve is produced by adding the evening peak demand for lighting, calculated from a daily load curve with no rotational outage on weekends and holidays in winter, to a daily load curve suppressed by rotational outage on weekdays in summer. By regressively analyzing the relation between the generated power energy calculated this way and the economic level indicated by the actual GDP and setting the load factor from a load curve that includes potential demands, PSMP 2006 estimates the maximum power energy. The following table shows the result of the forecast of power demands indicated in PSMP 2006.

Table 7-2 PSMP 2006 demand forecast scenarios

Fiscal Year	Base Case Net Generation (GWh)	Base Case Net Peak Load (MW)	High Case Net Generation (GWh)	High Case Net Peak Load (MW)	Low Case Net Generation (GWh)	Low Case Net Peak Load (MW)	Projected Load Factor
2005	21,964	4,308	22,336	4,381	21,964	4,308	58.2%
2006	23,945	4,693	24,692	4,839	23,611	4,627	58.2%
2007	26,106	5,112	27,297	5,345	25,382	4,970	58.3%
2008	28,461	5,569	30,177	5,904	27,286	5,339	58.3%
2009	31,028	6,066	33,592	6,567	29,333	5,734	58.4%
2010	33,828	6,608	37,652	7,355	31,533	6,160	58.4%
2011	36,622	7,148	42,202	8,237	33,659	6,569	58.5%
2012	39,647	7,732	47,627	9,288	35,928	7,007	58.5%
2013	42,922	8,364	53,749	10,473	38,351	7,473	58.6%
2014	46,467	9,047	60,659	11,810	40,937	7,970	58.6%
2015	50,306	9,786	68,924	13,408	43,697	8,501	58.7%
2016	54,079	10,512	78,316	15,223	46,643	9,066	58.7%
2017	58,135	11,291	88,384	17,166	49,788	9,670	58.8%
2018	62,496	12,128	99,746	19,357	53,145	10,313	58.8%
2019	67,183	13,027	112,568	21,827	56,728	11,000	58.9%
2020	72,222	13,993	126,172	24,445	60,553	11,732	58.9%
2021	77,092	14,924	141,419	27,377	64,178	12,424	59.0%
2022	82,290	15,917	158,510	30,661	68,020	13,157	59.0%
2023	87,839	16,977	176,448	34,103	72,092	13,934	59.1%
2024	93,761	18,107	196,415	37,931	76,408	14,756	59.1%
2025	100,083	19,312	217,137	41,899	80,982	15,626	59.2%

Source: PSMP 2006, Bangladesh

7.3 PSMP 2010 power demand forecast using the conventional method

In the first step of PSMP 2010, the power demand will be forecast using a similar method as that used in PSMP 2006.

7.3.1 Formulating of economic growth scenarios

Since its independence in 1971, Bangladesh has striven to improve its socioeconomic conditions and grow its economy with support from domestic and international society. The average annual growth rate in the 14-year period from 1995 to 2008 was 5.6%. In the past three years, a high growth rate has been maintained since the stable and high growth of the mining and industrial sectors and the service sector has covered the low growth rate of the agricultural sector. The midterm macroeconomic framework of the Poverty Reduction Strategy Paper (PRSP), which the government has formulated, set a goal of achieving a GDP growth rate of 6.8% in fiscal 2007 and 7.0% in fiscal 2008 and 2009. However, due to negative factors such as increased pressure for inflation, soaring international prices of crude oil, disasters caused by floods and cyclones, and serious power shortages, the real GDP growth rate in fiscal 2008 was only 6.2%. The World Bank has drawn up a mid- to long-term growth scenario that by judging from circumstances, including the following facts: the country has assets required for growth, its economic fundamentals have improved and it has succeeded in first-stage reforms, its workforce is young, and corporate spirit

and cultures have been established, the country will break away from its present status of being the poorest country and advance to become a medium-income country in approximately 10 years[1].
Given such an environment, PSMP Study Team assume economic growth scenarios until 2030 in Bangladesh as follows.

Table 7-3 Record of economic growth rates

Fiscal Year	GDP (million Taka, at	Annual
1994	1,515,139	
1995	1,589,762	4.9%
1996	1,663,240	4.6%
1997	1,752,847	5.4%
1998	1,844,478	5.2%
1999	1,934,291	4.9%
2000	2,049,276	5.9%
2001	2,157,353	5.3%
2002	2,252,609	4.4%
2003	2,371,006	5.3%
2004	2,501,813	5.5%
2005	2,669,740	6.7%
2006	2,846,726	6.6%
2007	3,029,709	6.4%
2008	3,217,855	6.2%
2009	3,406,524	5.9%
Average		5.6%

Source: Bangladesh Bureau of Statistics, as of May 2010

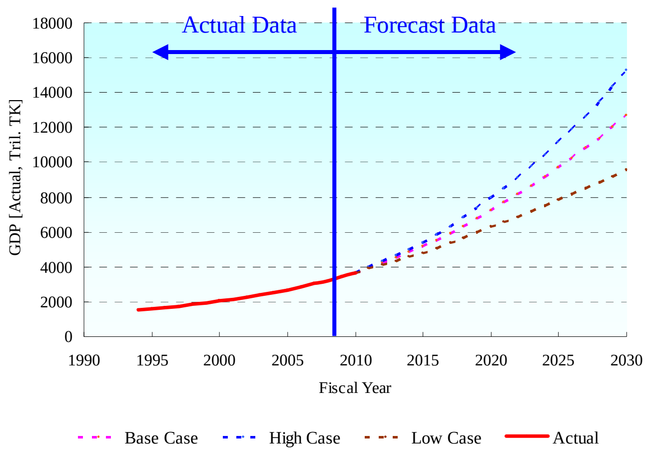
Table 7-4 Economic growth scenarios

Scenario	Mid-term forecast	Long-term forecast
	2010-2015	2016-2030
Base case	7% growth rate, a goal set by the Bangladeshi government in the Poverty Reduction Strategy Paper (PRSP), continues.	It is assumed that although the economic growth will continue, the growth rate will decrease by 0.5% every 5 years due to maturity of economic activities.
High growth case	Case in which the economy grows at 8.0%, which is 1.0% higher than the growth rate set by the government.	
Low growth case	Case in which the economy grows at 5.5%, which is 1.5% lower than the growth rate set by the government. It is equivalent to the average growth rate in the past 14 years.	

Source: PSMP Study Team

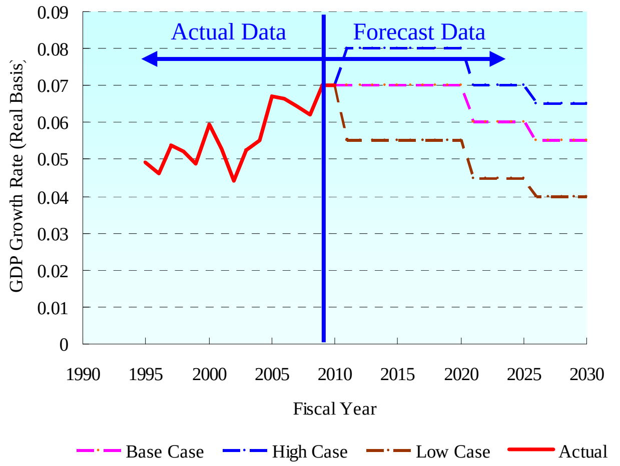
The economic growth change from 1994 to 2008 and the economic growth scenarios until 2030 are indicated in Fig. 7-3 and Fig. 7-4.

1 World Bank, "Bangladesh: Strategy for Sustained Growth," July 2007



Source: PSMP Study Team

Fig. 7-3 GDP change and forecasts

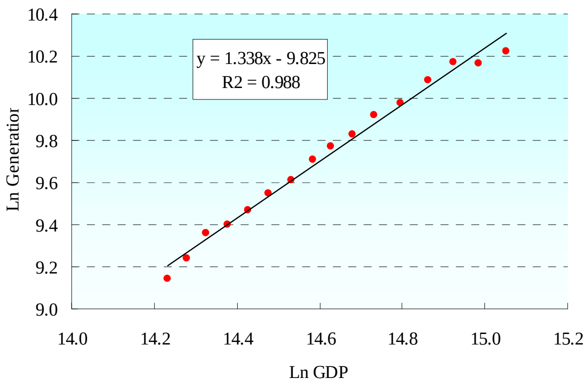


Source: PSMP Study Team

Fig. 7-4 GDP growth rate change and forecasts

7.3.2 Result of regression analysis of the economic growth and the generated power energy

The result of regression analysis of the GDP and the generated power energy indicates that there is a strong correlation between them as shown in the figure below. Therefore, PSMP Study Team judge that it is appropriate to examine the result with a similar method in this examination.



Source: PSMP Study Team

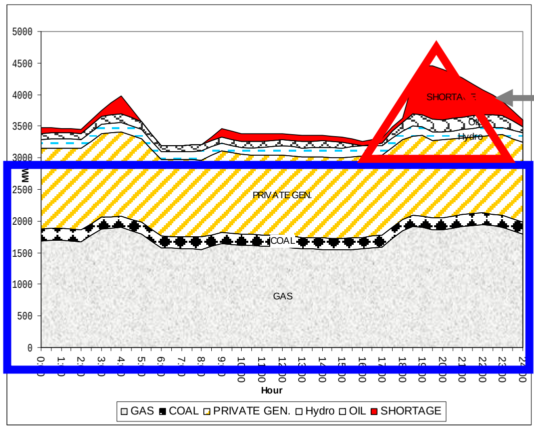
Fig. 7-5 Result of regression analysis of the GDP and the generated power energy

7.3.3 Assumption of the maximum power that includes potential demands

(1) Concept

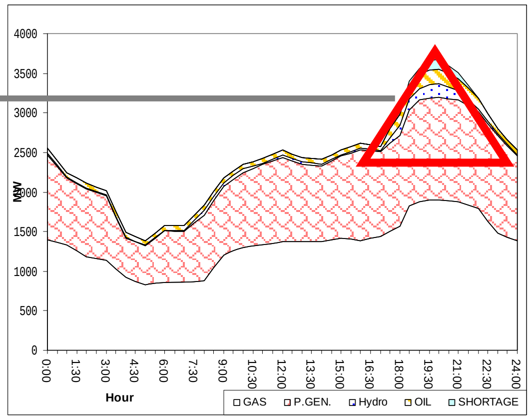
As described in the section above, to forecast the maximum demand that includes potential demands more accurately, it is necessary to theoretically estimate the load curve from daily operation data while placing focus on seasonal variation characteristics of the daily load curve and the rotational outage.

As shown in the figures below, rotational outage occurs relatively less frequently on weekends and holidays in winter, and the daily load curve looks very close to the actual peak load (lighting peak). To produce a compound load curve of the base load in summer and the lighting peak in winter, a PSMP Study Team collected and analyzed data from Daily-Generation Reports (PGCB-DGR), which are published on a daily basis by the electricity transmission company PGCB, in the past 16 years.



Source: PGCB Operation Data

Fig. 7-6 Typical load curve in summer



Source: PGCB Operation Data

Fig. 7-7 Typical load curve in winter

(2) Examination flow

The specific examination flow is as shown below.

Step-1: Capture half hourly load data for eastern and western zones from daily report furnished by PGCB for all days in a month;

↓

Step-2: Calculate the total of half hourly load data of both zones

↓

Step-3: Capture half hourly recorded load shedding for all days in a month.

↓

Step-4: Add half hourly recorded load shedding with half hourly load data of each day.

↓

Step-5: Find the Peak load of each day by taking maximum of each day.

↓

Step-6: Determine the base load of each day considering load at 6.00pm from April to October and load at 5.00pm from November to March. Then calculate incremental peak over base for each day by subtracting the base load from the corresponding Peak Load.

↓

Step-7: Determine the maximum base load and maximum peak over base for each month by taking the maximum of all days in a month.

↓

Step-8: Add maximum incremental peak over base of the fiscal year with maximum base load of that fiscal year to determine the estimated Peak Load of that fiscal year.

Source: PSMP Study Team

Fig. 7-8 Examination flow

(3) Result of examination

The analysis result is as shown in the table below. For the assumed maximum load in 2009, the analysis result is as shown in the table below. The actual recorded maximum load in fiscal 2009 was 4162 MW. However, the assumed maximum load, to which the base load of 4150 MW and the potential peak load of 1500 MW are added, is approximately 5500 MW, and the load factor is 57%.

Therefore, the annual average growth rate in the 16-year period from 1994 to 2009 is inferred to be 7.4%.

Consequently, in performing long-term demand forecast until 2030, PSMP Study Team adopt 5500 MW, which was derived in this examination, as the starting value for fiscal 2009.

Table 7-5 Estimated maximum load in 1994–2009

Fiscal year	Estimated Gross Base Load (MW)	Est Gross Peak over Base Load (MW)	Estimated Gross Peak Load (MW)	Actual Net/Gross	Estimated Net Peak Load (MW)	Growth (%)	Recorded Net Peak load (MW)	Growth (%)
1994	1,350	650	2,000	0.945	1,890		1,772	
1995	1,450	700	2,150	0.945	2,032	7.5%	1,862	5.1%
1996	1,550	750	2,300	0.945	2,174	7.0%	1,972	5.9%
1997	1,725	800	2,525	0.945	2,386	9.8%	1,998	1.3%
1998	1,900	850	2,750	0.945	2,599	8.9%	2,019	1.1%
1999	2,100	900	3,000	0.951	2,853	9.8%	2,330	15.4%
2000	2,200	950	3,150	0.952	2,999	5.1%	2,538	8.9%
2001	2,300	1,025	3,325	0.956	3,179	6.0%	2,904	14.4%
2002	2,450	1,100	3,550	0.956	3,394	6.8%	3,110	7.1%
2003	2,600	1,200	3,800	0.964	3,663	7.9%	3,333	7.2%
2004	2,850	1,250	4,100	0.964	3,952	7.9%	3,491	4.7%
2005	3,097	1,379	4,476	0.962	4,306	8.9%	3,713	6.4%
2006	3,600	1,413	5,013	0.959	4,808	11.7%	3,782	1.9%
2007	4,050	1,063	5,113	0.96	4,908	2.1%	3,717	-1.7%
2008	4,190	1,484	5,674	0.961	5,453	11.1%	4,130	11.1%
2009	4,150	1,500	5,650	0.962	5,435	-0.3%	4162	0.8%
Annual Average Load Growth Rate						7.4%		

Source: PSMP Study Team

Table 7-6 Estimated generated power energy and load factor in 1994–2009

Fiscal year	Recorded Net Energy Generation (GWh)	Recorded Load Shedding (GWh)	Estimated Load Shedding (GWh)	Est. Net Energy Generation (GWh)	Recorded Net Peak Load (MW)	Rec. Max. Load Shedding (MW)	Est.Load Shedding (MW)	Estimated Net Peak Load (MW)	Estimated Load Factor (%)
1994	9,221	99	149	9,370	1,772	540	118	1,890	56.6%
1995	10,166	87	131	10,297	1,862	537	170	2,032	57.9%
1996	10,833	500	750	11,583	1,972	545	202	2,174	60.8%
1997	11,243	550	825	12,068	1,998	674	388	2,386	57.7%
1998	12,194	516	774	12,968	2,019	711	580	2,599	57.0%
1999	13,638	264	396	14,034	2,330	774	523	2,853	56.2%
2000	14,739	121	182	14,921	2,538	536	461	2,999	56.8%
2001	16,254	119	179	16,433	2,904	663	275	3,179	59.0%
2002	17,445	70	105	17,550	3,110	367	284	3,394	59.0%
2003	18,422	69	104	18,526	3,333	468	330	3,663	57.7%
2004	20,062	147	221	20,283	3,491	694	461	3,952	58.6%
2005	21,162	258	387	21,549	3,713	895	593	4,306	57.1%
2006	22,741	810	1,215	23,956	3,782	1,342	1,026	4,808	56.9%
2007	22,783	1,251	1,877	24,660	3,717	1,427	1,191	4,908	57.3%
2008	24,311	1,286	1,929	26,240	4,130	1,140	1,323	5,453	54.9%
2009	25,621	1,372	2,058	27,679	4,162	1,538	1,273	5,435	58.1%

Source: Commercial Operation Statistics, BPDB

(4) Long-term demand forecasts until fiscal 2030

As with PSMP, the result of forecasting the demand through single regression analysis of the GDP and the generated power energy in terms of fiscal year 2030 is approximately 30 GW[1] in the base case, approximately 40 GW in the high case, and approximately 20 GW in the low case,

7.4 PSMP 2010 power demand forecast using the energy intensity method

7.4.1 Examination flow

In general, there is a certain tendency in the relation between economic growth and power consumptions. In an economic situation where the GDP per capita is approximately several hundred dollars, the electricity intensity significantly increases with the economic growth. However, if the GDP per capita exceeds approximately 1,000 dollars, the growth rate of electricity intensity with the economic growth slows down. As economic growth advances as in advanced counties, the electricity intensity hardly increases even if the GDP per capita grows. Major backgrounds for such a tendency in various countries include the following.

- With economic growth, the mainstay industry shifts from the industrial to the service industry.
- With the progress or reform of technologies, or the development/introduction of highly efficient fuels, the energy consumption efficiency of the industry increases.

Focusing on such a relation between economic growth and energy intensity, this section verifies the result of long-term demand forecasts in Bangladesh by referring to the process of economic growth in neighboring countries. Specifically, PSMP Study Team will first incorporate the records of neighboring countries and then perform verification by setting an approximation formula for estimating electricity intensity based on the GDP per capita and comparing this with the maximum load calculated using the conventional method of PSMP 2006 and PSMP 2010. The major steps of the verification are as follows.

- Setting an approximation formula for electricity intensity through regression analysis
- Calculating the GDP per capita until 2030 based on the economic growth forecasts of Bangladesh
- Calculating the power consumptions and the maximum load until 2030 by calculating electricity intensity until 2030 using the approximation formula, and multiplying the electricity intensity by the GDP
- Comparing the above calculation result with the forecast values obtained using the conventional method

7.4.2 Setting an approximation formula

For regression analysis, the log-quadratic approximation method is adopted. This method is designed to approximate electric intensity using a log-quadratic function with the GDP per capita as the parameter, as indicated below. Although the records of the respective countries show similar forms with this method, they have different positions. Therefore, in regression analysis, PSMP Study Team perform regression calculation using dummy variables so that the intercepts represent unique values of the respective counties, while the coefficients of GDP per capita are common for both the first-order and second-order terms.

$$e = \alpha + \beta y + \chi y^2 \left(+ \lambda_1 D_1 + \lambda_2 D_2 + \ldots + \lambda_{n-1} D_{n-1} \right)$$

e : power consumption per GDP 1 dollar

y : GDP per capita of population (logarithm)

D_i : dummy variable of foreign country i

n : number of foreign countries to be referred to

1 Value reported at the first seminar held during the third field survey.

7.4.3 Conditions for multiple regression analysis

The conditions used for analysis are as indicated in the table below.

Table 7-7 Conditions for multiple regression analysis

Fiscal Year	GDP (million Taka, at 1995-96 constant price)	GDP (million USD, at 2000 constant price)	GDP per capita USD, at 2000 constant price)	GDP Growth Rate	Population (mill, No.)	Total Sales (GWh)	Per Capita Consumption(kWh)	Consumption per GDP(Wh)
1994	1,515,139	33,659	290		116.2	6,149	64.08	0.221
1995	1,589,762	35,316	301	4.9%	117.4	6,935	71.32	0.237
1996	1,663,240	36,949	312	4.6%	118.6	7,454	75.88	0.243
1997	1,752,847	38,939	325	5.4%	119.7	7,822	78.89	0.243
1998	1,844,478	40,975	324	5.2%	126.5	8,382	80.44	0.248
1999	1,934,291	42,970	336	4.9%	128.0	9,305	88.69	0.264
2000	2,049,276	45,524	350	5.9%	130.0	10,083	95.85	0.274
2001	2,157,353	47,925	363	5.3%	132.0	11,409	106.08	0.292
2002	2,252,609	50,042	374	4.4%	134.0	12,535	113.80	0.305
2003	2,371,006	52,672	395	5.3%	133.4	13,877	122.43	0.310
2004	2,501,813	55,974	413	5.5%	135.4	15,332	133.11	0.322
2005	2,669,740	61,400	447	6.7%	137.4	16,338	139.68	0.313
2006	2,846,726	65,400	469	6.6%	139.5	18,128	150.22	0.320
2007	3,029,709	69,600	493	6.4%	141.2	18,776	149.98	0.304
2008	3,217,855	73,922	517	6.2%	143.0	20,415	158.20	0.306
2009	3,406,524	78,256	540	5.9%	144.8	21,955	165.32	0.306
2010	3,644,981	83,734	564	7.0%	148.5			
2011	3,900,129	89,596	589	7.0%	152.2			
2012	4,173,138	95,867	615	7.0%	155.9			
2013	4,465,258	102,578	643	7.0%	159.6			
2014	4,777,826	109,759	672	7.0%	163.3			
2015	5,112,274	117,442	703	7.0%	167.0			
2016	5,470,133	125,663	736	7.0%	170.7			
2017	5,853,042	134,459	771	7.0%	174.4			
2018	6,262,755	143,871	808	7.0%	178.1			
2019	6,701,148	153,942	847	7.0%	181.8			
2020	7,170,229	164,718	888	7.0%	185.6			
2021	7,672,145	176,248	940	7.0%	187.4			
2022	8,209,195	188,586	996	7.0%	189.3			
2023	8,783,838	201,787	1,055	7.0%	191.2			
2024	9,398,707	215,912	1,118	7.0%	193.1			
2025	10,056,617	231,026	1,185	7.0%	195.0			
2026	10,760,580	247,197	1,257	7.0%	196.7			
2027	11,513,820	264,501	1,334	7.0%	198.3			
2028	12,319,788	283,016	1,416	7.0%	199.9			
2029	13,182,173	302,828	1,502	7.0%	201.6			
2030	14,104,925	324,025	1,595	7.0%	203.2			

Source: PSMP Study Team

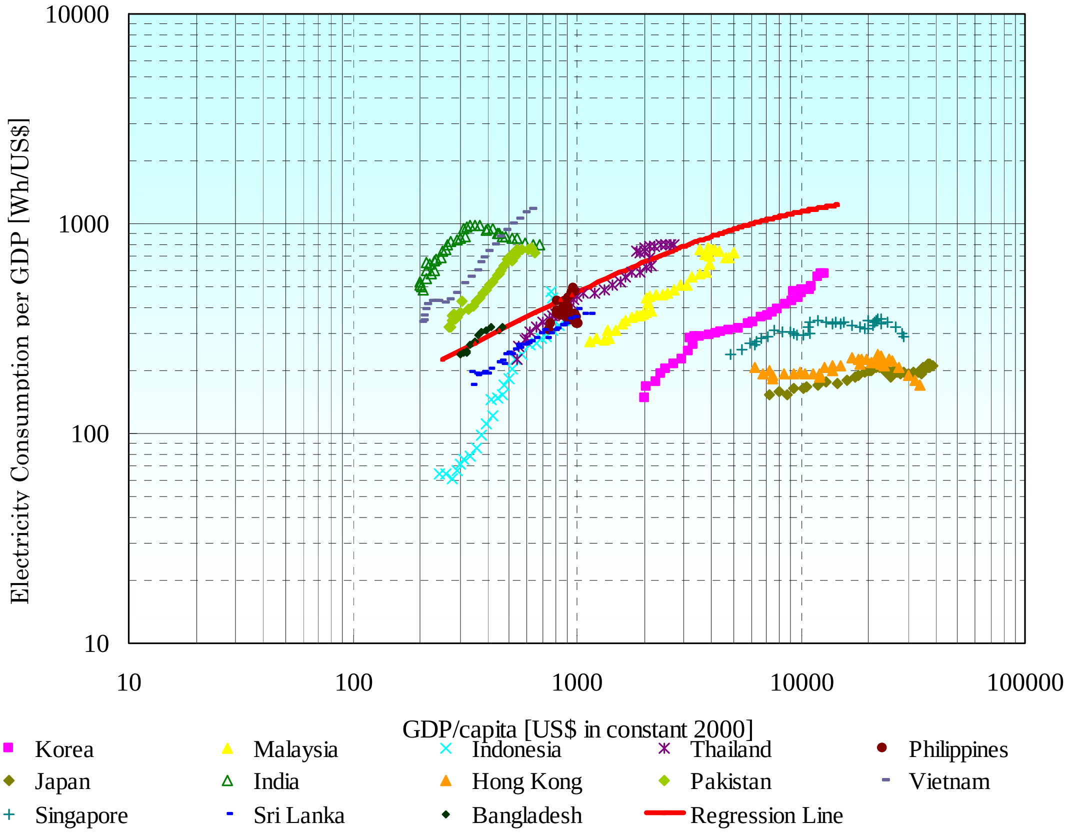
7.4.4 Result of regression analysis

The result of regression analysis is provided in the table below. The second coefficient of GDP per capita is a negative value, as assumed (the increase in electricity intensity slows down with the increase in GDP per capita). By countries, the dummy variable coefficients of advanced countries such as Japan, Singapore and Hong Kong are lower than those of other countries. This means that the regression curves of these countries are located lower than those of other countries. Overall, since the P-value is sufficiently small for any of the variables and the determination coefficient adjusted for the degrees of freedom is high at 0.83, it is judged that a favorable regression result was obtained.

Table 7-8 Result for multiple regression analysis

	Coefficient	Standard Error	t-Value	P-value	Lower 95%	Upper 95%	Lower 95%	Upper 95%
Intercept	-1.179	0.216	-5.449	0.000	-1.604	-0.754	-1.604	-0.754
LOG(GDP.pc)	1.850	0.137	13.508	0.000	1.581	2.119	1.581	2.119
LOG(GDP.pc^2)	-0.200	0.021	-9.676	0.000	-0.241	-0.160	-0.241	-0.160
Vietnam	0.542	0.029	18.792	0.000	0.485	0.599	0.485	0.599
Korea	-0.410	0.046	-8.868	0.000	-0.501	-0.319	-0.501	-0.319
Malaysia	-0.115	0.041	-2.838	0.005	-0.195	-0.035	-0.195	-0.035
Indonesia	-0.060	0.031	-1.971	0.049	-0.121	0.000	-0.121	0.000
Japan	-0.788	0.061	-12.980	0.000	-0.908	-0.669	-0.908	-0.669
Thailand	0.069	0.036	1.931	0.054	-0.001	0.139	-0.001	0.139
Philippines	0.066	0.034	1.931	0.054	-0.001	0.133	-0.001	0.133
India	0.690	0.029	23.985	0.000	0.634	0.747	0.634	0.747
Hong Kong	-0.737	0.057	-13.008	0.000	-0.848	-0.626	-0.848	-0.626
Pakistan	0.436	0.029	14.793	0.000	0.378	0.494	0.378	0.494
Singapore	-0.540	0.054	-9.963	0.000	-0.647	-0.434	-0.647	-0.434
Sri Lanka	0.016	0.031	0.501	0.617	-0.045	0.076	-0.045	0.076
China	0.704	0.030	23.656	0.000	0.645	0.762	0.645	0.762
Nepal	0.199	0.030	6.580	0.000	0.140	0.259	0.140	0.259

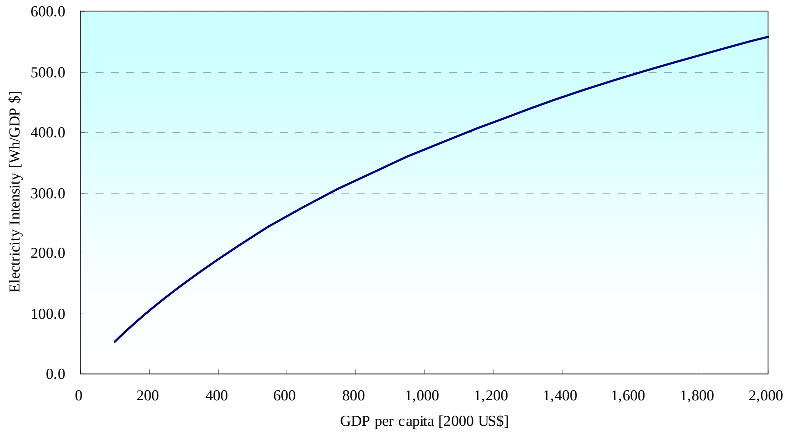
Source: PSMP Study Team



Source: IEA Energy Balance and IMF Economic data base, 2009

Fig. 7-9 Relation between GDP per capita and energy intensity (comparison with neighboring countries)

The relation between the GDP per capita and the electricity intensity in Bangladesh based on this regression result is indicated in the figure below. Reflecting case examples in other countries, the figure represents a tendency that as the GDP per capita exceeds approximately 1,000 dollars, the increase in electricity intensity slows down.



Source: PSMP Study Team

Fig. 7-10 Result of analysis in Bangladesh

7.4.5 Long-term demand forecasts until FY 2030

This section compares the base cases of PSMP 2006 and PSMP 2010 in terms of FY 2009 and FY 2025. In terms of FY 2009, PSMP 2006 forecasts a value approximately 10% higher than the present potential demand of 5500 MW. However, in terms of FY 2025, PSMP 2010 forecasts a value approximately 15% higher. This means that this evaluation method may result in a large variation in long-term forecasts depending on the gradient obtained through regression analysis of GDP and generated power energy and on the GDP scenario setting.

If power demand forecast is performed using the energy intensity method, it forecasts long-term demands based on the relation between economic growth and energy intensity by referring to the process of economic growth in neighboring countries. Therefore, it is possible to make a relative comparison, and a model in which the growth rate when economic growth has reached a certain level slows down is assumed. As a result, long-term demands are suppressed to a more realistic level than the conventional single regression analysis method with the GDP.

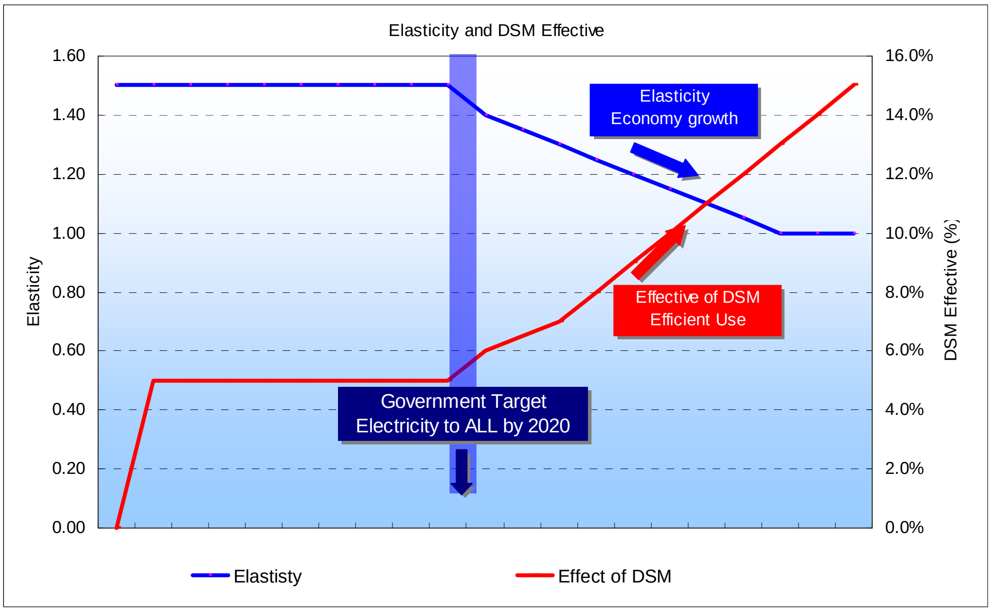
In terms of FY2025, the forecast value using the energy intensity method is almost equal to the values of PSMP 2006 and the gas master plan. In addition, in comparison to the conventional method, it is approximately 10% lower in terms of FY 2030. In this MP, the demand is calculated using a method that takes into account the relation between economic growth and energy intensity.

7.5 Demand forecast based on government policy

The Bangladesh government declares the policy "electricity to all by 2021", targeting the electrification rate 100% achievement and 600kWh per capita is set to the catchphrase, and the government develops the coherent strategy of the power supply plan for the government targets.

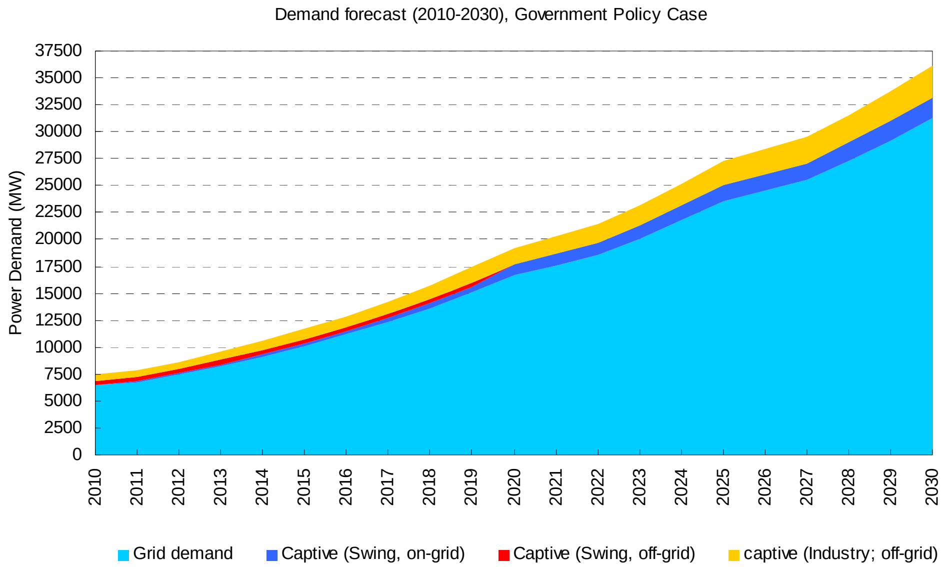
In this Master Plan, power demand forecast is also determined to attain those government targets, and power supply plan is developed in line with the demand forecast.

At the same time, the power load reduction strategy by DSM is included from the viewpoint of the power supply investment reduction in this scenario.



Source: PSMP Study Team

Fig. 7-11 Load factor reduction scenario by introducing DSM



Source: PSMP Study Team

Fig. 7-12 Government policy scenario for power demand forecast

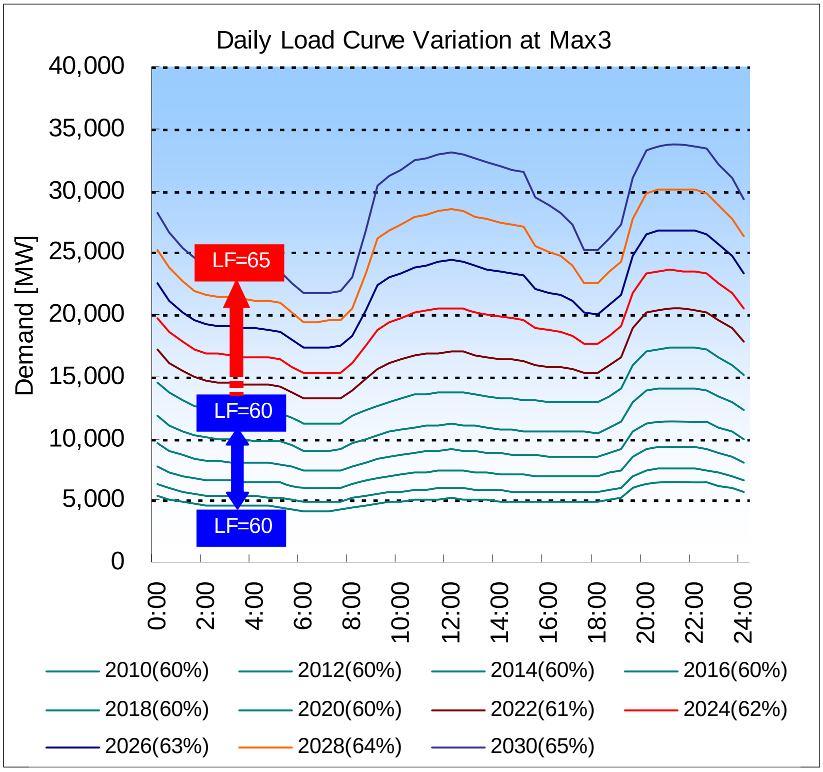
Table 7-9 Result of demand forecast based on government policy

FY	GDP growth rate	Elasticity	Effect of DSM	Electricity growth rate	Total Demand without DSM	Total Demand with DSM	Off-grid captive demand	Grid System Demand with DSM for MP
Unit	[%]	-	[%]	[%]	[MW]	[MW]	[MW]	[MW]
2010	5.5%	1.50	5.0%		7,454	7,454	1,000	6,454
2011	6.7%	1.50	5.0%	4.5%	8,203	7,793	1,027	6,765
2012	7.0%	1.50	5.0%	10.5%	9,064	8,611	1,093	7,518
2013	7.0%	1.50	5.0%	10.5%	10,016	9,515	1,166	8,349
2014	7.0%	1.50	5.0%	10.5%	11,068	10,514	1,246	9,268
2015	7.0%	1.50	5.0%	10.5%	12,230	11,618	1,335	10,283
2016	7.0%	1.50	5.0%	10.5%	13,514	12,838	1,433	11,405
2017	7.0%	1.50	5.0%	10.5%	14,933	14,186	1,542	12,644
2018	7.0%	1.50	5.0%	10.5%	16,501	15,676	1,662	14,014
2019	7.0%	1.50	5.0%	10.5%	18,233	17,322	1,794	15,527
2020	7.0%	1.40	6.0%	8.6%	20,020	18,819	1,515	17,304
2021	7.0%	1.35	6.5%	8.9%	21,912	20,488	1,649	18,838
2022	7.0%	1.30	7.0%	8.5%	23,906	22,233	1,790	20,443
2023	7.0%	1.25	8.0%	7.6%	25,998	23,918	1,925	21,993
2024	7.0%	1.20	9.0%	7.2%	28,182	25,645	2,064	23,581
2025	7.0%	1.15	10.0%	6.9%	30,450	27,405	2,206	25,199
2026	7.0%	1.10	11.0%	6.5%	32,795	29,187	2,349	26,838
2027	7.0%	1.05	12.0%	6.1%	35,205	30,981	2,494	28,487
2028	7.0%	1.00	13.0%	5.8%	37,670	32,773	2,638	30,134
2029	7.0%	1.00	14.0%	5.8%	40,306	34,664	2,790	31,873
2030	7.0%	1.00	15.0%	5.8%	43,128	36,659	2,951	33,708

Source: PSMP Study Team

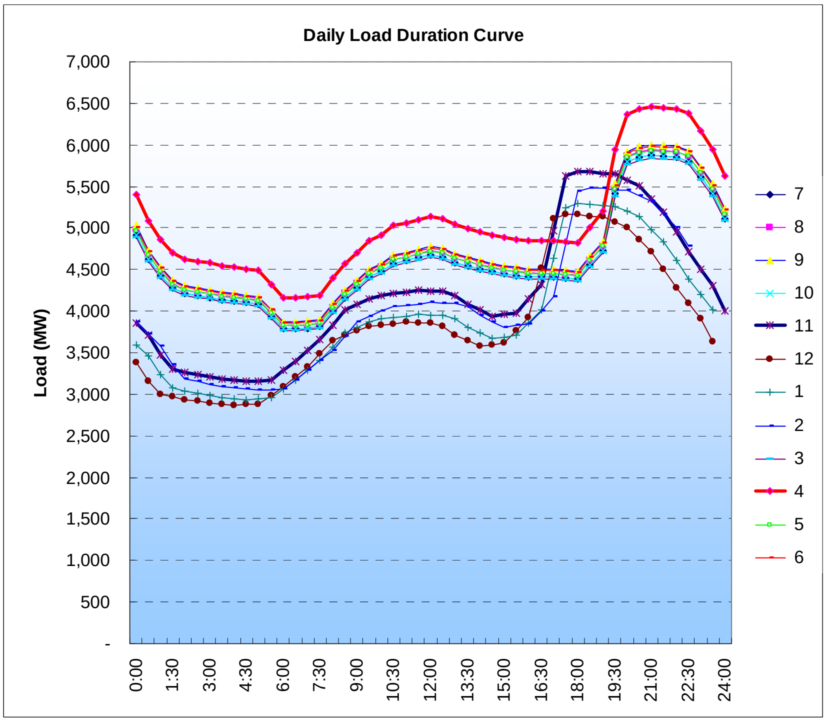
7.6 Setting of load factor

The load factor is set at 60% constant for ten years from 2010 to 2020, and it improves by 0.5% every year afterwards, reaching at 65% by 2030.



Source: PSMP Study Team

Fig. 7-13 Load factor scenario

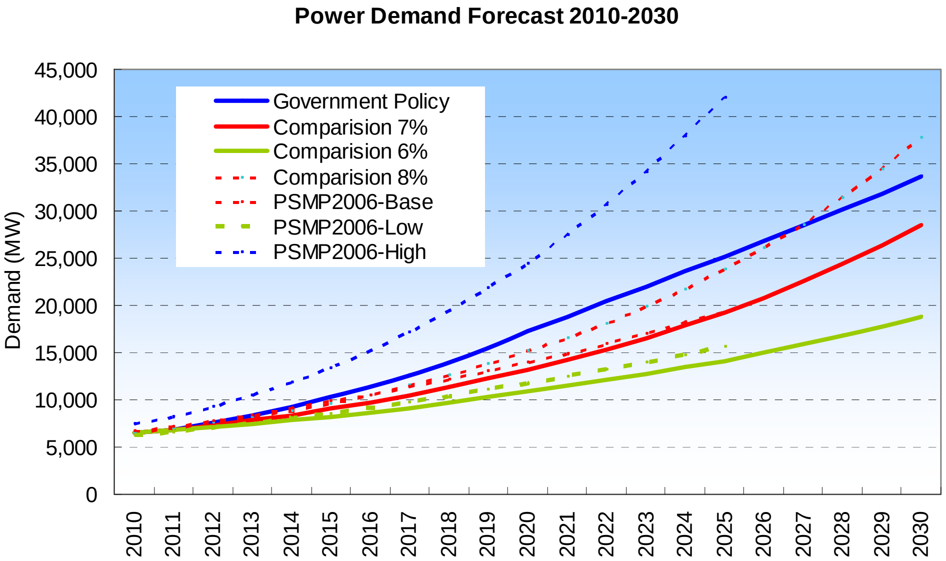


Source: PSMP Study Team

Fig. 7-14 Government policy scenario for power demand forecast

7.7 Adopted scenario of the power demand forecast

The adoption scenarios of the power demand forecast in this MP are as shown in the figure below. The figure indicates three scenarios; (i) GDP 7% scenario and (ii) GDP 6% scenario, based on energy intensity method, and (iii) government policy scenario.



Source: PSMP Study Team

Fig. 7-15 Three scenarios for power demand forecast

Table 7-10 Result of demand forecast (3 scenario)

FY	Government Policy Scenario		Comparison GDP7% Scenario		Comparison GDP6% Scenario	
	Peak Demand [MW]	Generation [GWH]	Peak Demand [MW]	Generation [GWH]	Peak Demand [MW]	Generation [GWH]
2010	6,454	33,922	6,454	33,922	6,454	33,922
2011	6,765	35,557	6,869	36,103	6,756	35,510
2012	7,518	39,515	7,329	38,521	7,083	37,228
2013	8,349	43,882	7,837	41,191	7,436	39,084
2014	9,268	48,713	8,398	44,140	7,819	41,097
2015	10,283	54,047	9,019	47,404	8,232	43,267
2016	11,405	59,945	9,705	51,009	8,680	45,622
2017	12,644	66,457	10,463	54,994	9,165	48,171
2018	14,014	73,658	11,300	59,393	9,689	50,925
2019	15,527	81,610	12,224	64,249	10,255	53,900
2020	17,304	90,950	13,244	69,610	10,868	57,122
2021	18,838	99,838	14,249	75,517	11,442	60,640
2022	20,443	109,239	15,344	81,992	12,056	64,422
2023	21,993	118,485	16,539	89,102	12,713	68,490
2024	23,581	128,073	17,840	96,893	13,416	72,865
2025	25,199	137,965	19,257	105,432	14,167	77,564
2026	26,838	148,114	20,814	114,868	14,979	82,666
2027	28,487	158,462	22,509	125,209	15,848	88,156
2028	30,134	168,943	24,353	136,533	16,776	94,053
2029	31,873	180,089	26,358	148,928	17,768	100,393
2030	33,708	191,933	28,537	162,490	18,828	107,207

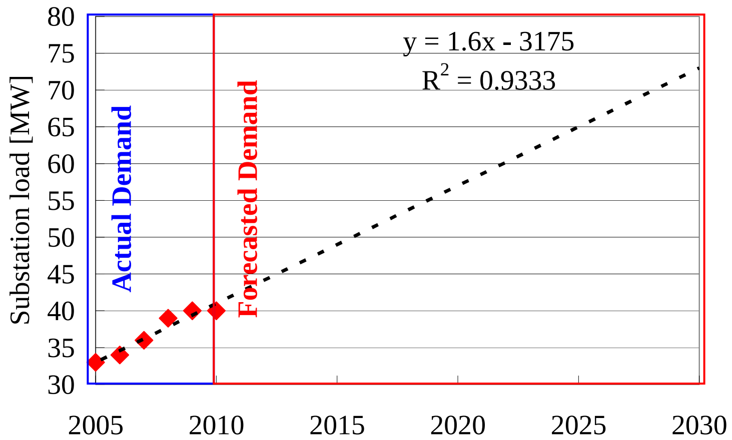
Source: PSMP Study Team

7.8 Each substation load forecast

7.8.1 Methodology

Each substation load forecast is carried out by the following methods.

- Maximum load data at each 132/33kV substation is collected from the past six years (FY 2005-2010).
- Regression analyses by 2030 are carried out based on the aforementioned data.
- The load forecast at each 132/33kV substation is estimated by using the regression equation, and proportionally distributed via the microanalysis power demand.



Source: PSMP Study Team

Fig. 7-16 Basic concept for substation load forecast

7.8.2 Analysis of the historical substation load data

The maximum load data at each 132/33kV substation over the period FY 2005-2010 is presented in Table 7-11. As for the calculation of the slope, only the year of increasing maximum load (shaded area) was considered. Meanwhile, the regional average slope was adopted for the substation of the no increased maximum load over the period due to the substation expansion etc.

Table 7-11 Maximum load data at each 132/33kV substation (2005-2010)

East or West	Region	Substation	Substation load (MW)						Slope Rev
			2005	2006	2007	2008	2009	2010	
East	Southern	Kaptai	5	5	7.5	7.5	8	5	0.85
East	Southern	Chandraghona	26.6	29.7	32.2	32.2	19.4	22.6	2.80
East	Southern	Hathazari	60	63	66	66	60	62	2.10
East	Southern	Madunaghat	0	42	42	42	52	52	3.00
East	Southern	Sikalbaha	37.1	37.1	37.1	37.1	34	34	2.91
East	Southern	Dohazari	38	42	42	49	52	58	3.91
East	Southern	Cox’s bazar	33	34	36	39	40	40	1.60
East	Southern	Halishahar	108	114	114	114	109	109	1.80
East	Southern	Agrabad	0	0	0	0	0	0	2.91
East	Southern	Kulsi	119	132	132	132	118	118	3.90
East	Southern	Baraulia	0	60	65	65	58	66	2.50
East	Southern	Baroirhat, Ctg	0	0	0	0	0	0	2.91
East	Southern	Feni	40	50	54	54	60	65	4.43
East	Southern	Chowmuhani	68	0	68	68	65	70	0.30
East	Southern	Ramganj	0	0	0	0	0	0	2.91
East	Southern	Comilla (N)	35	35	35	37	58	59	5.46
East	Southern	Comilla (S)	89	98	98	98	100	122	4.89

East or West	Region	Substation	Substation load (MW)						Slope Rev
			2005	2006	2007	2008	2009	2010	
East	Southern	Chouddagram	0	68	0	0	0	0	2.91
East	Southern	Chandpur	41	42	0	51	47	62	5.50
East	Southern	Rangamati	0	0	0	0	0	0	2.91
East	Southern	Khagrachari	0	0	0	0	0	0	2.91
East	Southern	Julda	0	0	15	16	15	18	0.80
East	Southern	Bakulia	0	56	72	73	81	82	6.10
East	Southern	Shahmirpur	0	0	0	0	0	0	2.91
East	Southern	Abul Khair Steel Mills	7	8	12.9	12.9	10	19.2	1.91
East	Southern	Daudkandi	0	124	0	124	0	0	2.91
West	Western	Goalpara	7.4	7.4	7.4	7.4	4	5	2.22
West	Western	Khulna(C)	99	99	99	99	90	90	2.22
West	Western	Gallamari	0	0	0	0	0	36	2.22
West	Western	Noapara	24	24	31.2	32.6	32	35	2.30
West	Western	Jessore	87	93	93	93	80	102	1.03
West	Western	Jhenaidah	64	64	64	64	63	72	1.06
West	Western	Magura	0	0	0	0	0	0	2.22
West	Western	Kustia(Bottail)	60	60	60	68	58	72	1.77
West	Western	Chuadanga	0	0	0	0	0	0	2.22
West	Western	Bheramara&GKProject	22	25.8	25.8	25.8	26	30.6	1.25
West	Western	Faridpur	46.2	49.2	49.2	57	56	58.6	2.58
West	Western	Madaripur	53	65.2	65.2	65.2	54.4	58	3.66
West	Western	Barisal	56	58	58	58	62	66.5	1.84
West	Western	Barisal (N)	58	0	0	0	0	0	2.22
West	Western	Bhandaria	16	17	18	22	20	31	2.51
West	Western	Bagerhat	28.5	28.5	34	56	30	37.4	2.03
West	Western	Mongla	19	19	19	24	25	18.2	1.70
West	Western	Patuakhali	33.2	33.2	0	34	41	42.5	4.25
West	Western	Gopalganj	0	13	13	16.6	21.6	21.6	2.58
West	Western	Satkhira	0	0	28	33.8	33.6	36.5	2.53
East	Central	Ashuganj	44.3	44.3	58	58	52	53	1.90
East	Central	Kishoreganj	33	36	40	40.5	42	47	2.53
East	Central	Mymensingh	71	77	80	80	80	81	1.69
East	Central	Bhaluka	0	0	0	0	0	0	2.91
East	Central	Jamalpur	41.5	55	62	78	71	78	7.04
East	Central	Sherpur	109	0	0	0	113	0	2.91
East	Central	Netrokona	26.8	26.8	31	44.5	33	33	1.80
East	Central	Shahjibazar	29	29	30	30	28	46	2.34
East	Central	Sreemangal	30	31	34	34	34	36	1.11
East	Central	Fenchuganj	26	26	26	26	31	34	1.57
East	Central	Sylhet	89	92	95	106	111	127	7.37
East	Central	Sylhet New	0	0	0	0	0	0	2.91
East	Central	Chhatak	24	25	25	30	29	33	1.77
East	Central	Brahmanbaria	0	0	0	0	0	0	2.91
West	Northern	Ishurdi	35.3	35.3	21	21	26.4	26.4	2.16
West	Northern	Natore	34	38	41	46	43	58	4.00
West	Northern	Rajshahi	54.7	54.7	57	66.5	71	78.5	5.07
West	Northern	Rajshahi New	0	0	0	0	0	0	2.91
West	Northern	Ch. Nowabganj	49	51	54	58	62	65	3.34
West	Northern	Pabna	37	44	48	48	48	46	1.63
West	Northern	Shahjadpur	27.2	27.2	28	35	39	41	3.18
West	Northern	Sirajganj	34.5	36.5	36.5	37	44	69.5	5.66
West	Northern	Bogra	74	74	82	93	101.5	113	8.24
West	Northern	Noagaon	49	78	78	86	90	85	6.40
West	Northern	Palashbari	28.8	28.8	30.8	30.8	46.6	43	3.55
West	Northern	Rangpur	41	42	53.2	57	58.8	62.3	4.59
West	Northern	Lalmonirhat	24	27	28	32	31	45	3.46

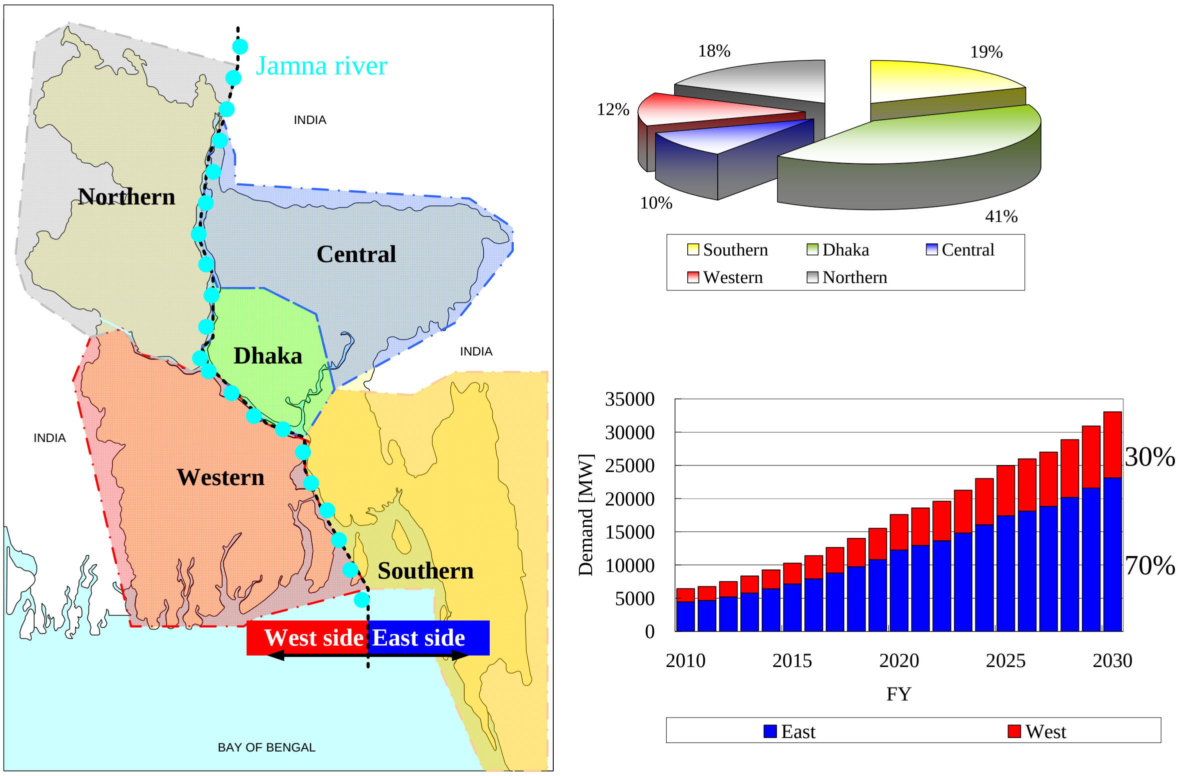
East or West	Region	Substation	Substation load (MW)						Slope Rev
			2005	2006	2007	2008	2009	2010	
West	Northern	Saidpur	54	64	64	64	57	60	0.26
West	Northern	Purbasadipur	29.7	37.2	37.5	39	41	53	3.70
West	Northern	Barapukuria	0	0	0	14	24	41	2.91
West	Northern	Panchaghar	0	0	34	0	0	0	2.91
West	Northern	Joypurhat	85	0	0	0	0	0	2.91
West	Northern	Thakurgaon	36.5	39	34	55	61	62	6.13
West	Northern	Niamatpur	0	0	0	0	0	0	2.91
East	Dhaka	Haripur	70	78	83	83	66	56	4.40
East	Dhaka	Siddhirganj	98	102	89	89	102	102	0.57
East	Dhaka	Maniknagar	64	67	67	70	64	58	1.80
East	Dhaka	Ullon	111	111	111	111	75	69	2.91
East	Dhaka	Moghbazar	111	112	112	119	110	106	2.91
East	Dhaka	Dhanmondi	0	0	124	0	147	143	2.91
East	Dhaka	Narinda	107	107	107	107	90	90	2.91
East	Dhaka	BangaBhaban	43	72	72	72	57	57	2.91
East	Dhaka	Shyampur	0	118	128	128	0	113	2.91
East	Dhaka	Madanganj	63	80	80	80	54	58	2.91
East	Dhaka	Hasnabad	100	107	107	119	91	111	5.70
East	Dhaka	Mirpur	105	116	118	121	122	122	3.03
East	Dhaka	Kalyanpur	0	134	134	138	156	156	6.60
East	Dhaka	Basundhara	144	145	145	145	107	116	9.00
East	Dhaka	Tongi	115	115	115	115	55	60	5.00
East	Dhaka	NewTongi	0	0	0	0	56	58	2.00
East	Dhaka	Kabirpur	134	93	97	112	97	98	9.50
East	Dhaka	Manikganj	52	70	70	70	60	65	5.40
East	Dhaka	Tangail	50	58	58	66	84	86	7.60
East	Dhaka	Ghorasal	75	75	75	84	50	78	2.70
East	Dhaka	Joydebpur	87	87	99	100	105	78	4.90
East	Dhaka	Bhulta	61	65	65	65	62	53	1.20
East	Dhaka	Uttara	0	12	67.3	67.3	75.7	97.1	9.78
East	Dhaka	Cantonment	0	0	42	0	0	0	2.91
East	Dhaka	Nabinagar(Md.pur)	69	0	0	0	0	0	2.91
East	Dhaka	OldAirport	0	0	0	0	0	0	2.91
East	Dhaka	DhakaUniversity	118	0	0	0	0	0	2.91
East	Dhaka	Kamrangirchar	0	0	0	45	56.8	73.6	14.30
East	Dhaka	Madartek	42	0	0	0	0	0	2.91
East	Dhaka	Gulshan	0	0	56	77.9	88	79.4	8.03
East	Dhaka	Matuail	0	0	0	23	16.4	40	8.50
East	Dhaka	Sitalakhya	57.4	86	86	86	84.4	70	5.40
East	Dhaka	Meghnaghat	0	0	0	0	0	0	2.91
East	Dhaka	Narsingdi	0	0	0	0	0	0	2.91
East	Dhaka	Savar	0	0	0	0	0	0	2.91
East	Dhaka	Purbachal	0	0	0	0	0	0	2.91
East	Dhaka	Munshiganj	0	0	0	0	0	0	2.91
East	Dhaka	Sreepur	0	0	0	0	0	0	2.91

Source: PGCB

7.8.3 Results of substation load forecast

The regional substation load based on the results of the aforementioned substation load forecast is shown in Fig. 7-17. The substation load of Dhaka region is approximately 40%, which is the largest out of the five regions. Therefore, power supply from other regions to the Dhaka region is necessary.

In addition, the substation load of the east region is approximately 70%. If the amount of the power generation is equally located in both the east and west, the power flow from the west to the east will be approximately 20%. Since the Jamuna River is separated into east and west in Bangladesh, a huge amount of money will be invested to construct the river-crossing transmission line. Therefore, it is important that the power development plan be consistent with the regional load balance.



Source: PSMP Study Team

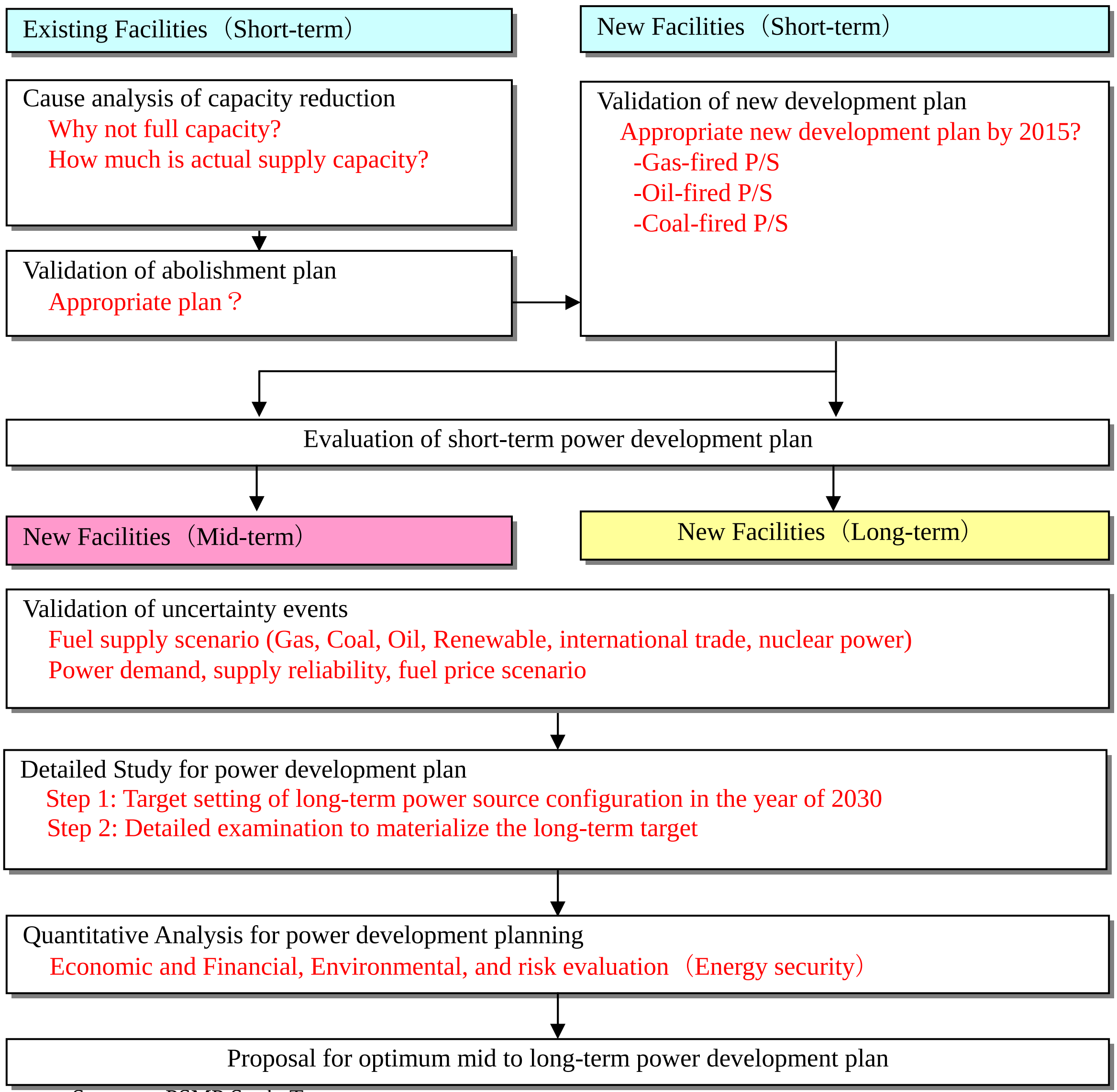
Fig. 7-17 Demand forecast by the each substation demand forecast

Chapter 8 Power Development Plan

8.1 Discussion flow for power development plan

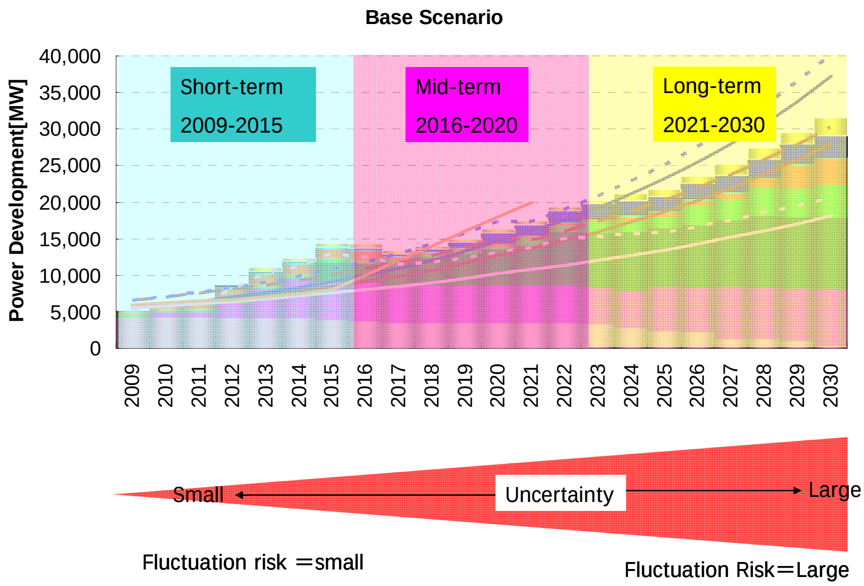
8.1.1 Flow diagram

In formulating the long-term power development plan, it is important to review the low uncertainty events which such as existing facility conditions and plan for the short term as a foundation and to build up to the mid to long-term which has a high uncertainty under the short term plan. The specific flow is depicted below.



Source: PSMP Study Team

Fig. 8-1 Flow Diagram for power development planning



Source: PSMP Study Team

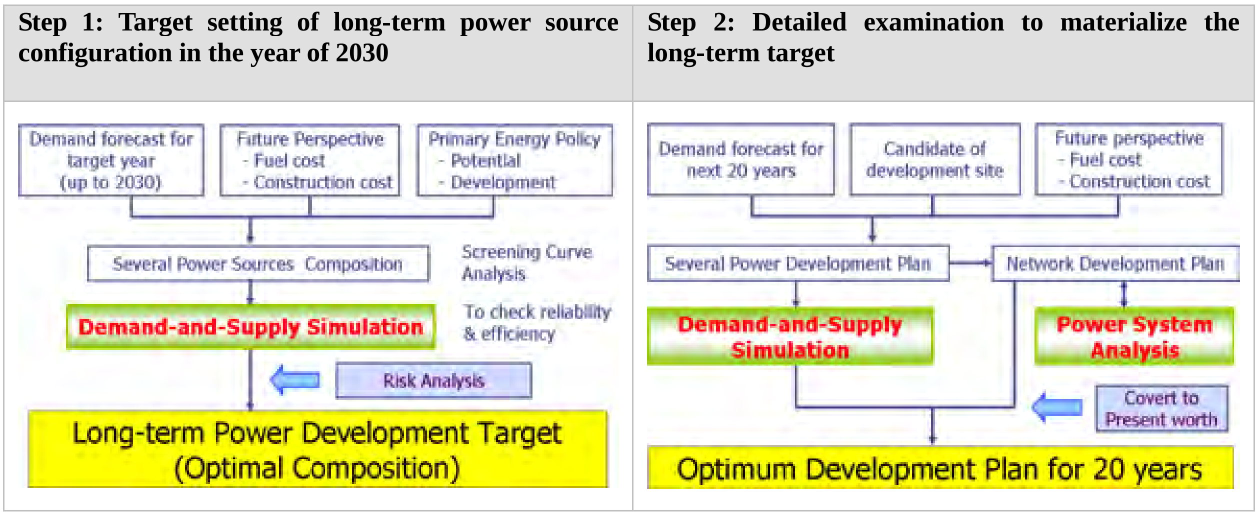
Fig. 8-2 Concept of flow diagram for power development planning

8.1.2 Detailed flow diagram for power development planning

When working out the long-term power development plan, it is necessary to verify the demand and supply of electric power in the future, required reliability for supply, fuel restriction conditions, risks, and costs, and to work out the portfolio to develop a new optimal power source.

The purpose of this chapter is, in order to contribute to the continuous growth of the country Bangladesh, to work out the electric power source plan while effectively using energy, maintaining the environment, and maximizing the energy security, satisfying various conditions required under various restrictions, and minimizing costs required for expansion and operation of the supply systems by 2030.

When working out the optimum power development plan, the two steps below are used:



Source: PSMP Study Team

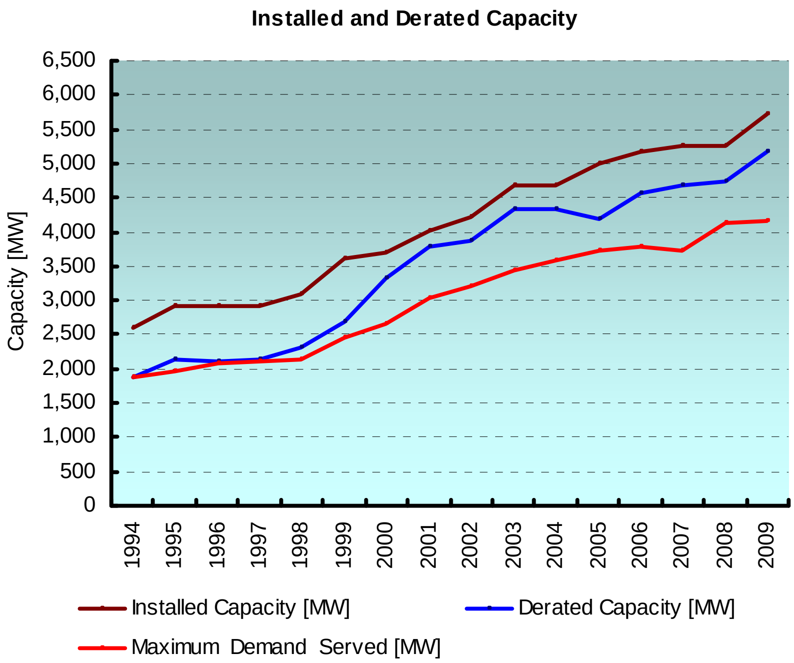
Fig. 8-3 Flow Diagram for power development planning (detail)

8.2 Analysis of the cause of reduced supply

When starting to work out the power source plan, it is necessary to arrange prerequisites and various conditions. Since, in particular, there is a great gap among installed capacity, derated capacity, and maximum demand served in Bangladesh, it is very important to analyze causes of such reduced supply and define the true supply ability of the existing facilities when working out the future power source plan.

8.2.1 Trends in installed capacity, derated capacity, and maximum demand served

The following shows the trends in installed capacity, derated capacity, and maximum demand served in Bangladesh. At the end of FY2009, installed capacity was 5,719 MW, derated capacity was 5,166 MW, and maximum demand served was 4,162 MW. Therefore, they are increased to about 2 to 3 times compared with those in 1994 and the average increase rate in 10 years (2000 to 2009) shows a high growth: 5% to 6%.



Source: BPDB, system planning

Fig. 8-4 Trends in installed capacity, derated capacity, and maximum demand served

The main reason why derated capacity is considered to be lower than installed capacity is because the performance of facilities cannot be shown as designed due to of aging. In addition, a maximum of derated capacity cannot be supplied and the max demand served is actually much lower than derated capacity, due to higher forced and maintenance outages. They seem to be caused by insufficient fuel gas, and facility outage due to maintenance or other reasons, which is as explained in the BPDB Annual Report. Detailed analyses of these differences are described in following part.

8.2.2 Relationship between installed capacity and derated capacity

The following table shows installed capacity and derated capacity of BPDB, IPP, and rental power at the end of June 2009. It shows that the total installed capacity is 5,719 MW, but the actual possible power generation capacity considering aging deterioration is shown as 5,166 MW, i.e., lower by about 10%.

Table 8-1 Installed capacity, derated capacity of each power plant (at 2009.6.30)

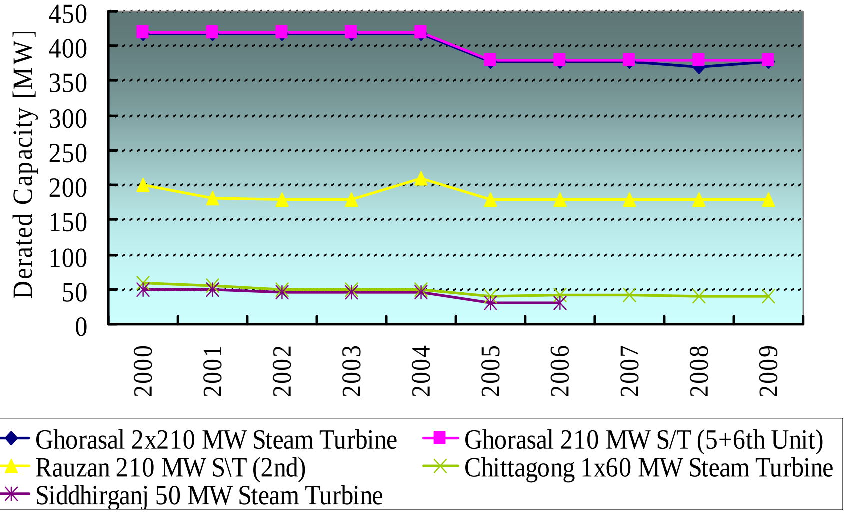
Category			Power Station Name	Fuel	Type	Region	Commissioning	Installed Capacity (MW)	Derated Capacity (MW)
Ex	Pub	BPDB	Ashuganj 64MW ST #1	Gas	ST	EAST	1970/7/17	64	64
Ex	Pub	BPDB	Ashuganj 64MW ST #2	Gas	ST	EAST	1970/7/8	64	64
Ex	Pub	BPDB	Ashuganj 150 MW ST #3	Gas	ST	EAST	1986/12/17	150	100
Ex	Pub	BPDB	Ashuganj 150 MW ST #4	Gas	ST	EAST	1987/5/4	150	140
Ex	Pub	BPDB	Ashuganj 150 MW ST #5	Gas	ST	EAST	1988/3/21	150	140
Ex	Pub	BPDB	Ashuganj CC (GT 1,2,ST)	Gas	CC	EAST	1982-1987	146	98
Ex	Pub	BPDB	Shkalbaha (Chittagong) 60 MW ST	Gas	ST	EAST	1984/4/24	60	40
Ex	Pub	BPDB	Shkalbaha (Chittagong) 28 MW BMGT	Gas	GT	EAST	1986/10/13	28	10
Ex	Pub	BPDB	Fenchuganj CC (GT1,2,ST)	Gas	CC	EAST	1994-1995	97	91
Ex	Pub	BPDB	Ghorasal 55 MW ST #1	Gas	ST	EAST	1974/6/16	55	55
Ex	Pub	BPDB	Ghorasal 55 MW ST #2	Gas	ST	EAST	1976/2/13	55	30
Ex	Pub	BPDB	Ghorasal 210 MW ST #3	Gas	ST	EAST	1986/9/14	210	190
Ex	Pub	BPDB	Ghorasal 210 MW ST #4	Gas	ST	EAST	1989/3/18	210	190
Ex	Pub	BPDB	Ghorasal 210 MW ST #5	Gas	ST	EAST	1994/9/15	210	190
Ex	Pub	BPDB	Ghorasal 210 MW ST #6	Gas	ST	EAST	1999/1/31	210	190
Ex	Pub	BPDB	Haripur 33 MW GT #1	Gas	GT	EAST	1987/10/31	32	32
Ex	Pub	BPDB	Haripur 33 MW GT #2	Gas	GT	EAST	1987/11/15	32	32
Ex	Pub	BPDB	Haripur 33 MW GT #3	Gas	GT	EAST	1987/12/2	32	32
Ex	Pub	BPDB	Karnafuli Hydro #1	Hydro	-	EAST	1962/2/26	40	40
Ex	Pub	BPDB	Karnafuli Hydro #2	Hydro	-	EAST	1962/8/1	40	40
Ex	Pub	BPDB	Karnafuli(Kaptai) Hydro #3	Hydro	-	EAST	1982/8/1	50	50
Ex	Pub	BPDB	Karnafuli(Kaptai) Hydro #4	Hydro	-	EAST	1988/11/1	50	50
Ex	Pub	BPDB	Karnafuli(Kaptai) Hydro #5	Hydro	-	EAST	1988/11/1	50	50
Ex	Pub	BPDB	Rauzan (Chittagong) 210 MW ST #1	Gas	ST	EAST	1993/3/28	210	180
Ex	Pub	BPDB	Rauzan (Chittagong) 210 MW ST #2	Gas	ST	EAST	1997/9/21	210	180
Ex	Pub	BPDB	Shahjibazar 35 MW GT	Gas	GT	EAST	2000/3/28	35	34
Ex	Pub	BPDB	Shahjibazar 35 MW GT	Gas	GT	EAST	2000/10/25	35	35
Ex	Pub	BPDB	Shahjibazar GT (4 units, 2,4,5,6)	Gas	GT	EAST	1968-69	60	38
Ex	Pub	BPDB	Siddhirganj 210 MW ST	Gas	ST	EAST	2004/9/3	210	190
Ex	Pub	BPDB	Sylhet 20 MW GT	Gas	GT	EAST	1986/12/13	20	20
Ex	Pub	BPDB	Tongi 100 MW GT	Gas	GT	EAST	2005/3/28	105	105
Ex	Pv	IPP	CDC, Haripur 360MW (Haripur Power Ltd.), Narshin	Gas	CC	EAST	2001/12/1	360	360
Ex	Pv	IPP	CDC, Meghnaghat 450MW	Gas	CC	EAST	2002/11/26	450	450
Ex	Pv	IPP	NEPC (Haripur 110MW BMPP)	Gas	D	EAST	1999/6/30	110	110
Ex	Pv	IPP	RPCL (Mymensingh 210MW)	Gas	GT	EAST	2006/6/30	210	175
Ex	Pv	Rental	Feni SIPP (22 MW)	Gas	GT	EAST	2009/2/16	22	22
Ex	Pv	Rental	Jangalia, Comilla SIPP	Gas	GT	EAST	2009/6/25	33	33
Ex	Pv	Rental	Barobkundo SIPP	Gas	GT	EAST	2009/5/23	22	22
Ex	Pv	Rental	Kumargao 10 MW (15 Years)	Gas	GT	EAST	2009/3/15	10	10
Ex	Pv	Rental	Kumargoan 48MW (3 Years)	Gas	GT	EAST	2008/7/23	48	48
Ex	Pv	Rental	Sahzibazar RPP (3 Years)	Gas	GT	EAST	2008/11/13	50	50
Ex	Pv	Rental	Sahzibazar RPP (15 Years)	Gas	GT	EAST	2009/2/9	86	86
Ex	Pv	Rental	Tangail SIPP (22 MW)	Gas	GT	EAST	2008/11/12	22	22
Ex	Pv	Rental	Feni SIPP (11 MW) REB	Gas	GT	EAST	2009/4/22	11	11
Ex	Pv	Rental	Rupganj, Narayanganj, Summit SIPP, REB	Gas	GT	EAST	2009/6/9	33	33
Ex	Pv	Rental	Chandina, Comillaj Summit SIPP, REB	Gas	GT	EAST	2006/11/15	25	25
Ex	Pv	Rental	Mahdabdi, Narsindi Summit SIPP, REB	Gas	GT	EAST	2006/12/16	35	35
Ex	Pv	Rental	Ashulia, Dhaka Summit SIPP, REB	Gas	GT	EAST	2007/12/4	45	45
Ex	Pv	Rental	Mouna, Gazipur Summit SIPP, REB	Gas	GT	EAST	2009/5/12	33	33
Ex	Pv	Rental	Narsindi SIPP, REB	Gas	GT	EAST	2008/12/21	22	22
Ex	Pv	Rental	Hobiganj SIPP, REB	Gas	GT	EAST	2009/1/10	11	11
Ex	Pub	BPDB	Baghabari 71 MW GT	Gas	GT	WEST	1991/6/4	71	71
Ex	Pub	BPDB	Baghabari 100 MW GT	Gas	GT	WEST	2001/11/25	100	100
Ex	Pub	BPDB	Barapukuria 2x125 MW ST (COAL)	COAL	ST	WEST	2006/1/31	250	220
Ex	Pub	BPDB	Barisal 20 MW GT #1	HSD	GT	WEST	1984/8/5	20	16
Ex	Pub	BPDB	Barisal 20 MW GT #2	HSD	GT	WEST	1987/10/4	20	16
Ex	Pub	BPDB	Barisal Diesel (4 units)	HSD	D	WEST	1975-1980	5.5	3
Ex	Pub	BPDB	Bheramara 20 MW GT #1	HSD	GT	WEST	1976/7/28	20	18
Ex	Pub	BPDB	Bheramara 20 MW GT #2	HSD	GT	WEST	1976/4/27	20	18
Ex	Pub	BPDB	Bheramara 20 MW GT #3	HSD	GT	WEST	1980/1/19	20	18
Ex	Pub	BPDB	Bhola Diesel	FO/HSD	D	WEST	1988/10/8	3	2
Ex	Pub	BPDB	Bhola New	HSD	D	WEST	1905/6/28	2	2
Ex	Pub	BPDB	Khulna 60 MW ST	FO	ST	WEST	1973/5/25	60	35
Ex	Pub	BPDB	Khulna 110 MW ST	FO	ST	WEST	1984/7/7	110	60
Ex	Pub	BPDB	Rangpur 20 MW GT	HSD	GT	WEST	1988/8/16	20	20
Ex	Pub	BPDB	Saidpur 20 MW GT	HSD	GT	WEST	1987/9/17	20	19
Ex	Pv	IPP	KPCL (Khulna, BMPP)	FO	D	WEST	1998/10/12	110	106
Ex	Pv	IPP	WEST MONT (Baghabari BMPP)	Gas	GT	WEST	1999/6/26	90	70
Ex	Pv	Rental	Ullapara, Sirajganj Summit SIPP (REB)	Gas	GT	WEST	2009/3/2	11	11
Ex	Pv	Rental	Bogra Rental (15 Years)	Gas	GT	WEST	2008/4/11	18	18
Ex	Pv	Rental	Khulna Rental (3 Years)	HSD	GT	WEST	2008/6/12	40	40
Total Capacity (MW)								**5,719**	**5,166**
Total Public East (MW)								3,070	2,700
Total Private East (MW)								1,638	1,603
Total East (MW)								**4,708**	**4,303**
Total Public West (MW)								742	618
Total Private West (MW)								269	245
Total West (MW)								**1,011**	**863**

Source: BPDB, system planning

The reason why the derated capacity is lower than the installed capacity (each plant cannot demonstrate its full capacity) is because of aging deterioration. Generally, thermal power plants need to conduct regular inspections in order to maintain their performance levels, because long term operation leads to deteriorating performance levels due to aging or existence of scale. In Japan, every plant must conduct regular inspections per regulations and independently, so that the performance levels are maintained. However, thermal power plants in Bangladesh are always operated nonstop for long periods of time, so that regular inspections are not conducted.

When comprehensively considering problems above, there seems to be a gap of about 10% (5719 – 5166 = 553 MW) between installed capacity and derated capacity since Bangladesh does not have check/maintenance institution defined by law and no intentional regular maintenance is carried out because of tight demand. In Japan, where regular maintenance is defined by law, the gap is generally equal to zero (excluding the case where the gap is reduced by temperature increase in summer).

Regarding the possibility of recovery for the gap, although in the past there was some recovery experience when the plant was not old, currently considering the operation year and situation of operations, it is very difficult to recover lost MW fully / cost effectively. However, if the maintenance system improves, it is possible to maintain current capacity. Therefore, it is important to continue maintenance to maintain performance during the operation term of each plant.



Source: BPDB, system planning

Fig. 8-5 Example of derated capacity trend

8.2.3 Relationship between derated capacity and max demand served

Next, PSMP Study Team analyze the cause of the difference between the derated capacity and the maximum capacity actually supplied. As shown in Table 8-1, the derated capacity is 5,166 MW and the max demand served is 4,162 MW at the end of 2009. The difference between them is considered to be caused by outage or reduced output of gas-fired power generation because of insufficient gas or by outage of facilities because of forced and maintenance outage.

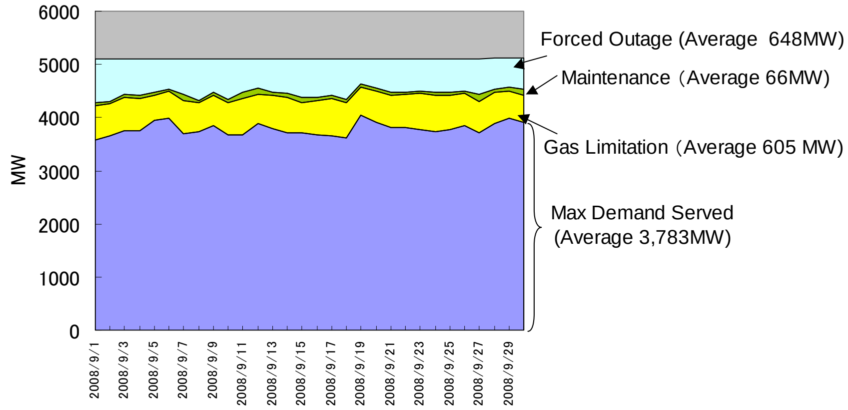
The problems above are concretely analyzed as shown below. The facility operation daily report obtained from PGCB shows the daily derated capacity and the result of the max demand served for it, outage status of each facility (in some cases, reason for outage).The following shows the result of analyzing the daily reports of 12 months (from July 2008 to June 2009) in the year of 2009. a graph indicating the example of data for one month, i.e., September in 2008, and monthly average of 12 month.

Table 8-2 Cause analysis of supply restriction (4 months of FY2009)

(MW)

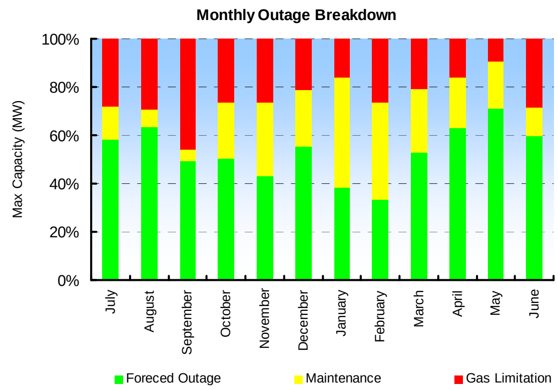
	2008		2009		Average
	Sep.	Dec.	Mar.	Jun.	
Derated Capacity	5,104	5,104	5,282	5,166	5,164
Max Demand Served	3,784	3,560	3,601	3,816	3,691
Reason for shortage					
(1) Gas limitation	605	330	354	385	418
(2) Maintenance	66	358	442	162	257
(3) Forced Outage	648	856	885	803	798

Source: PGCB



Source: PGCB

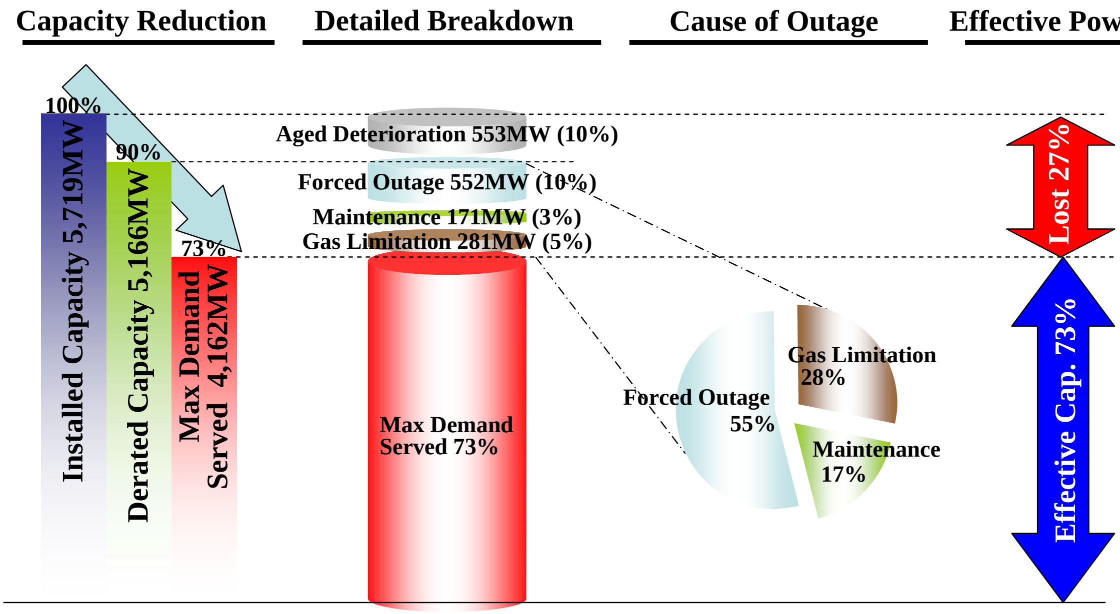
Fig. 8-6 Cause analysis of supply restriction (September 2008)



Source: PGCB

Fig. 8-7 Cause analysis of supply restriction (FY2009)

As shown above, the major cause of supply restriction is a forced outage, the reason that trouble easily occurs is due to unexpected trouble because inspections are not conducted regularly. In order to decrease such trouble, it is a good way to proceed with regular inspections. The analysis of the actual result data clarifies that the restricted operation of gas thermal plants caused by obstructed fuel gas supply is the main cause to the decrease of the maximum supply capacity, as explained above. The value in the year 2009 is equal to 400 to 600 MW. The average is 418 MW which is about 8.1% of the de-rated capacity and is equal to 109 mmcfd as the gas supply amount.



Source: PSMP Study Team

Fig. 8-8 Relationship between derated capacity and max demand served

8.2.4 Conclusion and recommendation

In summarizing the above contents, the following sentences could be read as the results of an analysis for supply shortage.

- In Bangladesh, compared with the installed capacity (5,719MW at June 2009), de-rated capacity which means the raw power of plant, is decreased by about 10% (5166MW), in addition the real max demand served is to decrease to about 20% (4162MW).
- The reason why de-rated capacity is lower than installed capacity is that the regular inspection is not working so that aged deterioration and equipment trouble would occur.
- The reason why the max demand served is lower than the de-rated capacity include stop and restriction caused by maintenance or trouble along with fuel gas shortage. The latter was about 418MW as the average on 2009, equal to about 40% of the causes, it would be a serious problem.
- The first priority in avoiding such gaps is to proceed with regular inspections. It should be considered not only for existing plants but also new constructed plants. If the situation of O&M would not be improved, new constructed plants could not keep good performance, so that the prompt improvement of O&M management should be necessary.
- At the same time, to solve the gas shortage problem is also important for the stable supply of power.

8.3 Validity evaluation of the retirement plans for existing gas-fired power plants

This section investigates the details of the existing gas-fired power plants in Bangladesh analyzes the current states, studies the retirement plans considered by our investigation team, and describes the results of validity verification of the retirement plan prepared by BPDB.

8.3.1 Current status of existing gas-fired power plants

Facilities under BPDB control can be roughly classified into 4 groups. The current state of each is shown below:

Table 8-3　Classification of gas-fired power plants under BPDB control

	Type Name	Capacity	Number	Ave.Heat Efficiency (Actual)[1]
(A)	Mid Capacity Steam Turbine Conventional Type	150～210MW	10	31.1%
(B)	Small Capacity Steam Turbine Conventional Type	55～64MW	5	25.6%
(C)	Simple Gas Turbine	15～100MW	15	24.1%
(D)	Combined Cycle	97～146MW	2	29.5%

Source:　Gathered by PSMP Study Team from BPDB Annual Report

(1) Investigation results of the facilities

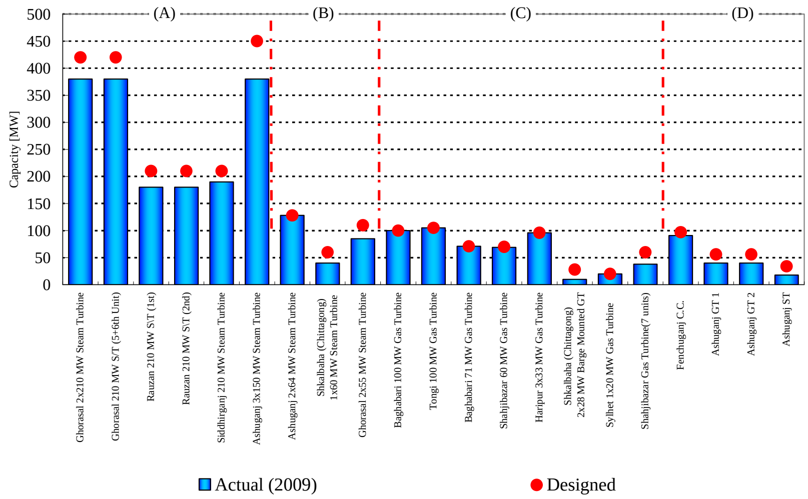
The results of investigating specifications and basic information of each facility are as follows.

The capacity of a conventional facility using the steam turbine (ST) is from 55 MW up to 210 MW. The oldest facility was produced in 1974 and many facilities are from China and Russia. For the steam conditions mainly adopted, the pressure is 13 MPa for a 210 MW unit (maximum capacity), 9.0 MPa for re-heat type with a temperature of 540 °C/540 °C and other small-capacity type, and non-re-heat type with a temperature of 535 °C. None of them are used for the business facilities in Japan. Their design performance (thermal efficiency) is 30% or so, which is lower than that of the coal thermal power generation facility mainly used in Japan.

Almost all gas turbine facilities (GT) are old, small-capacity, and low thermal efficient types, excluding large-capacity types recently installed in Tongi and Baghabari. The oldest type was produced in 1968. Various manufacturers supply the facilities, e.g., GE (USA), ALSTOM (France), Mitsubishi (Japan), and Hitachi (Japan).

(2) Investigation results of operation states

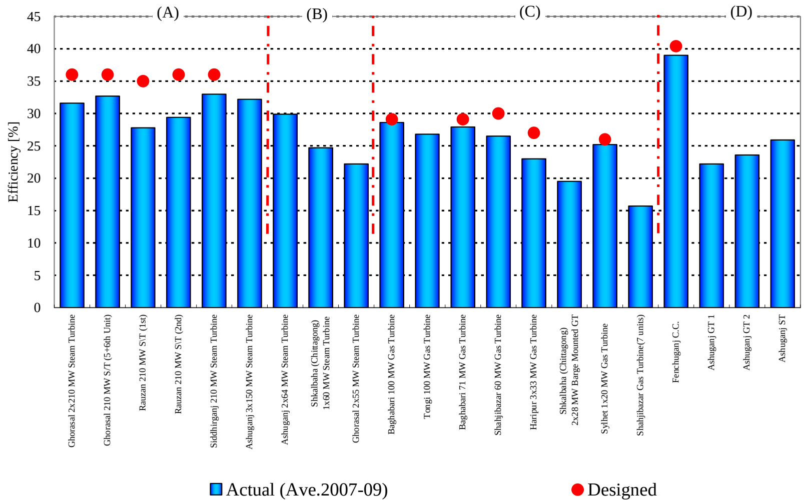
Fig. 8-9 and Fig. 8-10 show the results of investigating the current states of capacity and efficiency of each facility. They show that both capacity and efficiency do not satisfy the design performance as a whole.



Source:　BPDB, system planning

Fig. 8-9　Actual capacity of gas-fired power plants

[1] The average thermal efficiency is the average in 3 years from 2007.



Source: BPDB, system planning

Fig. 8-10 Actual efficiency of gas-fired power plants

8.3.2 Verification of operation status and management organization and selection of problems to improve efficiency

Four evaluation items are set to analyze the current state of each facility, i.e., a) performance (thermal efficiency), b) forced outage, c) operation years, and d) power generation cost, and each item is analyzed and evaluated as shown below:

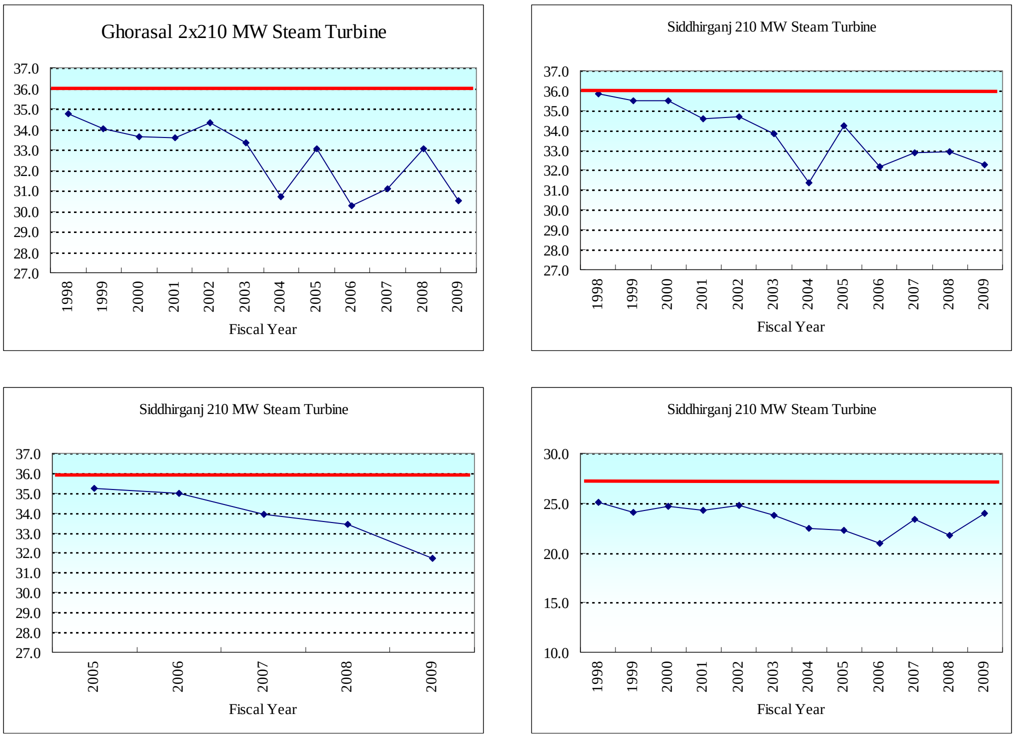
(1) Analysis of actual data

(a) Performance (thermal efficiency)

Fig. 8-11 shows the actual thermal efficiency of each facility in the past 10 years. The red lines in the figure show the design values.

In particular, the steam turbine facility shows the remarkable reduction of efficiency caused by aging. The investigation result shows that regular maintenance were not made as a whole. While a boiler is regularly inspected once every two years and a turbine was inspected once every four years in Japan (including simple check), they were not inspected in the period of 10 to 16 years in Bangladesh Therefore, it is considered that reduced efficiency of the steam turbine facilities was caused by the difficulty to keep the efficiency because of the steam leakage from the turbine, the impossibility to use a high-pressure heater, difficulty to keep a vacuum in condenser, and leakage from thin pipes in the condenser.

On the other hand, some gas turbine facilities may not satisfy the design performance, but they do not clearly show reduced efficiency because of aging. The reason is considered to be that almost all gas turbines were produced by various manufacturers such as GE, ALSTOM, Mitsubishi, and Hitachi, and maintenance required minimum is carried out. However, it is considered that the maintenance is not carried out as scheduled but as required. In addition, many gas turbine facilities in Bangladesh are small-capacity types (excluding Baghabari and Tongi) and low-efficient; therefore, they should be used for peak-corresponding type in the future from the viewpoint of the efficient use of natural gas.



Source: BPDB system planning

Fig. 8-11 Efficiency performance

(b) Forced outage

Table 8-4 shows the result that is obtained by arranging the past performance data of forced outage rate of each facility (forced outage rate = (forced outage time) ÷ (operation time + forced outage time) × 100%). For data analysis, the steps below are used to calculate the performance values:

- The average value and the standard deviation (σ) in the past 10 years (max.) are calculated.
- If σ is less than 10%, the average value is used as the performance value.
- If the deviation is large, i.e., σ is 10% or more, incorrect data are judged to be included, i.e., data out of the average value ±σ are excluded and the average value is calculated again to obtain the performance value.

Table 8-4 Performance of forced outage ratio

	Unit Name	1999 -00	2000 -01	2001 -02	2002 -03	2003 -04	2004 -05	2005 -06	2006 -07	2007 -08	2008 -09	Average
(A) ST over 150MW	Ghorasal 4x210 ST (#3,4,5,6)	6.84%	9.28%	4.67%	5.14%	1.01%	22.20%	20.47%	2.13%	1.48%	0.00%	6.12%
		13.97%	19.76%	13.21%	58.82%	2.45%	5.38%	2.32%	2.99%	1.36%	1.54%	
		2.61%	1.45%	1.34%	3.79%	2.73%	1.27%	20.47%	2.13%	1.48%	0.00%	
		16.19%	12.29%	4.65%	2.75%	9.52%	5.49%	2.32%	2.99%	1.36%	1.54%	
	Raozan 210 ST #1	11.46%	2.98%	34.62%	6.99%	1.80%	1.97%	4.97%	1.61%	0.00%	10.50%	5.29%
	Raozan 210 ST #2	27.96%	15.61%	22.47%	1.39%	2.74%	1.95%	2.31%	0.00%	0.00%	5.56%	4.93%
	Siddhirgonj 210 MW ST						10.42%	0.12%	0.33%	0.11%	0.07%	0.16%
	Ashuganj 3x150 MW ST (#3,4,5)	0.66%	0.95%	0.27%	2.21%	3.69%	0.88%	3.63%	2.27%	3.84%	0.36%	2.01%
		0.62%	0.56%	0.64%	0.51%	2.85%	9.39%	41.50%	3.89%	2.43%	2.10%	
		0.60%	0.57%	0.06%	1.53%	3.47%	3.33%	100.00%	100.00%	0.27%	2.66%	
(B) ST under 150MW	Ashuganj 2x64 MW ST (#1,2)	1.44%	6.97%	3.60%	1.01%	2.78%	14.00%	11.52%	12.06%	10.09%	11.05%	5.69%
		7.57%	4.60%	2.85%	2.61%	3.91%	5.42%	1.49%	2.78%	4.36%	3.73%	
	Shikalbaha(Chittagong) 60 MW ST	9.29%	2.45%	0.77%	1.74%	3.08%	1.81%	2.04%	2.03%	6.36%	3.04%	3.26%
	Ghorasal 2x55 ST	9.33%	25.60%	15.41%	24.49%	70.63%	22.82%	3.77%	0.00%	18.37%	0.00%	10.89%
		7.25%	15.29%	6.01%	7.25%	20.82%	10.95%	5.00%	5.55%	0.97%	2.39%	
(C) Gas Turbine	Baghabari 100 MW CT	80.08%	0.78%	0.32%	1.54%	1.82%	2.50%	7.11%	0.00%	0.09%	4.44%	9.75%
	Tongi 80 MW GT							16.64%		11.41%		13.94%
	Baghabari 71 MW CT			1.33%	0.97%	2.06%	6.07%	6.68%	0.32%	0.12%	0.68%	2.28%
	Shahjibazar2x35MW CT			24.13%	100.00%	17.97%	2.52%	26.19%	92.34%	4.81%	0.53%	9.91%
				0.00%	0.00%	100.00%	92.51%	9.65%	100.00%	2.49%	0.87%	
	Haripur 3x33 CT	5.36%	1.71%	2.62%	3.75%	0.14%	0.96%	100.00%	0.00%	0.00%	0.07%	4.12%
		0.07%	0.64%	1.43%	0.55%	0.34%	0.05%	34.50%	0.00%	0.03%	24.67%	
		1.16%	2.81%	0.55%	0.02%	0.71%	1.27%	100.00%	0.00%	0.00%	11.31%	
	Shikalbaha 2x28MW CT	11.01%	20.95%	67.91%	98.04%	97.29%	94.02%	21.40%	7.94%			25.84%
	Sylhet 20 MW CT					4.02%	4.08%	3.19%	0.00%	2.73%	4.09%	14.27%
	Shahjibazar CT	1.39%	7.08%	3.94%	93.30%	0.78%	2.32%	2.32%	46.34%	11.73%	0.00%	9.72%
		1.45%	4.05%	0.18%	55.60%	34.49%	0.00%	0.63%	72.40%	24.22%	0.00%	
		5.60%	14.68%	95.58%	0.00%	3.39%	50.72%	0.00%	71.17%	3.69%	9.45%	
		18.38%	0.90%	0.89%	0.00%	1.45%	1.25%	1.91%	1.84%	2.91%	1.69%	
(D) Combined Cycle	Ashuganj 90 MW CC (GT1,2 +ST)	16.19%	9.10%	2.36%	13.79%	27.06%	15.01%	16.08%	4.79%	5.87%	1.39%	13.70%
		22.45%	24.23%	13.18%	20.39%	24.87%	69.26%	47.41%	20.40%	14.42%	3.67%	
		80.39%	19.14%	1.78%	6.55%	15.46%	16.12%	40.12%	3.17%	1.56%	0.71%	
	Fenchuganj CC (#1,2)		0.75%	0.14%	0.08%	5.72%	3.05%	0.61%	0.78%	0.00%	0.00%	3.03%
			7.22%	3.89%	8.17%	44.52%	70.72%	0.61%	0.78%	0.00%	0.00%	
			6.01%	0.27%	3.74%	2.50%	11.22%	1.84%	0.00%	0.00%	0.09%	

Source: BPDB system planning

The performance values are in the range from a large one-digit value to a small 10s value with partial exception. The table generally shows that while the forced outage rate in Japan is a small one-digit value, that in Bangladesh is a large value. It is considered that this is caused since regular maintenance is not carried out and the operation is basically done with the policy

"Operation proceed until outage occurs because of a failure." Therefore, there seems to be a sufficient possibility that intentional maintenance may allow the forced outage to reduce.

(c) Operation years

Table 8-5 shows the operation start date and operation years of each facility (as of June 30, 2009).

Table 8-5 Operation start date and operation years

	Unit Name	Operation Start Date	Operation Years	Planned Retire Year by BPDB
(A) ST over 150MW	Ghorasal 4x210 ST (#3,4,5,6)	1986/9/14	22	2029
		1989/3/18	20	2029
		1994/9/15	14	2029
		1999/1/31	10	2029
	Raozan 210 ST #1	1993/3/28	16	2026
	Raozan 210 ST #2	1997/9/21	11	2028
	Siddhirgonj 210 MW ST	2004/9/3	4	2035
	Ashuganj 3x150 MW ST (#3,4,5)	1986/12/17	22	2023
		1987/5/4	22	2023
		1988/3/21	21	2023
(B) ST under 150MW	Ashuganj 2x64 MW ST (#1,2)	1970/7/17	38	2014
		1970/7/8	38	2014
	Shikalbaha(Chittagong) 60 MW ST	1984/4/24	25	2019
	Ghorasal 2x55 ST	1974/6/16	36	2016
		1976/2/13	34	2016
(C) Gas Turbine	Baghabari 100 MW CT	2001/11/25	7	2022
	Tongi 80 MW GT	2005/3/28	4	2030
	Baghabari 71 MW CT	1991/6/4	18	2016
	Shahjibazar2x35MW CT	2000/3/28	9	2023
		2000/10/25	8	2023
	Haripur 3x33 CT	1987/10/31	21	2014
		1987/11/15	21	2014
		1987/12/2	21	2014
	Shikalbaha 2x28MW CT	1986/10/13	22	2010
	Sylhet 20 MW CT	1986/12/13	22	2014
	Shahjibazar CT	1968-69	41	2010
(D) Combined Cycle	Ashuganj 90 MW CC (GT1,2 +ST)	1982-1987	22-27	2014
	Fenchuganj CC (#1,2)	1994-1995	15	2022

Source: BPDB system planning

The oldest introduction time is the year of 1968, when Bangladesh was founded, and the newest time is the year of 2005. Old facilities which have been used for 20 years or more are mainly included in the small-capacity steam turbine and small-capacity gas turbine facilities.

(d) Power generation costs

Table 8-6 shows the power generation cost of each facility. The simple average values are used as the average values.

Table 8-6 Power generation costs (Taka/kWh)

	Unit Name	2004-05	2005-06	2006-07	2007-08	2008-09	Average
(A) ST over 150MW	Ghorasal 4x210 ST (#3,4,5,6)	1.38	1.37	1.37	1.35	1.32	1.358
	Raozan 210 ST #1 Raozan 210 ST #2	1.60	1.33	1.6	1.76	1.94	1.65
	Siddhirgonj 210 MW ST	1.11	2.37	1.52	1.86		1.715
	Ashuganj 3x150 MW ST (#3,4,5)						
(B) ST under 150MW	Ashuganj 2x64 MW ST (#1,2)						
	Shikalbaha(Chittagong) 60 MW ST	2.21	1.92	2.9	2.56	12.21	4.36
	Ghorasal 2x55 ST	1.38	1.37	1.37	1.35	1.32	1.36
(C) Gas Turbine	Baghabari 100 MW CT	1.69	1.59	1.9	1.9	1.56	1.728
	Tongi 80 MW GT		1.81	2.68	1.76	1.54	1.9475
	Baghabari 71 MW CT	1.69	1.59	1.9	1.9	1.56	1.728
	Shahjibazar2x35MW CT	3.72	2.88	6.16	2.93	1.83	3.50
	Haripur 3x33 CT	2.28	4.5	9.99	2.72	3.26	4.55
	Shikalbaha 2x28MW CT	2.21	1.92	2.9	2.56	12.21	4.36
	Sylhet 20 MW CT						
	Shahjibazar CT	3.72	2.88	6.16	2.93	1.83	3.504
(D) Conbined Cycle	Ashuganj 90 MW CC (GT1,2 +ST)						
	Fenchuganj CC (#1,2)	2.66	1.97	1.05	1.74	1.2	1.724

Source: BPDB Annual Report

It is found that as a whole trend, small-capacity facilities, in particular, gas turbines, include those with high generation costs.

(2) Comprehensive evaluation of each facility

Each facility is evaluated comprehensively using the result of analyzing four types of data. AHP method is used for the evaluation (for details of AHP method, see Chapter 12).

(a) Weighting of items

Four evaluation items (thermal efficiency, forced outage, operation years, and power generation costs) are weighted as shown below:

- Basically, the older the facility is, the lower the performance is. Therefore, efficient operation cannot be achieved; it should be abolished first. That is, the operation years is the important evaluation item.
- Since the reduced performance (thermal efficiency) and the increased force outage ratio are considered to be improved greatly by the execution of intentional regular check, they seem not to be very important when considering retirement.
- Since the power generation cost includes fuel cost, which is important for the performance and structural problems, i.e., there cannot be a simple solution, the power generation cost is the item considered as important when examining abolition.

The results of weighting items using AHP method based on the considerations above are shown in the table below:

Table 8-7 Weighting of evaluation items using AHP method

	Item	1	2	3	4	Geometric Average	Level of Importance	Point Allocation
1	Heat Efficiency	1	1	1/5	1	0.66874	0.151555	15.2
2	Forced Outage Ratio	1	1	1/3	1/3	0.57735	0.130843	13.1
3	Operation Years	3	3	1	2	2.059767	0.466799	46.7
4	Generation Costs	1	3	1/2	1	1.106682	0.250804	25.1

Source: PSMP Study Team

General evaluation is shown in the table below:

Table 8-8 General evaluation

	Unit Name	Efficiency	Forced Outage Ratio	Operation Year	Generation Cost	Total	Rank
		15.2	13.1	46.7	25.1		
1	Ghorasal 4x210 ST (#3,4,5,6)	0.5986	0.6475	2.6699	2.3877	6.3036	6
2	Raozan 210 ST #1	0.4073	0.7553	2.5934	2.0468	5.8028	9
3	Raozan 210 ST #2	0.4399	0.8158	3.6332	2.0468	6.9357	4
4	Siddhirgonj 210 MW ST	0.5131	1.2949	5.7431	1.8235	9.3747	1
5	Ashuganj 3x150 MW ST (#3,4,5)	0.8465	1.1537	1.8338	1.1053	4.9394	10
6	Ashuganj 2x64 MW ST (#1,2)	0.8465	0.7268	0.7497	1.1053	3.4283	17
7	Shikalbaha(Chittagong) 60 MW ST	0.8465	0.9516	1.3176	0.7521	3.8678	14
8	Ghorasal 2x55 ST	0.8465	0.4758	0.8714	2.3877	4.5813	11
9	Baghabari 100 MW CT	1.5083	0.5550	4.8309	1.5041	8.3984	2
10	Tongi 80 MW GT	0.8465	0.4079	5.7431	1.3400	8.3376	3
11	Baghabari 71 MW CT	1.1972	1.1101	2.3477	1.5041	6.1591	7
12	Shahjibazar2x35 MW CT	0.5542	0.5139	4.1561	0.9117	6.1360	8
13	Haripur 3x33 CT	0.4751	0.8811	1.9365	0.6700	3.9627	13
14	Shikalbaha 2x28 MW CT	0.8465	0.3497	1.6868	0.7521	3.6351	16
15	Sylhet 20 MW CT	1.3965	0.3776	1.6868	1.1053	4.5663	12
16	Shahjibazar CT	0.8465	0.5995	0.6640	0.8442	2.9541	18
17	Ashuganj 90 MW CC (GT1,2 +ST)	0.8465	0.4405	1.3693	1.1053	3.7617	15
18	Fenchuganj CC (#1,2)	1.2930	1.0278	2.8462	1.6883	6.8553	5

Source: PSMP Study Team

8.3.3 Recommendation of measures to improve the efficiency

BPDB prepares the retirement plan for the existing power generation facilities. The validity of the plan is evaluated by comparing it with the results of investigation by our team.

Classification is made as shown below using total points in the comprehensive evaluation of the investigation results by our team (Table 8-8). Table 8-9 shows the results of comparing the evaluation based on the following:

(1) Less than 4 points
Rapid retirement is desired (by 2015).

(2) 4 to 5 points
Relatively early retirement is desired (by 2020).

(3) 5 points or more
Currently aggressive retirement is not required.

Table 8-9 Comparison between BPDB plan and evaluation by PSMP Study Team

	Unit Name	Planned Retire Year by BPDB	Evaluation by PSMP Study Team		
			Turn for Retire	Suggested Retire Year	
1	Ghorasal 4x210 ST (#3,4,5,6)	2029	13	After 2020	
2	Raozan 210 ST #1	2026	10	After 2020	
3	Raozan 210 ST #2	2028	15	After 2020	
4	Siddhirgonj 210 MW ST	2035	18	After 2020	
5	Ashuganj 3x150 MW ST (#3,4,5)	2023	9	2016 - 2020	(1)
6	Ashuganj 2x64 MW ST (#1,2)	2014	2	Before 2015	
7	Shikalbaha(Chittagong) 60 MW ST	2019	5	Before 2015	(2)
8	Ghorasal 2x55 ST	2016	8	2016 - 2020	
9	Baghabari 100 MW CT	2022	17	After 2020	
10	Tongi 80 MW GT	2030	16	After 2020	
11	Baghabari 71 MW CT	2016	12	After 2020	(3)
12	Shahjibazar2x35 MW CT	2023	11	After 2020	
13	Haripur 3x33 CT	2014	6	Before 2015	
14	Shikalbaha 2x28 MW CT	2010	3	Before 2015	
15	Sylhet 20 MW CT	2014	7	2016 - 2020	
16	Shahjibazar CT	2010	1	Before 2015	
17	Ashuganj 90 MW CC (GT1,2 +ST)	2014	4	Before 2015	
18	Fenchuganj CC (#1,2)	2022	14	After 2020	

Source: PSMP Study Team, BPDB system planning

As shown above, almost all parts of the evaluation by our team are consistent with the BPDB plan, except for the following:

(1) For Ashuganj 150 MW, the evaluation is reduced a little since it is relatively old in the middle-capacity steam turbine facilities. However, its life can be prolonged if intentional maintenance is carried out. Actually the rehabilitation plan is proceeding at Ashuganj.

(2) For Shikalbaha 60 MW ST, the evaluation is reduced because of high power generation cost (which is relatively new in the small-capacity steam turbine facilities). To prolong its life in the future, it is desired to find out and solve the cause of high costs.

(3) For Baghabari 71 MW CT, since items evaluated as very low cannot be found out, it is considered that it can be operated for 30 years considering the life of the gas turbine.

8.3.4 Conclusion and recommendation

In summarizing the above, the following sentences could be read about the evaluation for a retirement plan,

- To investigate current status and after that to make the retirement plan of PSMP Study Team, and to evaluate their plan by comparing these plans.
- The evaluation results are almost the same.
- That means that the PSMP Study Team thinks that the plan of the BPDB is reasonable.

8.4 Validity evaluation of the new power plant development plan

This section investigates the current state of the plan for a newly installed gas-fired power plant already carried out by Bangladesh and evaluates its validity.

8.4.1 Planning and construction schedule of standard thermal power plant

For the evaluation of the new power plant development plan, a comparison with standard schedule is being conducted. The following shows the standard schedule from the planning, construction to the operation of the thermal power plant.

(1) From planning to construction

From the planning to construction, it is different between the public sector by BPDB and the private sector like IPP.

(a) Public sector

1) F/S (Feasibility Study), D/D(Detail Design)

About the candidate site, to investigate the detailed conditions concerning the construction of the power plant, to determine whether or not it is realistic to construct (F/S). If it is realistic, to determine the detailed specifications for the selection of the manufacturer such as the size, type (D/D). Generally, the large project or in the case of no experience, the required time is long, it takes 9 months for F/S and 6 months for D/D.

2) Development Project Proposal (DPP)

At the timing of the completion of F/S, to obtain this government agreement is needed.

3) Manufacture Selection

After the detailed specifications of the equipment has been determined, to proceed with the selection of the manufacturer. To create Procurement document (Request for Proposal in the case of an EPC contract) and collect proposals from the manufacturers, generally it takes 2 months.

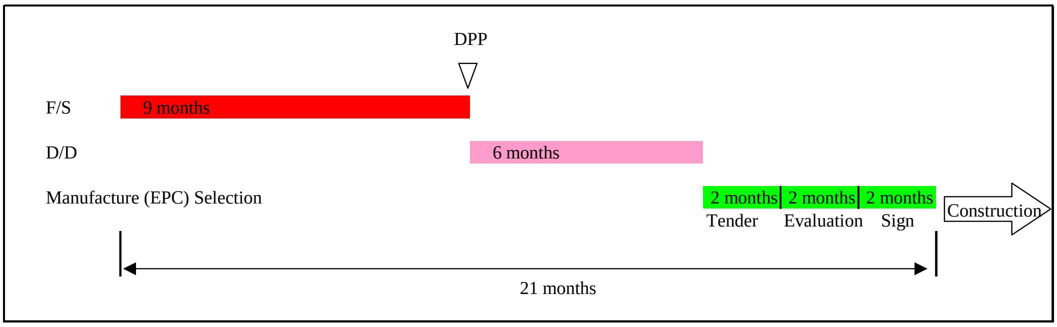
4) Evaluation

To evaluate each proposal to choose an appropriate one. To evaluate from a technical and economic perspective and put priority on negotiation, generally it takes 2 months.

5) Signing Contract

To proceed with negotiations according to the priority, and sign the contract. It takes about 2 months.

The following is the schedule for the above.



Source: PSMP Study Team

Fig. 8-12 Standard schedule toward signing (Public sector)

(b) Private sector

1) P/Q

To proceed with a pre-qualification prior to inviting the contractor. It takes about 4 months.

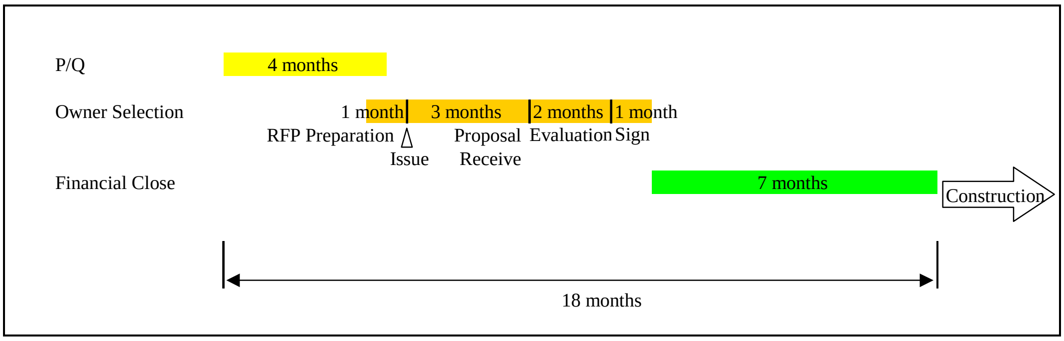
2) Contractor Selection

To select a contractor after P/Q. To issue the RFP and collect proposals (3 months), evaluation (2 month2), sign contract (1 month).

3) Loan agreement

The selected contractor will proceed with construction after signing the loan agreement. It takes about 7 months.

The following is the schedule for the above.



Source: PSMP Study Team

Fig. 8-13 Standard schedule toward signing (Private sector)

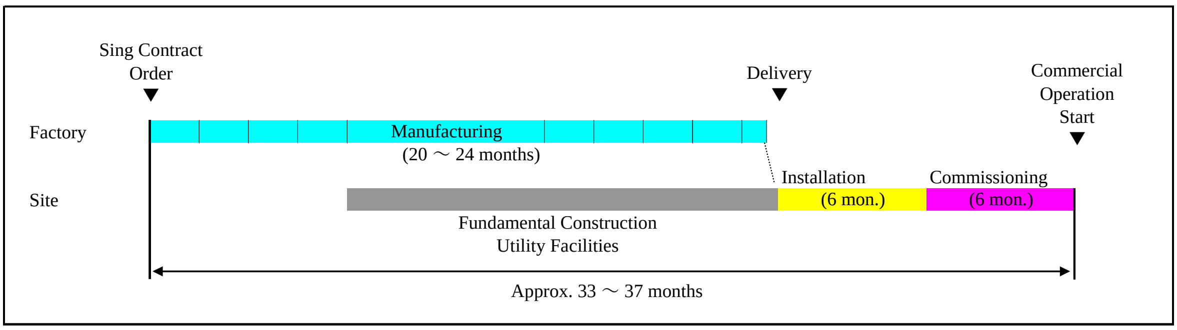
Public and private procedures are different, both of which takes 20 months to sign the contract.

(2) Construction period

The construction schedule of each type of plant is as follows. Each schedule does not include land preparation period.

(a) Gas or oil fired steam turbine (conventional type) and combined cycle facility

The following shows the standard construction schedule for a steam turbine and combined cycle power plant.



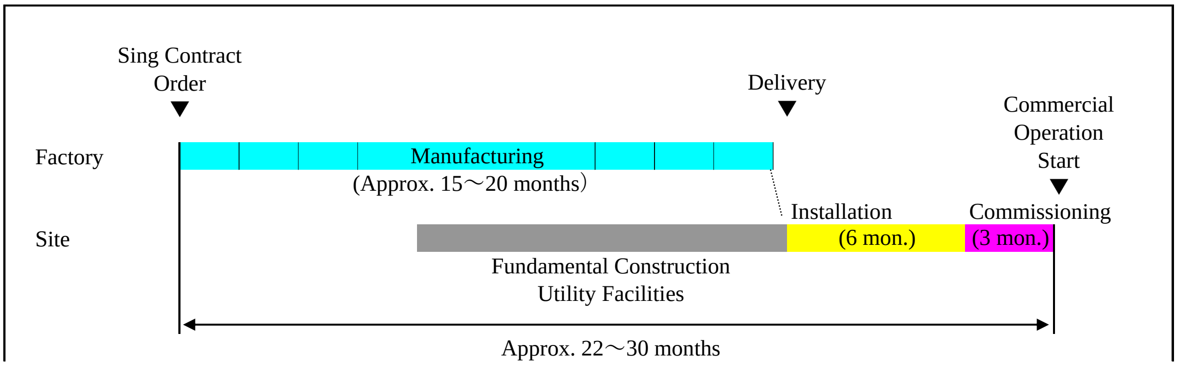
Source: PSMP Study Team

Fig. 8-14 Standard construction schedule for steam turbine and combined cycle power plant

For main facilities (boiler (or HRSG), turbine, power generator), a long time (about 25 months) is required until they are produced after ordering them (it changes depending on reception status of the manufacturer). During this period, the foundation work and the work for common facilities are carried out in advance on the power plant site and about one year is required until the test run is executed after delivering and installing the main facilities (it changes depending on the type of required items). Therefore, 3 years or more are required until the commercial operation starts after ordering (contract).

(b) Simple gas turbine facility

The following shows the standard building processes for a single gas turbine facility.



Source: PSMP Study Team

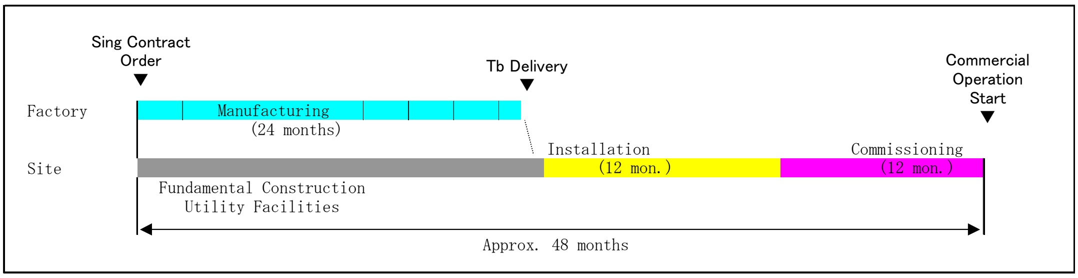
Fig. 8-15 Standard construction schedule for a gas turbine power plant

For the main body of the gas turbine and the power generator, a long time is also required until they are produced after ordering them (it changes depending on the reception status of the manufacturer). However, since the power generation facilities of it are simpler than those of a steam turbine and the combined cycle, the required time for work (installation and commission) at the site after delivering the main facilities is relatively short. According to the standard processes of the manufacturer, about 22 to 30 months are required until starting the commercial operation after ordering, i.e., it can be started sooner than the steam turbine and combined cycle.

(c) Coal-fired power plant (USC)

The USC coal-fired power plant has more auxiliary equipment than gas and oil-fired ones, it takes more time for installation. Moreover, during the test run, many test items and detailed tuning for each type of coal are needed, so it takes a long time.

The following shows the standard construction schedule of a coal-fired power plant:



Source: PSMP Study Team

Fig. 8-16 Standard construction schedule for a coal-fired power plant

The following table is a summary of the above schedules. This table shows the standard lead time of each period.

Table 8-10 Construction period and lead time (toward signing)

Step	Public Sector (BPDB)	Lead Time (Month)	Private Sector (IPP, Rental)	Lead Time (Month)
1	F/S,	9	P/Q(after F/S)	4
2	D/D	6	Selection (RFP)	4
3	Selection（Tender）	2	(Evaluation)	2
4	（Evaluation）	2	(Sign Contract)	1
5	（Sign Contract）	2	Financial Close	7

Source: PSMP Study Team

Table 8-11 Construction period and lead time (from start of construction)

Step		Lead Time (Month)			
		CT	ST/CC	GE	USC
6	Construction (0-30%)	10	16	6	28
7	Construction (30-70%)	6	7	3	12
8	Construction (70-100%)	6	9	3	12

Source: PSMP Study Team

The required construction time differs according to plant type.

8.4.2 Review for current status of new power development

For Bangladesh's new power development plan as of Aug.31.2010, the evaluation preceded in comparison with the above standard schedule.

For example, Ashuganj 50

Current status: Contract Signed

It is on the 5th step. That means the remaining term is step 6 to step 8, the type of plant is GE, so that the remaining time is assumed to be 4+5+3=12 months, this is the evaluation conducted by the PSMP Study Team.

The following shows the results of the evaluation using this method:

Table 8-12 Current status and evaluation result of new power development toward 2015 (BPDB)

Plant name	Fuel	Type	Cap. [MW]	Step	Planned Commercial Operation	Period until commercial operation (months)	
						Plan	Evaluation
Ashuganj 50	Gas	GE	50	5	Mar-11	6	12
Ghorasal, Dual Fuel, Peaking Plant	Gas	GE	290	5	Jun-12	21	12
Khulna 150MW , Dual Fuel, Peaking Plant	Gas	CT	150	4	Jun-12	21	27
Sirajganj 150MW , Dual Fuel, Peaking Plant	Gas	CT	150	4	Jun-12	21	27
Sylhet 150 MW CCPP (BPDB), U/C	Gas	CC	150	6	Oct-11	13	16
Chandpur 150 MW CCPP (BPDB), U/C	Gas	CC	150	6	Mar-12	18	16
Siddhirgonj 450 MW CC	Gas	CC	450	4	Jan-13	28	34
Bhola 150MW CCPP(Ist unit), BPDB	Gas	CC	150	1	Jan-13	28	44
Sikalbaha 225 MW Dual Fuel, CC	Gas	CC	225	2	Dec-13	39	43
Ashuganj 150 MW	Gas	CC	150	2	Dec-13	39	38
Haripur 360 MW CCPP (EGCB)	Gas	CC	360	3	Jan-14	40	36
Bheramara 360 MW CCPP (NWPGC)	Gas	CC	360	2	Jan-14	40	38

Plant name	Fuel	Type	Cap. [MW]	Step	Planned Commercial Operation	Period until commercial operation (months)	
						Plan	Evaluation
Kodda (North Dhaka) 450MW CCPP	Gas	CC	450	2	Jun-14	45	38
Ashuganj 450 MW CCPP	Gas	CC	450	1	Mar-15	56	44
FaridpurPeaking Plant	FO	GE	50	5	Aug-11	11	12
Gopalgonj Peaking Plant	FO	GE	100	5	Aug-11	11	12
Bera, Pabna, Peaking Plant	FO	GE	70	5	Aug-11	11	12
Dohazari Peaking Plant	FO	GE	100	5	Sep-11	12	12
Hathazari Peaking Plant	FO	GE	100	5	Sep-11	12	12
Baghabari Peaking Plant	FO	GE	50	5	Sep-11	12	12
Daudkandi	FO	GE	50	5	Sep-11	12	12
Katakhali Peaking Plant	FO	GE	50	5	Dec-11	15	12
Santahar Peaking Plant	FO	GE	50	5	Dec-11	15	12
Gazipur 50 MW	FO	GE	50	4	Jun-12	21	14
BPDB & RPCL, 150MW	FO	GE	150	2	Jun-12	21	18
Raujan 20 MW	FO	GE	20	2	Jun-12	21	18
Barapukuria 250MW (3rd unit)	Coal	ST	125	2	Dec-13	39	38

Source: PSMP Study Team

Table 8-13 Current status and evaluation result of new power development toward 2015 (IPP)

Plant name	Fuel	Type	Cap. [MW]	Step	Planned Commercial Operation	Period until commercial operation (months)	
						Plan	Evaluation
Comilla Peaking, Dual Fuel, Peaking Plant	Gas	GE	50	3	May-12	20	26
Kaliakair, Dual Fuel, Peaking Plant	Gas	GE	100	4	Jan-13	28	12
Savar, Dual Fuel, Peaking Plant	Gas	GE	100	3	Jan-13	28	26
Bhola CCPP(2nd unit)	Gas	CC	225	3	Dec-12	27	40
Madanganj,Keraniganj CCPP Dual Fuel	Gas	CC	225	3	Dec-12	27	40
Bibiana 450 MW CCPP(Ist Unit)	Gas	CC	450	3	Dec-12	27	40
Bibiana 450 MW CCPP(2nd Unit)	Gas	CC	450	3	Jan-13	28	40
Meghnaghat CCPP (2nd unit) Dual Fuel	Gas	CC	450	3	Jan-13	28	40
Serajganj 450 MW CCPP	Gas	CC	450	3	Jun-14	45	46
Syedpur Peaking Plant	FO	GE	100	3	Apr-12	19	20
Jamalpur Peaking Plant	FO	GE	100	3	May-12	20	20
Chapai Nababgonj Peaking Plant	FO	GE	100	3	May-12	20	20
Khulna Peaking Plant	FO	GE	100	3	May-12	20	18
Tangail 20 MW	FO	GE	20	2	Jan-12	16	20
Chandpur 15 MW	FO	GE	15	2	Jan-12	16	20
Narayanganj 30MW	FO	GE	30	2	Jan-12	16	20
Khulna South 600 MW ST #1	Coal	ST	650	1	Jun-15	57	46
Khulna South 600 MW ST #2	Coal	ST	650	1	Jun-15	57	46
Chittagong 600 MW ST #1	Coal	ST	650	1	Jun-15	57	46
Chittagong 600 MW ST #2	Coal	ST	650	1	Jun-15	57	46

Source: PSMP Study Team

Table 8-14 Current status and evaluation result of new power development toward 2015 (Rental)

Plant name	Fuel	Type	Cap. [MW]	Step	Planned Commercial Operation	Period until commercial operation (months)	
						Plan	Evaluation
Fenchuganj – 3 Yrs rental, U/C	Gas	GE	50	8	Oct-10	1	1
Bogra –3 yrs rental, U/C	Gas	GE	20	8	Oct-10	1	1
Kadda, Sidhirganj(quick rental)	FO	GE	100	6	Oct-10	1	6
Noapara, Jessore, Rental, U/C	FO	GE	100	5	Nov-10	2	12
Barisal, Rental,U/C	FO	GE	50	6	Dec-10	3	6
Kadda, Meghna(quick rental)	FO	GE	100	6	Jan-11	4	5
Khulna(quick rental)	FO	GE	115	5	Mar-11	6	9
Modanganj(quick rental)	FO	GE	102	5	Mar-11	6	9
Keranigong(quick rental)	FO	GE	100	5	Mar-11	6	9
Meghnagat(quick rental)	FO	GE	100	5	Mar-11	6	9
Chapai Nawabgonj(quick rental)	FO	GE	50	5	Mar-11	6	9
Katakhali(quick rental)	FO	GE	50	5	Mar-11	6	9
Julda(quick rental)	FO	GE	100	5	Aug-11	11	9
Noapara(quick rental)	FO	GE	40	5	Aug-11	11	9
Bheramara, Rental , U/C	HSD	GE	100	8	Sep-10	0	1
Pagla, Narayaganj(quick rental)	HSD	GE	50	6	Nov-10	2	5
Siddirganj(quick rental)	HSD	GE	100	5	Mar-11	6	9

Source: PSMP Study Team

A quick rental refers to a rental contract which can be in service after 6 or 9 months from signing.

Regarding the period until commercial operation, in many cases, the evaluation is shorter than planned, or a little longer but no longer than 6 months. The evaluation is based on the standard schedule, so it is possible to shorten the actual schedule to about 6 months via smooth procedures, it means that generally there are no impediments to proceeding on schedule. Some plants show that the evaluation is very long compared with the plan. It means that strict schedule control should be required for the procedures on schedule.

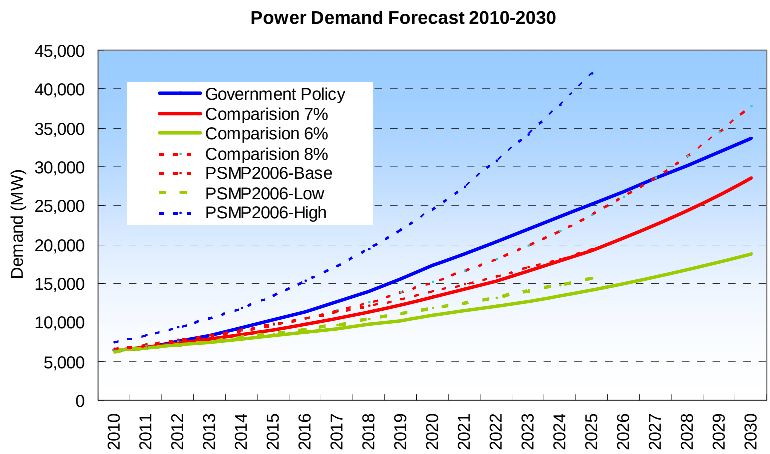
8.4.3 New import coal projects

In November 2010, BPDB commenced the bidding process for two smaller projects in the range of 150MW to 300MW in Chittagong and Khulna, and also two larger projects in the range of 300MW to 650MW in Chittagong Coastal Area and Maowa-Munshiganj area, total four imported coal fired power projects on BOO basis. These projects are on the same area where the Master Plan considered for potential site of coal power station projects. These projects are expected to commission by 2015. Implementation of these projects will help in lowering overall cost of production. However, these were the recent development and were not included in the Master Plan. If these fast track IPP projects are implemented on time successfully, the generation output by imported coal fired power stations in the Master Plan can be reduced.

8.5 Validation of uncertainty events for power development plan

8.5.1 Long term demand forecast

As indicated in the previous chapter, the power demand growth of the government policy scenario for 2030 has been forecasted at 34,000MW. The demand will reach 29,000MW on the comparison scenario (GDP=7%) with neighboring countries, and it will attain 19,000MW on the comparison scenario (GDP=6%).

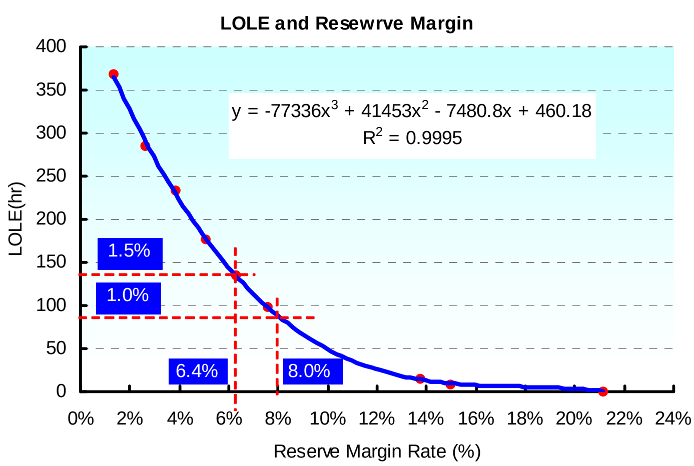


Source: PSMP Study Team

Fig. 8-17 Result of power demand forecast

8.5.2 Setting the appropriate reserve margin by consideration of the reliability level over the long term

The relationship between the supply reliability level and the reserve margin is as shown in the figure below. When LOLE is assumed to be 1% to 1.5%, the necessary reserve margin becomes 6.4 to 8.0%. In this examination, an appropriate reserve margin has been set at 10% over the long-term for the developing power supply plan.

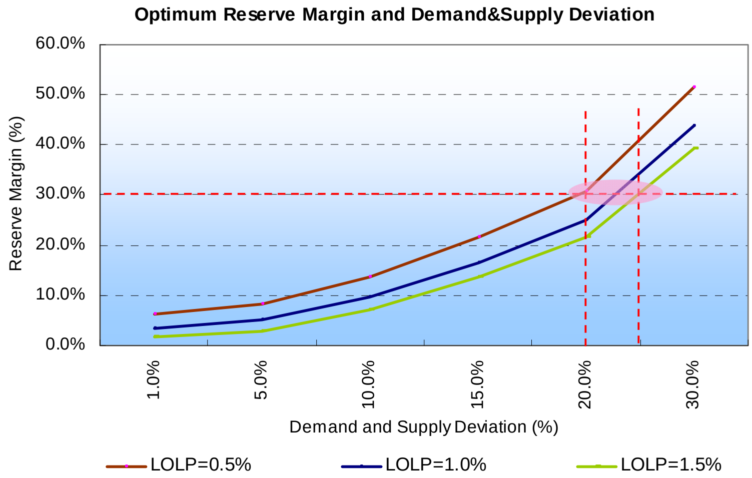


Source: PSMP Study Team

Fig. 8-18 Relationship between reliability and reserve margin

8.5.3 Setting appropriate reserve margin by consideration of delay risk of the project implementation

In the case of developing an appropriate power supply plan that corresponds to the assumed power demand, it is necessary to set an appropriate reserve margin in consideration of delay risks connected to project implementation, and fluctuation risks of the power demand forecast. As indicated in the following figure, the appropriate reserve margin is assumed to be at around 30% when the fluctuation probability of such risks is considered.

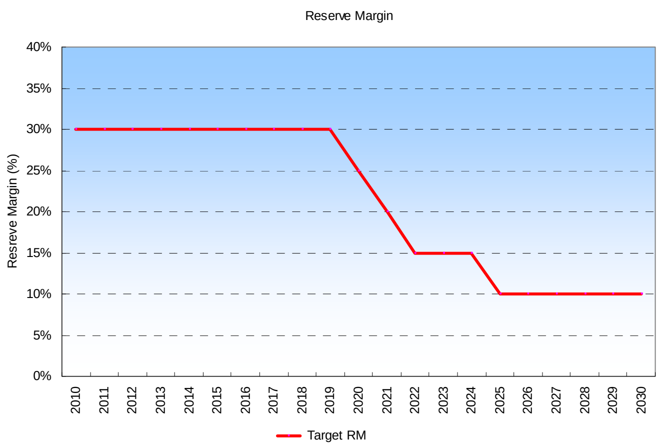


Source: PSMP Study Team

Fig. 8-19 Demand and fluctuation of supply and reserve margin

8.5.4 Reserve margin scenario

Therefore, over the short and mid-terms, the reserve margin is targeted at around 30% in consideration of the delay risks of project implementation, and the reserve margin will decrease gradually afterwards, and will reach 10% by the long-term period. The power supply plan is to be established based on such a reserve margin scenario.

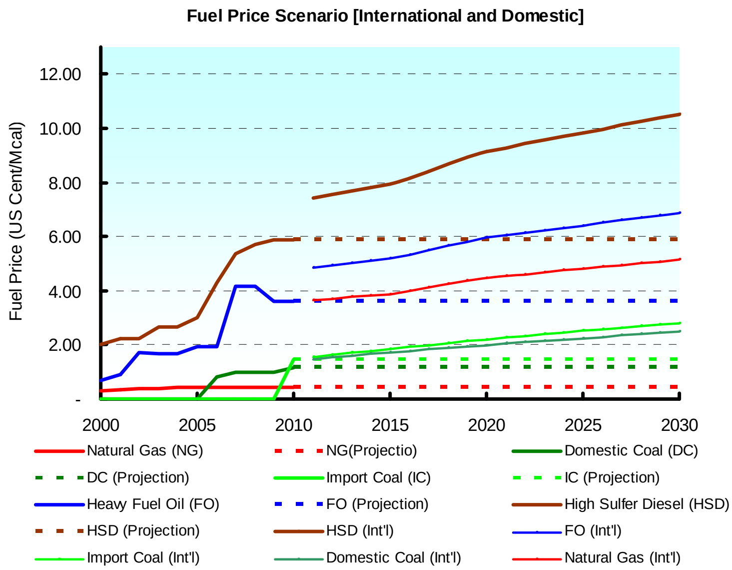


Source: PSMP Study Team

Fig. 8-20 Reserve margin scenario

8.5.5 Setting of fuel prices

The fuel price of gas in Bangladesh is overwhelmingly cheaper than the international price and the price of gas is controlled to be 1/8 of the international price. Under circumstances where primary energy demand is considered to increase greatly as economic growth expands, two cases have been studied; (i) where the domestic controlled price is kept and (ii) where the price changes to the international price, as shown below. Note that for the long-term forecast of the international price, IEA's forecast values are used.



Source: PSMP Study Team

Fig. 8-21 Fuel price scenario (international and domestic price case)

The fuel price scenario which is adopted in this MP is as follows;

Table 8-15 Fuel price scenario towards 2030

Fuel	Unit	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Revised Levelized
Crude Oil Price (2009 US$) 1 IEA E	$/BBL	61.3	79.8	81.2	82.5	83.9	85.3	86.67	89.3	92.0	94.7	97.3	100.0	101.5	103.0	104.5	106.0	107.5	109.0	110.5	112.0	113.5	115.0	77.89
Crude Oil price (2009 US$)	$/MT	468.24	609.55	620.05	630.54	641.04	651.53	662.03	682.39	702.76	723.12	743.48	763.85	775.31	786.76	798.22	809.68	821.14	832.59	844.05	855.51	866.97	878.43	594.96
Crude Oil price (2009 US$)	$/GJ	11.67	15.19	15.45	15.71	15.97	16.23	16.49	17.00	17.51	18.01	18.52	19.03	19.32	19.60	19.89	20.17	20.46	20.74	21.03	21.31	21.60	21.88	14.82
Heavy Fuel Oil Price 2	$/GJ	8.75	11.39	11.59	11.78	11.98	12.17	12.37	12.75	13.13	13.51	13.89	14.27	14.49	14.70	14.91	15.13	15.34	15.56	15.77	15.98	16.20	16.41	11.12
Heavy Fuel Oil Price 2	Cents/Mcal	3.66	4.76	4.84	4.92	5.01	5.09	5.17	5.33	5.49	5.65	5.81	5.97	6.06	6.14	6.23	6.32	6.41	6.50	6.59	6.68	6.77	6.86	4.65
Low Sulfur Diesel 3	$/GJ	14.00	18.22	18.54	18.85	19.16	19.48	19.79	20.40	21.01	21.62	22.23	22.84	23.18	23.52	23.86	24.21	24.55	24.89	25.23	25.58	25.92	26.26	17.79
Low Sulfur Diesel 3	Cents/Mcal	5.85	7.62	7.75	7.88	8.01	8.14	8.27	8.53	8.78	9.04	9.29	9.55	9.69	9.83	9.97	10.12	10.26	10.40	10.55	10.69	10.83	10.98	7.43
High Sulfur Diesel 3	$/GJ	13.41	17.46	17.76	18.06	18.37	18.67	18.97	19.55	20.13	20.72	21.30	21.88	22.21	22.54	22.87	23.20	23.53	23.85	24.18	24.51	24.84	25.17	17.05
High Sulfur Diesel 3	Cents/Mcal	5.61	7.30	7.43	7.55	7.68	7.80	7.93	8.17	8.42	8.66	8.90	9.15	9.28	9.42	9.56	9.70	9.83	9.97	10.11	10.25	10.38	10.52	7.13
Natural Gas Price 4	$/GJ	6.56	8.54	8.69	8.84	8.98	9.13	9.28	9.56	9.85	10.13	10.42	10.70	10.86	11.03	11.19	11.35	11.51	11.67	11.83	11.99	12.15	12.31	8.34
Natural Gas Price 4	Cents/Mcal	2.74	3.57	3.63	3.69	3.75	3.82	3.88	4.00	4.12	4.24	4.36	4.47	4.54	4.61	4.68	4.74	4.81	4.88	4.94	5.01	5.08	5.15	3.49
LPG 7	$/GJ	8.53	11.10	11.30	11.49	11.68	11.87	12.06	12.43	12.80	13.17	13.54	13.92	14.12	14.33	14.54	14.75	14.96	15.17	15.38	15.59	15.79	16.00	10.84
LPG 7	Cents/Mcal	3.57	4.64	4.72	4.80	4.88	4.96	5.04	5.20	5.35	5.51	5.66	5.82	5.90	5.99	6.08	6.17	6.25	6.34	6.43	6.51	6.60	6.69	4.53
Imported Coal 5	$/Ton	73.80	73.80	78.10	82.10	86.20	90.00	93.80	97.50	101.10	104.60	108.10	111.40	114.70	118.00	121.20	124.30	127.40	130.50	133.40	136.40	139.30	142.20	83.22
Imported Coal 5	$/GJ	3.48	3.48	3.68	3.87	4.06	4.24	4.42	4.60	4.77	4.93	5.10	5.25	5.41	5.56	5.71	5.86	6.00	6.15	6.29	6.43	6.57	6.70	3.92
Imported Coal 5	Cents/Mcal	1.45	1.45	1.54	1.62	1.70	1.77	1.85	1.92	1.99	2.06	2.13	2.19	2.26	2.32	2.39	2.45	2.51	2.57	2.63	2.69	2.74	2.80	1.64
Imported coal incl. transport	$/Ton	88.80	88.80	93.10	97.10	101.20	105.00	108.80	112.50	116.10	119.60	123.10	126.40	129.70	133.00	136.20	139.30	142.40	145.50	148.40	151.40	154.30	157.20	96.89
Imported coal incl. transport	$/GJ	4.19	4.19	4.39	4.58	4.77	4.95	5.13	5.30	5.47	5.64	5.80	5.96	6.11	6.27	6.42	6.57	6.71	6.86	6.99	7.14	7.27	7.41	4.57
Imported coal incl. transport	Cents/Mcal	1.75	1.75	1.83	1.91	1.99	2.07	2.14	2.22	2.29	2.36	2.43	2.49	2.56	2.62	2.68	2.74	2.81	2.87	2.92	2.98	3.04	3.10	1.91
Domestic coal 6	$/Ton	85.38	85.38	89.51	93.36	97.30	100.95	104.61	108.16	111.63	114.99	118.36	121.53	124.70	127.87	130.95	133.93	136.91	139.89	142.68	145.57	148.35	151.14	93.16
Domestic coal	$/GJ	3.35	3.35	3.51	3.66	3.82	3.96	4.10	4.24	4.38	4.51	4.64	4.77	4.89	5.02	5.14	5.25	5.37	5.49	5.60	5.71	5.82	5.93	3.65
Domestic coal	Cents/Mcal	1.40	1.40	1.47	1.53	1.60	1.65	1.71	1.77	1.83	1.89	1.94	1.99	2.04	2.10	2.15	2.20	2.24	2.29	2.34	2.39	2.43	2.48	1.53

Source: PSMP Study Team

8.6 Target setting of long-term power source configuration in FY2030

8.6.1 Screening analysis

(1) Methodology

The screening analysis consists of a combination of the fuel/cost graph (upper) and the electric power demand duration curve (lower), shows which demand uses which power supply, i.e., economically optimal combination of power supplies. Therefore, this study, in its 1st step, calculates the optimal power supply configuration using the screening analysis.

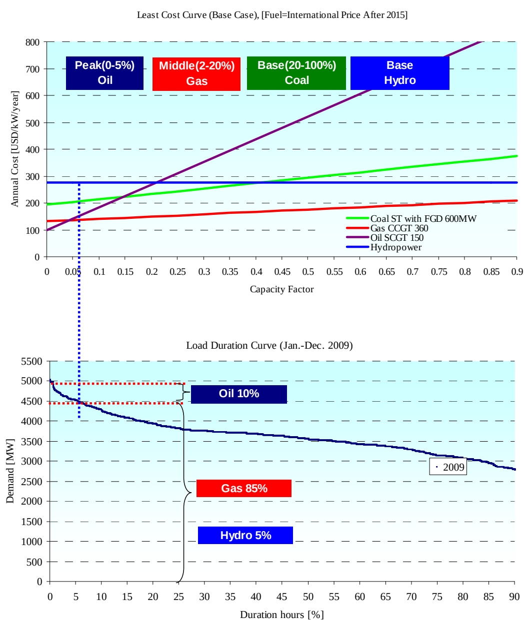
(2) Study result

(a) Domestic controlled price case

If the current model where the fuel price is controlled is used as the basic case, the analysis result shows the optimal power supply configuration of oil: 10%, gas: 85%, and hydroelectric power: 5%; i.e., the current configuration is judged to be economically superior.

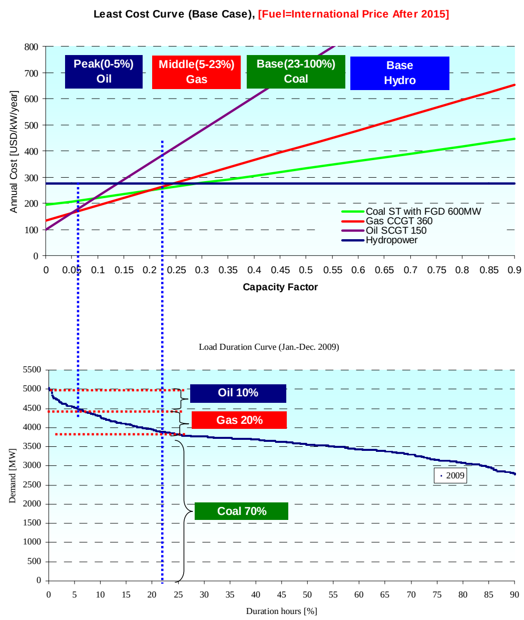
(b) International price case

The prerequisite that allows the current optimal power supply configuration is that the gas price is greatly cheaper than the international price. If the fuel price is assumed to increase because of the tight demand of primary energy, the optimal power supply configuration ratio will be oil: 10%, gas: 20%, and coal: 70%.



Source: PSMP Study Team

Fig. 8-22 Screening analysis (base case)

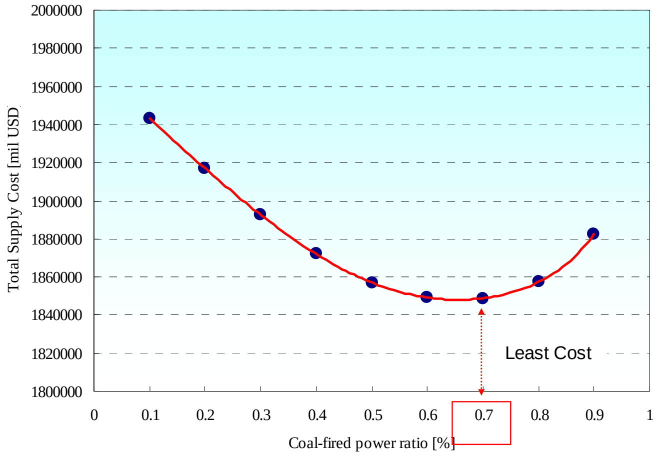


Source: PSMP Study Team

Fig. 8-23 Screening analysis (high case)

8.6.2 Calculation of optimal power supply configuration (PDPAT calculation value)

Since, in the screening analysis, the study is done with the prerequisite that all the power plants have the same economic characteristics and fuel efficiency in each power source type, the result is a little different from the actual operation level in the power plant. Therefore, in step 2, a study is done using the demand/supply operations simulation, which allows for a more realistic power plant operation pattern to be considered. As a result, when the ratio of coal is about 70%, the power source is the most economic as shown in the screening analysis result and as shown below



Source: PSMP Study Team

Fig. 8-24 Calculation of optimal power supply configuration (PDPAT calculation value)

8.6.3 Formulation of most economic scenario

The figure below depicts the general demand fluctuation and generating operational conditions on a typical day. Both nuclear and coal-fired power stations demonstrate several advantages over a stable fuel supply system and economic efficiency, so that the systems are suitable for base generation power. Gas (LNG) power stations are more suitable for mid-generation power due to environmental adaptability and operations capability as compared with other generations. Oil and hydro powers are able to operate flexibly over demand fluctuations; hence these powers are suitable for peak generations in general. In Bangladesh, domestic gas prices are one tenth of the international market prices. If the fuel price is assumed to increase because of the tight demand for primary energy, the optimal power supply configuration ratio will be oil: 10% for peak, gas: 20% for middle and peak, and coal: 70% for base generation.

Table 8-16 characteristic of base-middle-peak generation

		Base			Middle	Peak		
		Hydro	Nucear	coal	Gas/LNG	Oil	Hydro (Pumpted storage)	Hydro (Dam/ Pndage)
Economic condition	Fixed	High			Low			High
	Variable	-	Low		Middle	High		-
Operational condition	Start up duration	Fast	Slow	Middle			Fast	
	Load control	-	-	Slow	Middle		Fast	

Source: PSMP Study Team

8.7 Detailed study for realizing long-term target

8.7.1 Setting scenario of power development plan

The following scenarios are examined in consideration of uncertain events in regards to the power development plan.

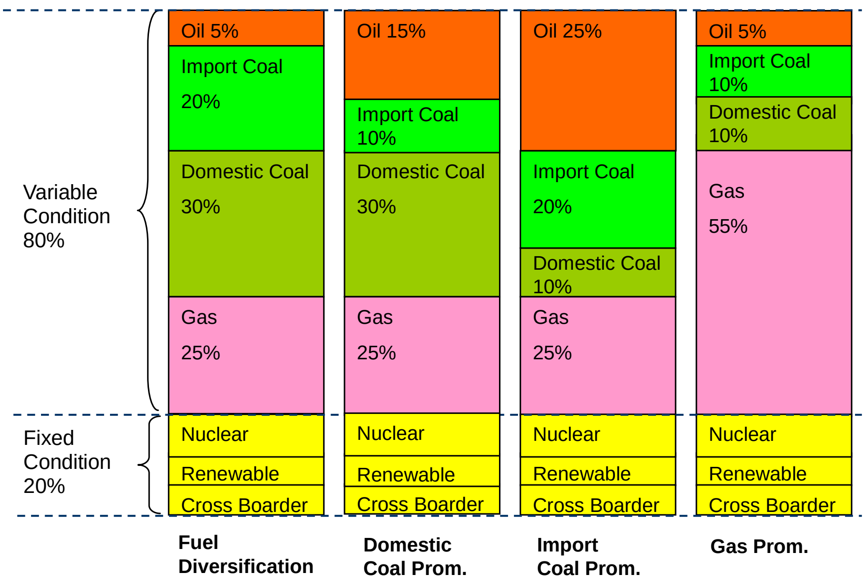
Table 8-17 Power development scenario

Scenario	Concept
Fuel Diversified Scenario (Base case)	Optimum power sources development plan, securing fuel supply via multiple sources based on coal development (developing new domestic mining, increasing existing mining capacity, securing imported coal) ; natural gases, fossil fuels (heavy and light oil), renewable energy.
Domestic Coal Promotion Scenario	For the Base Scenario, fuel supply mainly via a large-scale increase in production at domestic mining including strip mining is considered.
Import Coal Promotion Scenario	For the Base Scenario, fuel supply comes mainly from imported coal due to considerations regarding the impossibility or a long period to develop domestic mining.
Gas Promotion Scenario	For the Base Scenario, fuel supply mainly comes from new domestic gas development, and gas procurement secured from a long-term perspective.

Source: PSMP Study Team

8.7.2 Determination of power development scenario, being closely-interlinked with primary energy supply

The power development plan is closely-interlinked with prime energy supply. The government plan for renewable, cross boarder, and the nuclear power generation plan is provided in light of the power development plan. As detailed in chapter 5, the gas supply scenario will decrease gradually from its peak in 2017. In considering factors such as the construction lead time for gas-fired power stations, the government plan for the gas fired power station should be given in regards to the power development plan in the same manner. Therefore, the power development scenario is to be determined in combination with coal and oil as a variable condition.



Source: PSMP Study Team

Fig. 8-25 Fuel-wise composition for each scenario

8.7.3 Cross border trading

The cross border trading with the neighboring countries is meaningful not only for import power to supplement Bangladesh's power supply, but also for export power to the neighboring countries when sufficient power in Bangladesh due to seasonal and/or time difference. This could improve the overall system efficiency and reliability by effective plant utilization.

8.7.4 Power development plan

The detailed plan of power development by fuel diversification scenario is as follows,

Table 8-18 Unit additions and system reliability indices (Fuel Diversification scenario)

FY		Unit Additions, Number of Unit								Cross Border [MW]	Installed Capacity [MW]	System Reliability Indices		
	Peak Load [MW]	Domestic Coal 600MW	Domestic Coal 1,000MW	Import Coal 600MW	Gas CC 750MW	Gas CC 450MW	FO Engine 100MW	Nuclear 1,000MW	Hydro 100MW			LOLP [%]	ENS. GWH	Reserve Margin [%]
2016	11,405			2		1			1	250	14,943	0.001%	0	20.57
2017	12,644			3	1	1					16,399	0.000%	0	23.38
2018	14,014			1	1			1		500	19,249	0.000%	0	31.16
2019	15,527	2					2				20,649	0.000%	0	26.26
2020	17,304	1			1		2	1			22,509	0.000%	0	26.71
2021	18,838						1			500	23,809	0.006%	0	18.39
2022	20,443	1					1			750	24,961	0.017%	0	14.96
2023	21,993	1		1			1			1,000	26,954	0.006%	0	16.57
2024	23,581	2						1			28,966	0.011%	0	15.72
2025	25,199						1	1			29,717	0.079%	0	12.19
2026	26,838	1		2			2				31,388	0.114%	0	11.37
2027	28,487		1	2			1				33,513	0.126%	0	11.20
2028	30,134		2				1				35,253	0.277%	0	9.11
2029	31,873		2	2			2				37,263	0.110%	0	11.94
2030	33,708		1	1							38,685	0.321%	0	9.14
Total		8	6	14	3	2	14	4	1					
TotalMW		4,800	6,000	8,400	2,250	900	1,400	4,000	100	3,000	30,600			

Source: PSMP Study Team

Table 8-19 Year-wise power development plan (Fuel diversification scenario)

Station Name	Fuel Type	Type	Installed Cap. (MW)	In Service FY	Retirement FY
2011					
Fenchuganj – 3 Yrs rental, U/C	Gas-New	GE	50	2011	2014
Bogra –3 yrs rental, U/C	Gas-New	GE	20	2011	2014
Sikalbaha 150MW Peaking Plant, U/C	Gas-New	CT	150	2011	2031
Siddhirgonj 2X120 MW Peaking Plant (U/C)	Gas-New	CT	210	2011	2031
Fenchuganj CC(2nd Phase), U/C	Gas-New	CC	108	2011	2036
Khulna(quick rental)	FO-New	GE	115	2011	2017
Modanganj(quick rental)	FO-New	GE	102	2011	2017
Julda(quick rental)	FO-New	GE	100	2011	2017
Kadda, Meghna(quick rental)	FO-New	GE	100	2011	2017
Kadda, Sidhirganj(quick rental)	FO-New	GE	100	2011	2017
Keranigong(quick rental)	FO-New	GE	100	2011	2017
Meghnagat(quick rental)	FO-New	GE	100	2011	2017
Noapara, Jessore, Rental, U/C	FO-New	GE	100	2011	2017
Barisal, Rental,U/C	FO-New	GE	50	2011	2017
Chapai Nawabgonj(quick rental)	FO-New	GE	50	2011	2017
Katakhali(quick rental)	FO-New	GE	50	2011	2017

Station Name	Fuel Type	Type	Installed Cap. (MW)	In Service FY	Retirement FY
Noapara(quick rental)	FO-New	GE	40	2011	2017
Ghorashal (quick rental)	HSD-New	GE	145	2011	2014
Bheramara, Rental , U/C	HSD-New	GE	100	2011	2014
Siddirganj(quick rental)	HSD-New	GE	100	2011	2014
Khulna(quick rental)	HSD-New	GE	55	2011	2014
Pagla, Narayaganj(quick rental)	HSD-New	GE	50	2011	2014
Thakurgao, Rental, U/C	HSD-New	GE	50	2011	2014
Total MW			2,045		
2012					
Ashuganj 50	Gas-New	GE	50	2012	2032
Syedpur Peaking Plant	FO-New	GE	100	2012	2030
Jamalpur Peaking Plant	FO-New	GE	100	2012	2030
Chapai Nababgonj Peaking Plant	FO-New	GE	100	2012	2030
Khulna Peaking Plant	FO-New	GE	100	2012	2030
Dohazari Peaking Plant	FO-New	GE	100	2012	2032
Hathazari Peaking Plant	FO-New	GE	100	2012	2032
FaridpurPeaking Plant	FO-New	GE	50	2012	2032
Baghabari Peaking Plant	FO-New	GE	50	2012	2032
Katakhali Peaking Plant	FO-New	GE	50	2012	2032
Santahar Peaking Plant	FO-New	GE	50	2012	2032
Gopalgonj Peaking Plant	FO-New	GE	100	2012	2032
Bera, Pabna, Peaking Plant	FO-New	GE	70	2012	2032
Doudkandi	FO-New	GE	50	2012	2032
Total MW			1,070		
2013					
Ghorasal, Dual Fuel, Peaking Plant	Gas-New	GE	290	2013	2033
Comilla Peaking, Dual Fuel, Peaking Plant	Gas-New	GE	50	2013	2028
Khulna 150MW , Dual Fuel, Peaking Plant	Gas-New	CT	150	2013	2033
Sirajganj 150MW , Dual Fuel, Peaking Plant	Gas-New	CT	150	2013	2033
Chandpur 150 MW CCPP (BPDB), U/C	Gas-New	CC	150	2013	2038
Sylhet 150 MW CCPP (BPDB), U/C	Gas-New	CC	150	2013	2038
Gazipur 50 MW	FO-New	GE	50	2013	2033
Katakhali, Rajshahi, Peaking Plant	FO-New	GE	50	2013	2028
Raujan 20 MW	FO-New	GE	20	2013	2033
Tangail 20 MW	FO-New	GE	20	2013	2028
Chandpur 15 MW	FO-New	GE	15	2013	2028
Narayanganj 30MW	FO-New	GE	30	2013	2028
Sarishabari, Jamalpur(Solar)	Hydro/RE-New	SP	3	2013	2063
Rajabarihat Goat Development Firm(Solar)	Hydro/RE-New	SP	3	2013	2063
Kaptai Power Plant(Solar)	Hydro/RE-New	SP	5	2013	2063
Patenga Offshore, Chittagong(Wind)	Hydro/RE-New	WP	100	2013	2063
BAHARAMPUR to BHERAMARA Phase-1	Int-conect	IC	500	2013	2063
Total MW			1,736		
2014					
Barapukuria 250MW (3rd unit)	Coal-New-D	ST	125	2014	2044
Kaliakair, Dual Fuel, Peaking Plant	Gas-New	GE	100	2014	2029
Savar, Dual Fuel, Peaking Plant	Gas-New	GE	100	2014	2029
Siddhirgonj 2X150 MW CT(450CC)	Gas-New	CC	450	2014	2039
Haripur 360 MW CCPP (EGCB)	Gas-New	CC	360	2014	2039
Bhola CCPP(2nd unit)	Gas-New	CC	225	2014	2039
Madanganj,Keraniganj CCPP Dual Fuel	Gas-New	CC	225	2014	2039

Station Name	Fuel Type	Type	Installed Cap. (MW)	In Service FY	Retirement FY
Sikalbaha 225 MW Dual Fuel, CC	Gas-New	CC	225	2014	2039
BPDB & RPCL, 150MW	FO-New	GE	150	2014	2034
Total MW			1,960		
2015					
Ashuganj 150 MW (150CC)	Gas-New	CC	150	2015	2040
Bibiana 450 MW CCPP(Ist Unit)	Gas-New	CC	450	2015	2040
Bibiana 450 MW CCPP(2nd Unit)	Gas-New	CC	450	2015	2040
Meghnaghat CCPP (2nd unit) Dual Fuel	Gas-New	CC	450	2015	2040
Serajganj 450 MW CCPP	Gas-New	CC	450	2015	2040
Bheramara 360 MW CCPP (NWPGC)	Gas-New	CC	360	2015	2040
Bhola 150MW CCPP(Ist unit), BPDB	Gas-New	CC	150	2015	2040
Total MW			2,460		
2016					
Khulna South 600 MW ST #1	Coal-New-I	ST	600	2016	2045
Khulna South 600 MW ST #2	Coal-New-I	ST	600	2016	2046
North Dhaka 450MW CCPP	Gas-New	CC	450	2016	2040
Karnafuli Hydro (#6&7, 2x50 MW)	Hydro/RE-New	HY	100	2016	2066
PALLATANA to COMILLA	Int-conect	IC	250	2016	2066
Total MW			2,000		
2017					
Chittagong 600 MW ST #1	Coal-New-I	ST	600	2017	2045
Chittagong 600 MW ST #2	Coal-New-I	ST	600	2017	2046
Chittagong South 600MW #1	Coal-New-I	ST	600	2017	2047
Meghnaghat Large #1, 750 MW, CC	Gas-New	CC	750	2017	2042
Ashuganj 450 MW CCPP	Gas-New	CC	450	2017	2041
Total MW			3,000		
2018					
Megnagatt 600MW #1	Coal-New-I	ST	600	2018	2048
Keraniganj, 750 MW, CC	Gas-New	CC	750	2018	2043
Myanmmer to Bangladesh (should refer from PGCB PP)	Hydro/RE-New	IC	500	2018	2068
Rooppur Nuclear # 1, 1000 MW	Nuclear	Nuclear	1,000	2018	2058
Total MW			2,850		
2019					
B-K-D-P 1 600MW #1	Coal-New-D	ST	600	2019	2049
B-K-D-P 1 600MW #2	Coal-New-D	ST	600	2019	2049
Comilla Peaking	FO-New	GE	100	2019	2033
Jessore Peaking	FO-New	GE	100	2019	2034
Total MW			1,400		
2020					
B-K-D-P 1 600MW #3	Coal-New-D	ST	600	2020	2050
Meghnaghat Large #2, 750 MW, CC	Gas-New	CC	750	2020	2044
Ashuganj Peaking	FO-New	GE	200	2020	2035
Rooppur Nuclear # 2, 1000 MW	Nuclear	Nuclear	1,000	2020	2061
Total MW			2,550		
2021					
Khulna Center Peaking	FO-New	GE	100	2021	2036
BAHARAMPUR to BHERAMARA Phase-2	Int-conect	IC	500	2021	2071
Total MW			600		
2022					
B-K-D-P 1 600MW #4	Coal-New-D	ST	600	2022	2052
Halishahar Peaking	FO-New	GE	100	2022	2037

Station Name	Fuel Type	Type	Installed Cap. (MW)	In Service FY	Retirement FY
SILCHAR to FENCHUGANJ 1	Int-conect	IC	750	2022	2072
Total MW			1,450		
2023					
B-K-D-P 2 600MW #1	Coal-New-D	ST	600	2023	2053
Matarbari 600MW #1	Coal-New-I	ST	600	2023	2053
Jhenaidah Peaking	FO-New	GE	100	2023	2038
Hydro from Nepal (Kishanganj (PURNIA) to Bogra)	Hydro/RE-New	IC	500	2023	2073
Hydro from Bhutan (Alipurduar to Bogra)	Hydro/RE-New	IC	500	2023	2073
Total MW			2,300		
2024					
B-K-D-P 2 600MW #2	Coal-New-D	ST	600	2024	2054
B-K-D-P 2 600MW #3	Coal-New-D	ST	600	2024	2054
Rooppur Nuclear # 3, 1000 MW	Nuclear	Nuclear	1,000	2024	2064
Total MW			2,200		
2025					
Bogra Peaking	FO-New	GE	100	2025	2040
Rooppur Nuclear # 4, 1000 MW	Nuclear	Nuclear	1,000	2025	2065
Total MW			1,100		
2026					
B-K-D-P 2 600MW #4	Coal-New-D	ST	600	2026	2056
Matarbari 600MW #2	Coal-New-I	ST	600	2026	2056
Megnagatt 600MW #2	Coal-New-I	ST	600	2026	2056
Keraniganj Peaking	FO-New	GE	200	2026	2041
Total MW			2,000		
2027					
B-K-D-P 3 1000 MW #1	Coal-New-D	ST	1,000	2027	2057
Mawa 600MW #1	Coal-New-I	ST	600	2027	2057
Mawa 600MW #2	Coal-New-I	ST	600	2027	2057
Rajshahi Peaking	FO-New	GE	100	2027	2042
Total MW			2,300		
2028					
B-K-D-P 3 1000 MW #2	Coal-New-D	ST	1,000	2028	2058
B-K-D-P 4 1000 MW #1	Coal-New-D	ST	1,000	2028	2058
Daudkandi Peaking	FO-New	GE	100	2028	2043
Total MW			2,100		
2029					
B-K-D-P 4 1000 MW #2	Coal-New-D	ST	1,000	2029	2059
B-K-D-P 5 1000 MW #1	Coal-New-D	ST	1,000	2029	2059
Matarbari 600MW #3	Coal-New-I	ST	600	2029	2059
Zajira 600MW #1	Coal-New-I	ST	600	2029	2059
Mymensingh Peaking	FO-New	GE	100	2029	2044
Rangpur Peaking	FO-New	GE	100	2029	2044
Total MW			3,400		
2030					
B-K-D-P 5 1000 MW #2	Coal-New-D	ST	1,000	2030	2060
Matarbari 600MW #4	Coal-New-I	ST	600	2030	2060
Total MW			1,600		

Source: PSMP Study Team

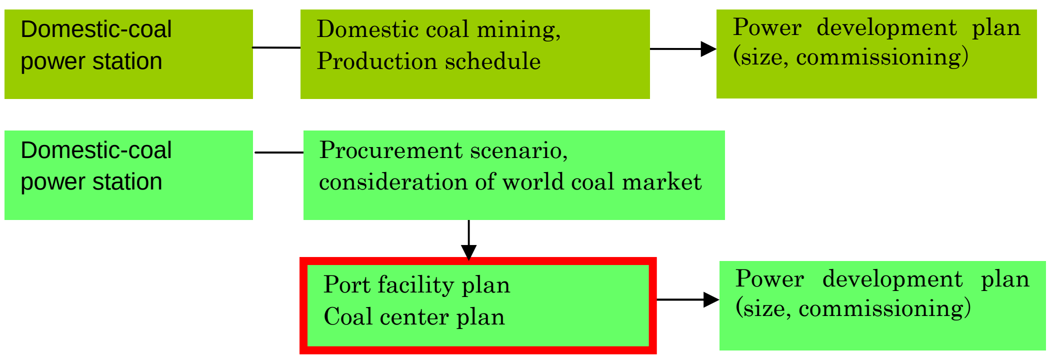
Table 8-20 Net Generation and Fuel consumption (Fuel diversification scenario)

	Net Generation							Fuel Consumption				
	Total [GWH]	D-Coal [GWH]	I-Coal [GWH]	Gas [GWH]	FO [GWH]	HSD [GWH]	Others [GWH]	D-Coal [1,000t/y]	I-Coal [1,000t/y]	Gas [mmcfd]	FO [1,000t/y]	HSD [1,000t/y]
2011	35,474	659	0	28,885	3,948	1,564	416	239	0	792	882	405
2012	39,467	659	0	29,691	7,383	1,320	416	239	0	811	1,614	359
2013	43,882	659	0	32,037	5,165	1,226	4,796	239	0	851	1,205	341
2014	48,713	2,306	0	36,936	4,369	306	4,796	792	0	898	1,067	104
2015	54,047	2,306	0	42,839	3,801	306	4,796	792	0	989	960	104
2016	59,945	2,300	8,081	40,911	3,676	0	4,976	789	3,188	949	919	0
2017	66,457	2,086	19,496	37,734	2,165	0	4,976	722	7,705	921	549	0
2018	73,671	1,652	18,966	35,096	2,165	0	15,791	588	7,590	898	549	0
2019	81,610	9,474	18,539	35,380	2,281	0	15,938	2,810	7,432	898	562	0
2020	90,950	12,931	16,075	37,122	2,427	0	22,395	3,795	6,517	942	598	0
2021	99,838	13,443	18,830	38,078	2,574	0	26,911	3,938	7,542	939	634	0
2022	108,636	17,025	17,883	37,641	2,721	0	33,363	4,962	7,192	917	670	0
2023	118,485	20,407	17,992	35,078	2,867	0	42,140	5,923	7,320	867	706	0
2024	127,368	25,722	17,016	33,459	2,867	0	48,304	7,470	6,964	823	706	0
2025	137,964	26,453	17,885	33,459	3,028	0	57,141	7,669	7,286	806	745	0
2026	147,245	30,166	23,577	33,151	3,192	0	57,158	8,728	9,584	791	785	0
2027	158,456	37,319	28,891	31,401	3,347	0	57,499	10,748	11,740	754	822	0
2028	167,938	48,404	28,456	30,162	3,378	0	57,538	13,924	11,581	714	827	0
2029	180,089	60,352	31,473	27,053	3,604	0	57,608	17,327	12,882	653	886	0
2030	190,752	66,286	35,130	28,653	3,076	0	57,608	19,023	14,335	677	753	0

Source: PSMP Study Team

8.7.5 Concept for formulation of coal development

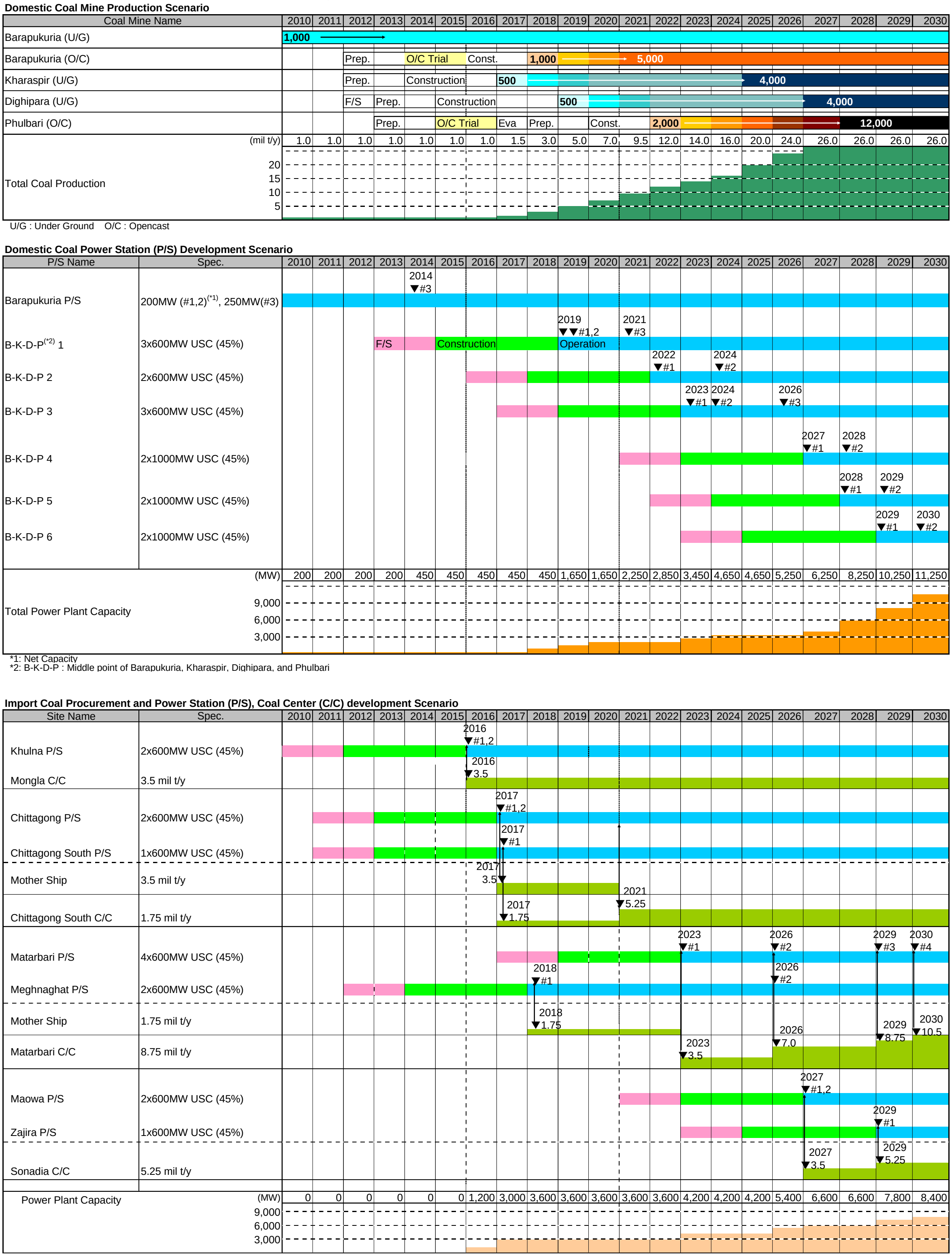
The power supply plan by the domestic coal-fired power station is determined by the mining development and production schedule, and the plan by imported coal-fired power station is also determined by the procurement scenario in consideration of coal demand and the supply balance at the world market, and the construction schedule for the port facility, which dominates the importable capacity of coal from abroad. Fig. 8-26 to Fig. 8-29 indicates coal development and supply plan on each scenario.



Source: PSMP Study Team

Fig. 8-26 Relationship between coal supply plan, infrastructure development plan and power development plan

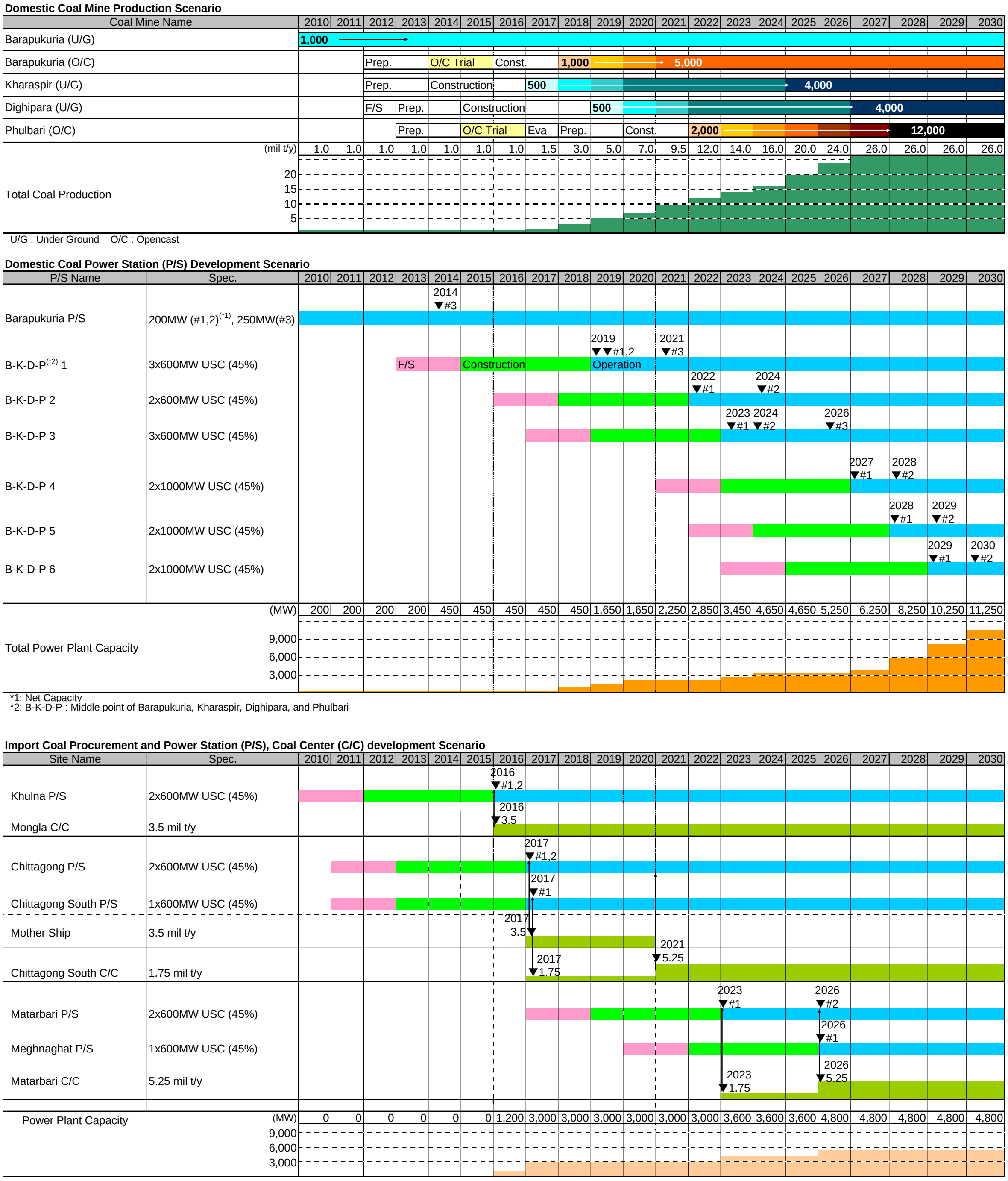
(1) Coal development and supply plan on Base scenario (Fuel Diversification)



Source: PSMP Study Team

Fig. 8-27 Coal development and supply plan on Base scenario (Fuel Diversification)

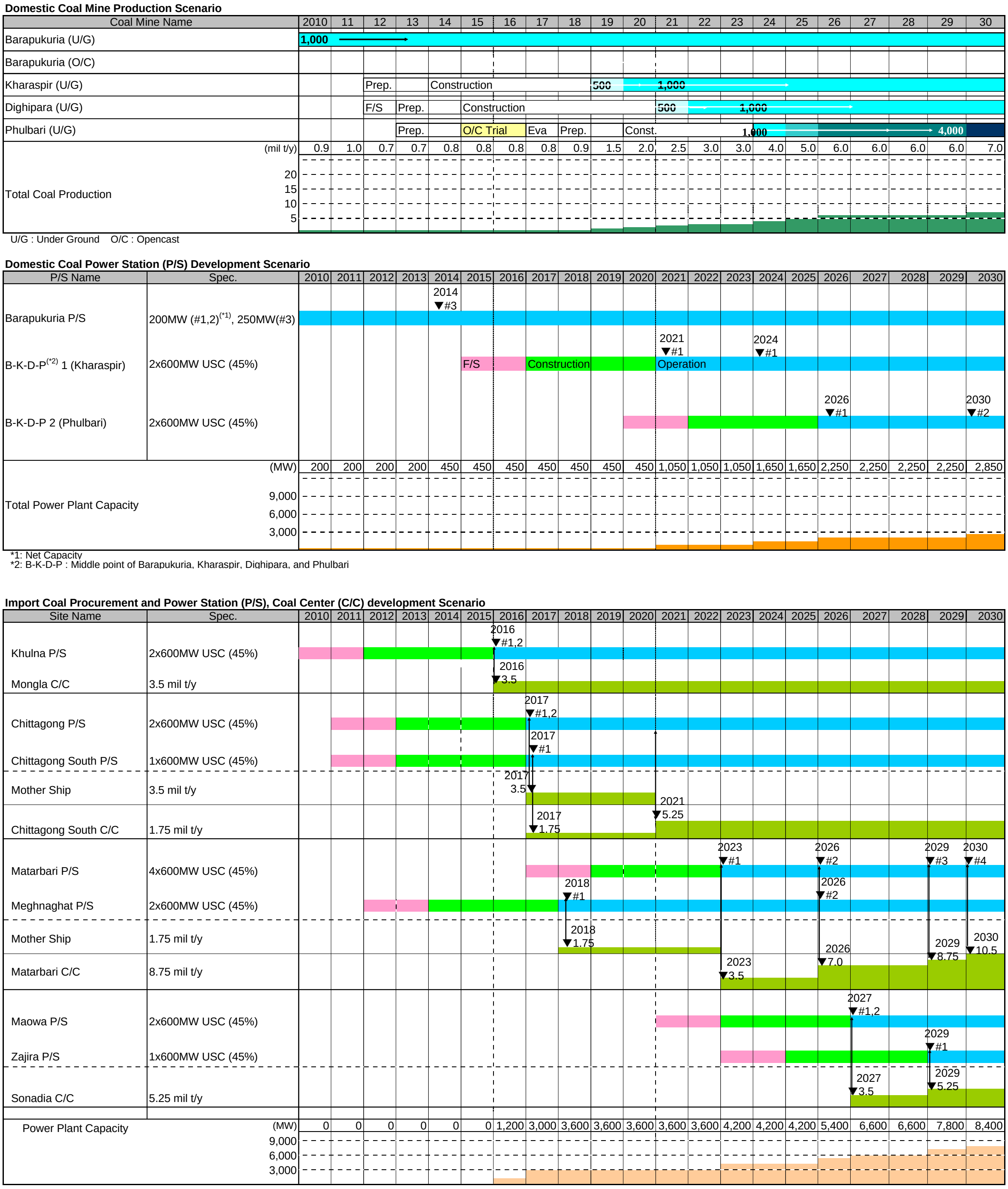
(2) Coal development and supply plan on Domestic Coal Promotion scenario



Source: PSMP Study Team

Fig. 8-28 Coal development and supply plan on Domestic Coal Promotion scenario

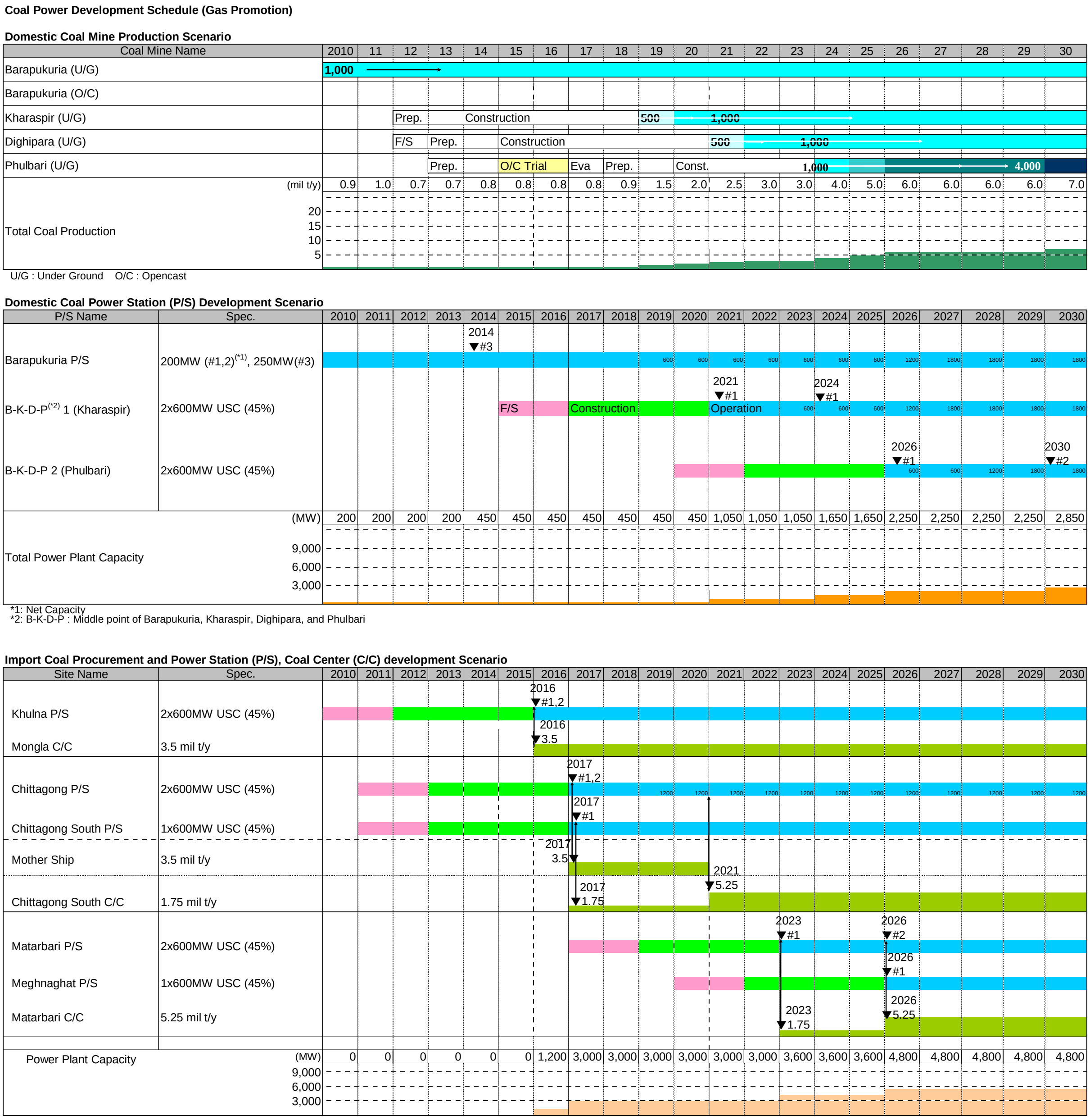
(3) Coal development and supply plan on Import Coal Promotion scenario



Source: PSMP Study Team

Fig. 8-29 Coal development and supply plan on Import Coal Promotion scenario

(4) Coal development and supply plan on Gas Promotion scenario



Source: PSMP Study Team

Fig. 8-30 Coal development and supply plan on Gas Promotion scenario

8.7.6 Determination of optimum power supply plan at each scenario

As indicated in the previous clause, a short-term power supply plan has been combined with the most economical power supply composition in the section for fiscal year 2030, having a fuel procurement restriction condition. Furthermore, the amount of fuel supply is fixed in consideration of the infrastructure necessary for fuel procurement such as coal mining development, the port facility, and the power supply composition for each year is determined as shown in the figure below. In particular, the power supply plan for both domestic and import coal-fired power stations is determined by the mining development schedule for domestic coal and the infrastructure plan such as the port facility and the coal center for import coal. Therefore, it is obviously difficult to attain a composition ratio of 70% coal dominantly under the circumstance of fuel procurement constraints. As a result, an optimum composition ratio of around 50% coal dominant is determined by linear programming and sticking to the upper limit, which was determined by fuel constraints.

Table 8-21 Case number of Power development scenarios

Scenario	Power Demand Forecast			Remarks
Scenario/Demand	Government Policy Scenario	Comparison 7% Scenario	Comparison 6% Scenario	Fuel composition rate at each scenario is different
Fuel Diversification	Case 1-1	Case 1-2	Case 1-3	
Domestic Coal Prom.	Case 2-1	-	-	
Import Coal Prom.	Case 3-1	-	-	
Gas Prom.	Case 4-1	-	-	
Remarks	Fuel composition rate is same on the same scenario with different power demand.			

Source: PSMP Study Team

(1) Fuel Diversification Scenario

To satisfy power demand via the government policy scenario, fuel diversification is promoted multifariously and considerable effort is required to attain domestic and import coal scenarios.

(2) Domestic Coal Promotion Scenario

Based on scenario (1), the risk of the unsuccessful development of import coal procurement will be considered. To make up for this shortage, oil will be increased. (Oil: 6% to 15%)

(3) Import Coal Promotion Scenario

Based on scenario (1), the risk of the unsuccessful development of domestic coal development will be considered. To make up for this shortage, oil will be increased. (Oil: 6% to 28%)

(4) Gas Promotion Scenario

Based on scenario (1), the risk of the unsuccessful development of both import and domestic coal development is considered. To make up for this shortage, gas will be increased. (Gas: 23% to 54%)

Fuel-wise composition at each scenario is shown as follows;

Table 8-22 Fuel-wise composition

Case	Dom. Coal	Imp.Coal	Gas	Oil	Nuclear	RE/Border
Fuel Diversification	29%	22%	23%	6%	10%	10%
Domestic Coal Prom.	29%	12%	23%	15%	10%	10%
Import Coal Prom.	7%	22%	23%	28%	10%	10%
Gas Prom.	7%	12%	54%	6%	10%	10%

Source: PSMP Study Team

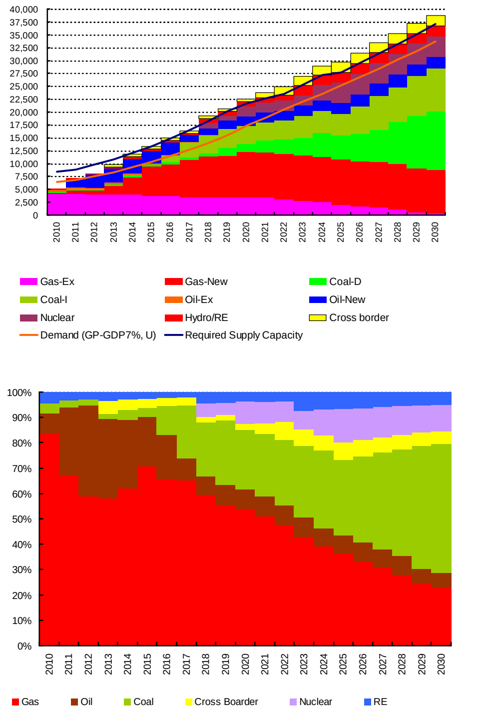


Fig. 8-31 CS1-1:Fuel Diversification

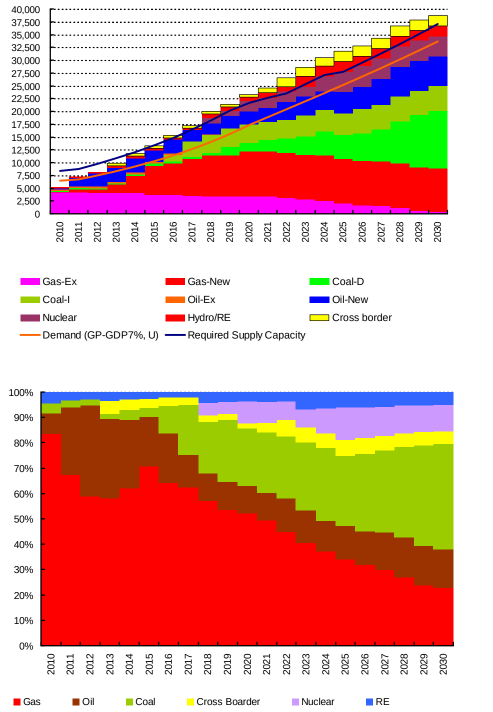


Fig. 8-32 CS2-1:Domestic Coal Prom.

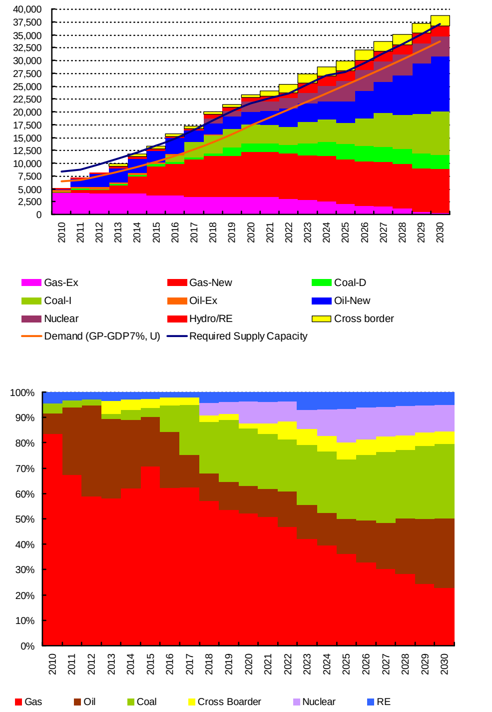


Fig. 8-33 CS3-1:Import Coal Prom.

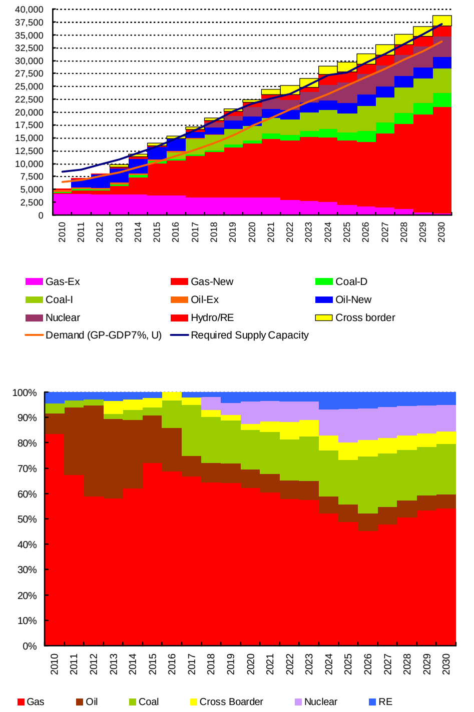


Fig. 8-34 CS4-1:Gas Prom.

Source: PSMP Study Team

Table 8-23 Characteristics of power plants

No.	Power Station	Thermal Parameters	Fuel	Net Unit Capacity (At Grid) [MW]	Auxiliary Power Including Main Transformer Loss	Heat Rate (LHV)				Design Efficiency	Construction Cost			O&M Cost			Others				
						(At Gen. Term Btu/ kWh)	(At Gen. Term kCal/ kWh)	(At Grid kCal/ kWh)	at Minimum Operation	(At Gen.LHV, 100% load)	Equipment Cost $/kW	Installation Cost $/kW (Include utility)	Total Project Cost $/kW	Fixed ($/kW/Year)	Fixed ($/kW/ Month)	Variable ($/MWh)	Fuel Cost ($//MWh)	Time required for Construction	Forced outage Rate	Schedule Maintenance Required (Weeks/year)	Life Time
1	750MW CC (Gas)	1300 degree C class	Gas	750	2.0%	6,206	1,564	1,596	1,877	55.00%	US$429	US$231	US$660	13.2	1.10	0.8	55.6	36	6%	6	25
2	450MW CC (Gas)	1300 degree C class	Gas	450	2.0%	6,206	1,564	1,596	1,877	55.00%	US$600	US$330	US$860	17.2	1.43	1.0	55.6	36	6%	6	25
3	360MW CC (Gas)	1300 degree C class	Gas	360	2.0%	6,206	1,564	1,596	1,877	55.00%	US$618	US$333	US$950	19.0	1.58	1.1	55.6	36	6%	6	25
4	150MW CC (Gas)	1300 degree C class	Gas	150	2.0%	6,206	1,564	1,596	1,877	55.00%	US$761	US$410	US$1,170	23.4	1.95	1.3	55.6	36	6%	6	25
5	300MW ST (Gas)	SubC(16.6MPa,566/566deg)	Gas	300	3.0%	8,031	2,024	2,086	2,196	42.50%	US$832	US$208	US$1,040	20.8	1.73	1.2	72.7	36	6%	6	30
6	150MW CT (Gas)	-	Gas	150	6.0%	9,481	2,389	2,542	3,177	36.00%	US$312	US$315	US$500	10.0	0.83	0.6	88.6	24	4%	4	20
7	120MW CT (Gas)	-	Gas	120	6.0%	10,038	2,530	2,691	3,364	34.00%	US$338	US$286	US$530	10.6	0.88	0.6	93.8	24	4%	4	20
8	Gas Engine (Gas)	GE	Gas	16.5	5.0%	7,230	1,822	1,918	2,019	47.27%	US$800	US$200	US$1,000	20.0	2.6	1.1	66.8	24	4%	2	15
9	1000MW ST USC (Coal)	USC(24.5MPa,600/600deg)	Coal	1000	7.0%	7,585	1,911	2,055	2,163	45.00%	US$1,080	US$270	US$1,350	45.0	3.75	2.6	31.4	48	8%	8	30
10	600MW ST USC (Coal) Domestic	USC(24.5MPa,600/600deg)	Coal	600	5.0%	7,585	1,911	2,012	2,118	45.00%	US$1,200	US$300	US$1,500	50.0	4.17	2.9	30.7	48	8%	8	30
11	600MW ST USC (Coal) Import	USC(24.5MPa,600/600deg)	Coal	600	5.0%	7,585	1,911	2,012	2,118	45.00%	US$1,280	US$320	US$1,600	53.3	4.44	3.0	30.7	48	8%	8	30
12	300MW ST (FO)	SubC(16.6MPa,566/566deg)	F.oil	300	6.0%	8,031	2,024	2,153	2,266	42.50%	US$944	US$236	US$1,180	31.5	2.62	1.8	100.0	36	6%	6	30
13	Gas Engine (FO)	GE	F.oil	16.5	5.0%	7,780	1,961	2,064	2,172	43.93%	US$904	US$226	US$1,130	30.1	2.51	1.7	95.9	24	4%	2	15
14	120MW CT (HSD)	-	HSD	120	6.0%	10,038	2,530	2,691	3,364	34.00%	US$338	US$286	US$600	16.0	1.33	0.9	191.7	24	4%	4	20
15	Gas Engine (HSD)	GE	HSD	16.5	5.0%	7,230	1,822	1,918	2,019	47.27%	US$904	US$226	US$1,130	30.1	2.51	1.7	136.7	24	4%	2	15
16	1000MW Nuclear	Light Water		1000	6.0%	10,343	2,606	2,773	2,919	33.00%			US$2,400					60	6%	8	40

Source: PSMP Study Team

8.8 Quantitative evaluation of 3E (Economy, Environment, Energy Security)

A quantitative evaluation has been examined to find the optimum power development plan in terms of the economy, environment, and energy security risks.

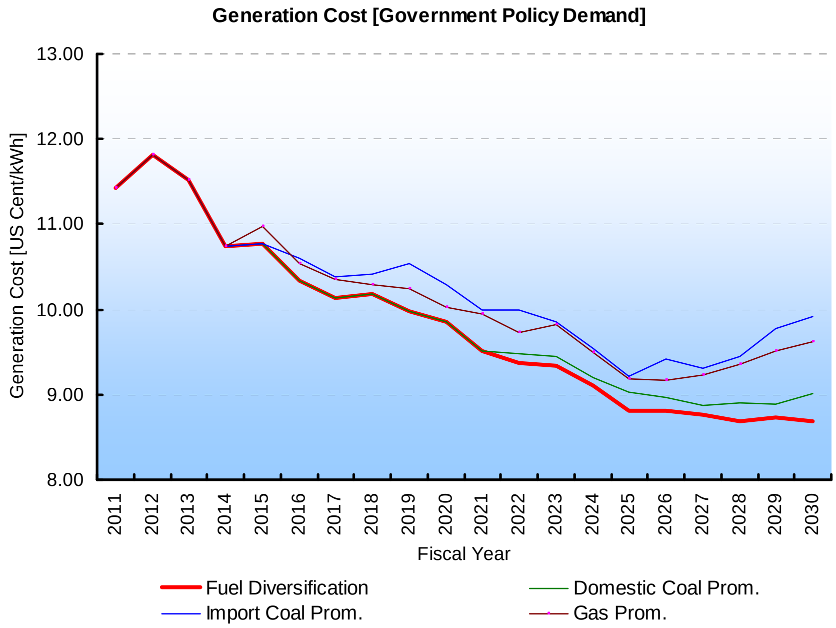
8.8.1 Economic evaluation

(1) Index

Generation cost (US Cent/kWh) of the grid average is adopted as an index for the economic evaluation.

(2) Time-series data

The power generation cost in the base case is as shown in the figure below. The generation cost becomes about 8TK/kWh in the section in fiscal year 2030 afterwards, though the power generation cost faces a peak of about 12TK/kWh in 2013 when the price of fuel becomes an international price value.



Source: PSMP Study Team

Fig. 8-35 Trend of Generation Cost

(3) Quantitative analysis result

Evaluation criteria and results are shown as follows.

Table 8-24 Evaluation criteria

Range (USCent/kWh)	Point
10 ～	1
9.5 ～ 10	2
9.0 ～ 9.5	3
8.5 ～ 9.0	4
～ 8.5	5

Source： PSMP Study Team

Table 8-25 Evaluation Result

Scenario	Index (USCent/kWh)	Point (Economy)
Fuel Diversification	8.68	4
Domestic Coal Prom.	9.01	3
Import Coal Prom.	9.92	2
Gas Prom.	9.62	2

Source： PSMP Study Team

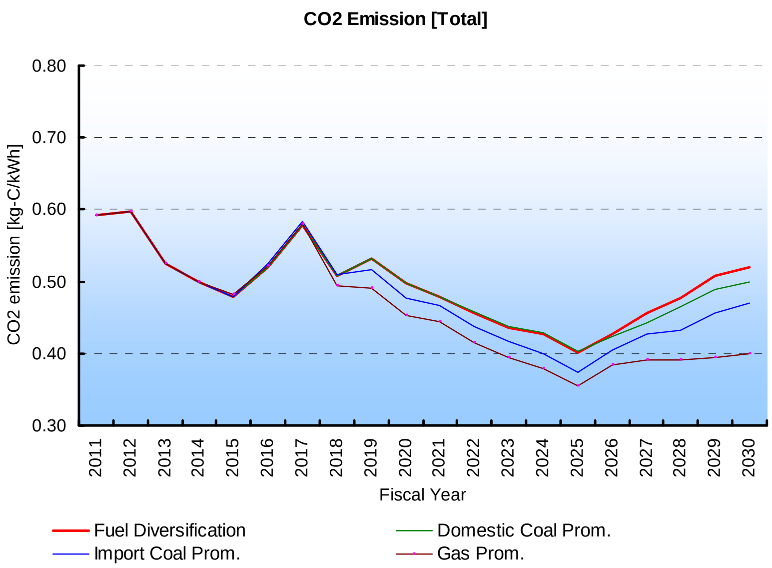
8.8.2 Environmental evaluation

(1) Index

CO2 Emissions (kg-C/kWh) on the grid average has been adopted as an index for the environmental evaluation.

(2) Time-series data

The introduction of a more efficient generation facility such as USC and the abolishment of an existing lower efficient facility, CO2 emissions somewhat increase within the limit range even for coal power generation which has a higher rate of CO2 emissions.



Source: PSMP Study Team

Fig. 8-36 Trend of CO2 Emission Source: PSMP Study Team

(3) Quantitative analysis result

The evaluation criteria and results are shown as follows.

Table 8-26 Evaluation criteria

Range (kg-CO2/kWh)	Point
0.55 ～	1
0.50 ～ 0.55	2
0.45 ～ 0.50	3
0.40 ～ 0.45	4
～ 0.40	5

Source: PSMP Study Team

Table 8-27 Evaluation Result

Scenario	Index (kg-CO2/kWh)	Point (Environment)
Fuel Diversification	0.52	2
Domestic Coal Prom.	0.50	3
Import Coal Prom.	0.47	3
Gas Prom.	0.40	4

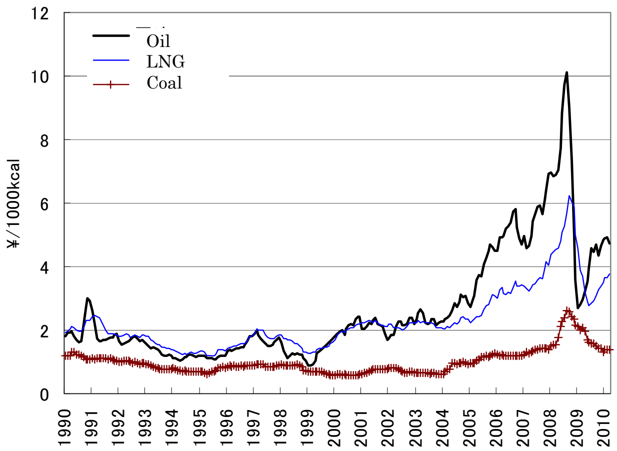
Source: PSMP Study Team

8.8.3 Energy security evaluation

(1) Index

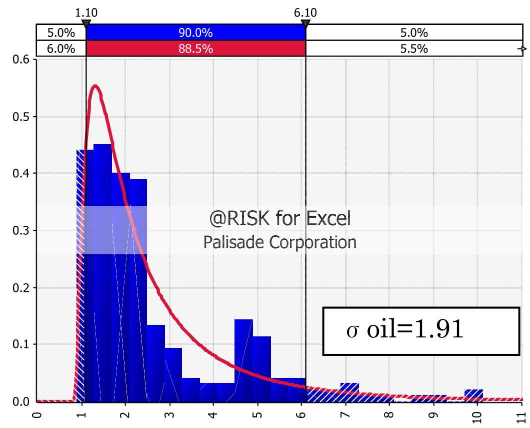
The figure below shows the price of oil, gas, and coal over the past 20 years in the time series. The change level is different as described in the preceding chapter. In this paragraph, it pays attention to such a fluctuation band, the Monte Carlo simulation model via a lognormal distribution was constructed, and the quantitative evaluation of the risk flexibility to the price of the fuel has been examined as follows.

Energy Security Index = (Coal rate) × Standard Deviation(Coal)
+ (Gas rate) × Standard Deviation (Gas)
+ (Oil rate) × Standard Deviation (Oil)



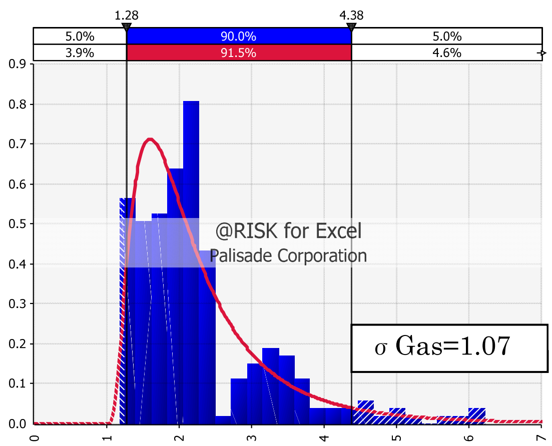
Source: PSMP Study Team

Fig. 8-37 Fuel Price Fluctuation



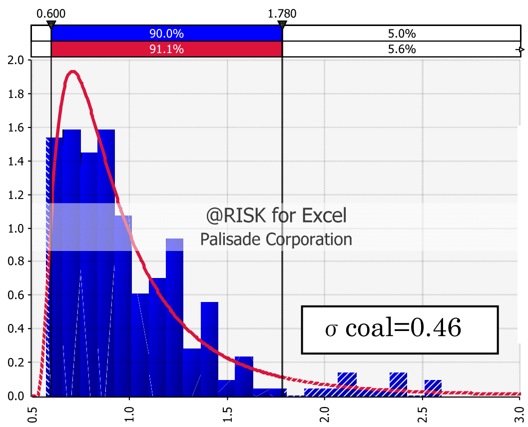
Source: PSMP Study Team

Fig. 8-38 Oil Price Lognormal Distribution



Source: PSMP Study Team

Fig. 8-39 Gas Price Lognormal Distribution

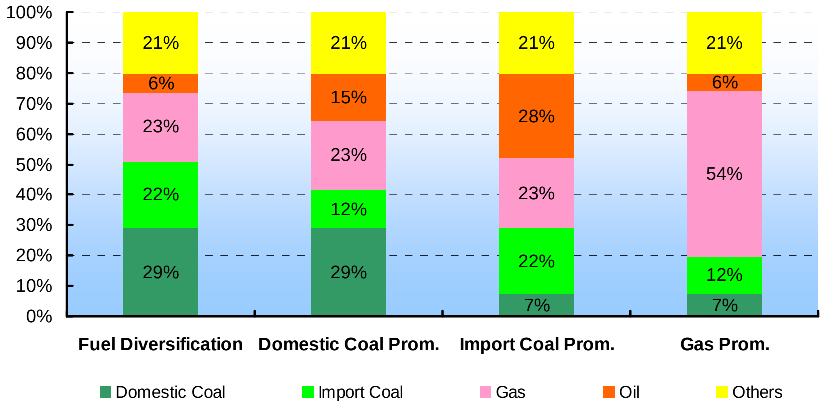


Source: PSMP Study Team

Fig. 8-40 Coal Price Lognormal Distribution

(2) Fuel-wise composition

Fuel-wise composition in FY 2030 is shown as follows.



Case	Domestic Coal	Import Coal	Gas	Oil	Others	Total	Energy Security Index
Risk Index	-	0.46	1.07	1.91	-		-
Fuel Diversification	29%	22%	23%	6%	21%	100%	0.46
Domestic Coal Prom.	19%	12%	23%	15%	21%	100%	0.59
Import Coal Prom.	7%	22%	23%	28%	21%	100%	0.87
Gas Prom.	7%	12%	54%	6%	21%	100%	0.74

Source: PSMP Study Team

Fig. 8-41 Fuel-wise composition

(3) Quantitative analysis result

Evaluation criteria and results are shown as follows.

Table 8-28 Evaluation criteria

Range (Risk index)	Point
0.80 ～	1
0.70 ～ 0.80	2
0.60 ～ 0.70	3
0.50 ～ 0.60	4
～ 0.50	5

Source: PSMP Study Team

Table 8-29 Evaluation Result

Case	Risk Index	Point (Security)
Fuel Diversification	0.46	5
Domestic Coal Prom.	0.59	4
Import Coal Prom.	0.87	1
Gas Prom.	0.74	2

Source: PSMP Study Team

8.8.4 Priority of evaluation item is given weight according to the AHP method

When it undertook a quantitative evaluation of 3E, the weight putting of the evaluation item was conducted utilizing the AHP method. Each scenario was evaluated from the viewpoint of the economy, environment, and overall risk flexibility, and the validity of the diversification base scenario was finally verified. The results are shown as follows.

Table 8-30 Priority of evaluation item is put weight according to the AHP method

Index	1	2	3	Average	Priority
Economy	1	5	4	2.714	0.7
Environment	1/5	1	1/4	0.368	0.1
Energy Security	1/4	4	1	1.000	0.2

Source: PSMP Study Team

Based on the above conditions, the fuel diversification scenario has been selected as the most optimum scenario, maximizing 3E value.

Table 8-31 3E Quantitative evaluation result

Scenario	Economy	Environment	Energy Security	Total Point	Priority
	0.7	0.1	0.2		
Fuel Diversification	4	2	5	4.064	1
Domestic Coal Prom.	3	3	4	3.245	2
Import Coal Prom.	2	3	1	1.845	4
Gas Promotion	2	4	2	2.180	3

Source: PSMP Study Team

8.9 Proposal of mid to long-term power development plan

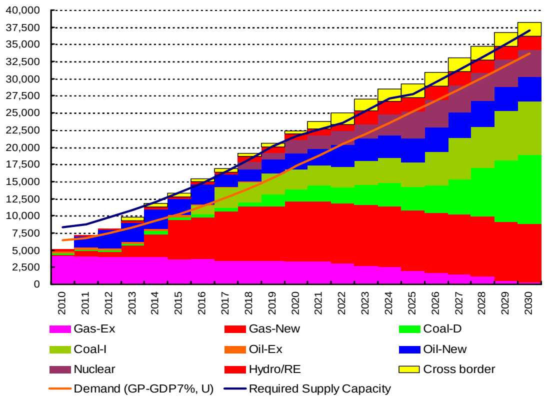
8.9.1 Optimum composition

The component ratio that becomes the maximization of the most optimum power supply composition in the section in fiscal year 2030, that is, 3E is about 50% coal, and becomes about 25% of unifying oil, nuclear power, cross border trade, and renewable energy, though accounting for over 80% and most of the gas in the section in fiscal year 2010. As a result, the optimum fuel-wise composition will shift from the exclusive devotion to gas, to a fuel diversification scenario. On the following page, an optimum scenario is shown at each power demand scenario.

8.9.2 Characteristics of operation condition for optimum power development planning

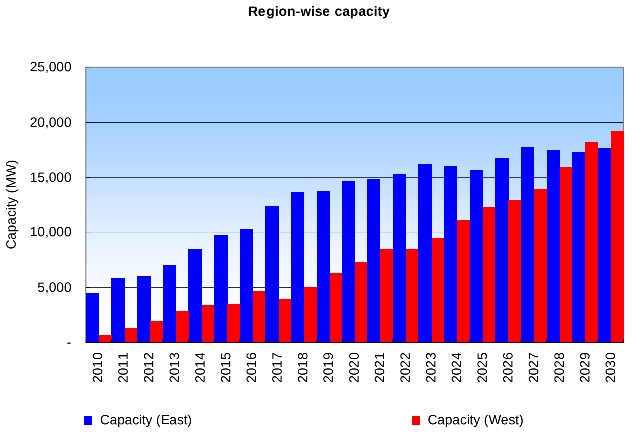
Fig.8-48 ～ 49indicates the characteristics of operating conditions for the optimum power development planning. The recommended focal points are shown as follows.

- Fuel diversification shift from Gas to Coal.
- Gas is shifted from base to middle to peak generation.
- For a higher load period, cheaper coal and other generations are to be for the base load.
- Coal generation with load following capability for even low load period is introduced.



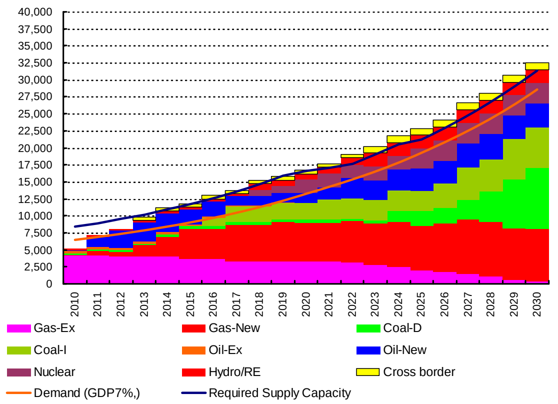
Source: PSMP Study Team

Fig. 8-42 Power development plan by 2030 (Demand: Government policy)



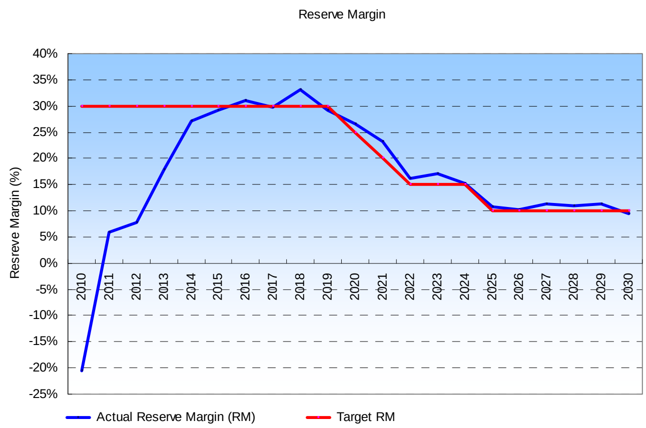
Source: PSMP Study Team

Fig. 8-43 East-West wise Generation capacity



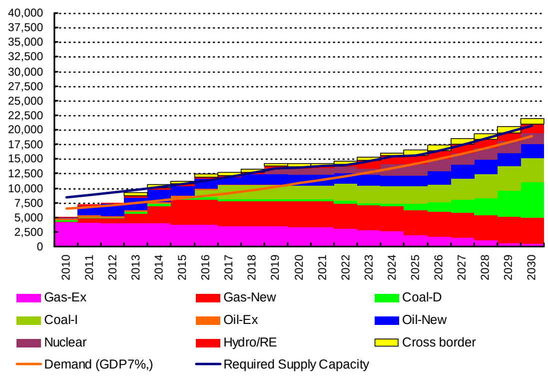
Source: PSMP Study Team

Fig. 8-44 Power development plan by 2030 (Demand: Comparison 7%)



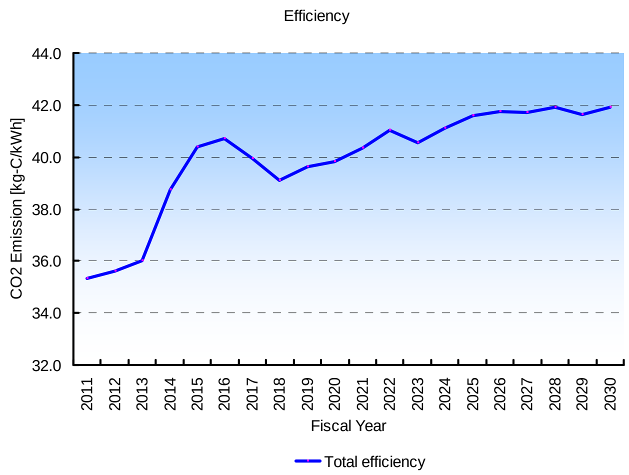
Source: PSMP Study Team

Fig. 8-45 Reliability level and reserve margin



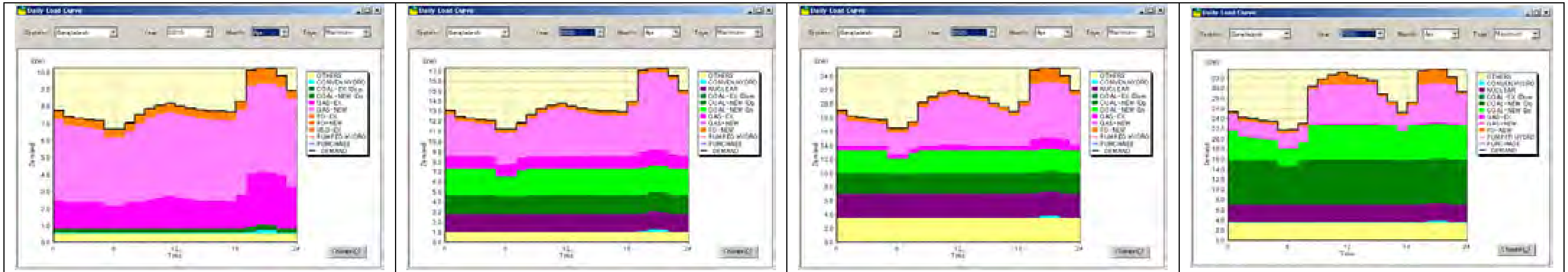
Source: PSMP Study Team

Fig. 8-46 Power development plan by 2030 (Demand: Comparison 6%)



Source: PSMP Study Team

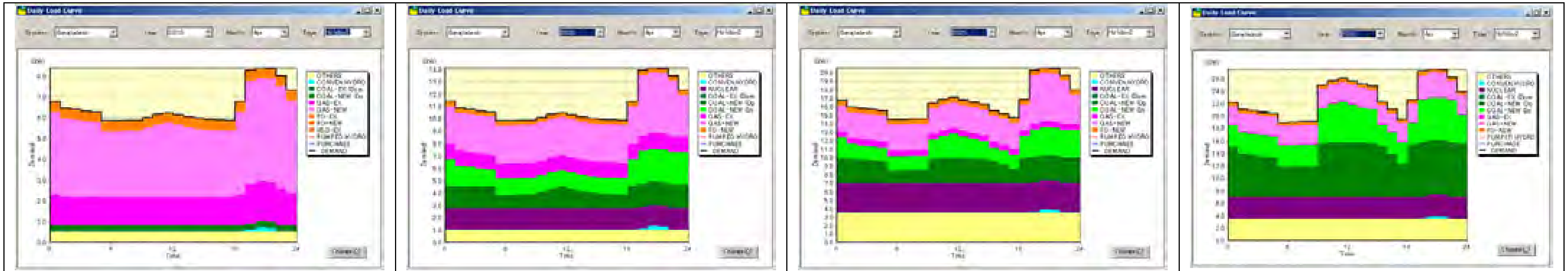
Fig. 8-47 Efficiency



FY2015 FY2020 FY2025 FY2030

Source: PSMP Study Team

Fig. 8-48 Daily Operation Model (Peak-month, Maximum)



FY2015 FY2020 FY2025 FY2030

Source: PSMP Study Team

Fig. 8-49 Daily Operation Model (Peak-month, Minimum)

Table 8-32 Power Development Plan (Fuel Diversification Scenario 2011-2030)

Station Name	Type	Fuel Type	Min Unit Net Capacity (MW)	Max Unit Net Capacity (MW)	In Service FY	Retirement FY	Net Heat Rate (kCal/kWh) Min. Load	Net Heat Rate (KCal/KWh) Incremental	Sping Resv (%)	Forced Outage (%)	Maint. Req'd D/yr	Maint. Class Size (MW)	Fuel Cost (Cents/10^6 KCal) Domst	Fuel Cost Foreign	Fixed O&M ($/KW-mon)	Variable O&M ($/MWh)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total																	**11191**	**12127**	**13865**	**15810**	**17323**	**18975**	**20433**	**23285**	**24687**	**26549**	**27851**	**29005**	**31000**	**33014**	**33767**	**35440**	**37567**	**39309**	**41321**	**42745**
Barapukuria 2x125 MW ST	ST	Coal-Ex	50	100	2009	2036	2800	2350	5	10	60	100	1527	0	5.95	5.20	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Barapukuria 250MW (3rd unit)	ST	Coal-New-D	58	250	2014	2044	2670	2295	5	10	60	125	1527	0	4.69	3.22				250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
B-K-D-P 1 600MW #1	ST	Coal-New-D	180	600	2019	2049	2118	1966	5	8	60	600	1527	0	4.17	2.85									600	600	600	600	600	600	600	600	600	600	600	600
B-K-D-P 1 600MW #2	ST	Coal-New-D	180	600	2019	2049	2118	1966	5	8	60	600	1527	0	4.17	2.85									600	600	600	600	600	600	600	600	600	600	600	600
B-K-D-P 1 600MW #3	ST	Coal-New-D	180	600	2020	2050	2118	1966	5	8	60	600	1527	0	4.17	2.85											600	600	600	600	600	600	600	600	600	600
B-K-D-P 2 600MW #1	ST	Coal-New-D	180	600	2022	2052	2118	1966	5	8	60	600	1527	0	4.17	2.85												600	600	600	600	600	600	600	600	600
B-K-D-P 2 600MW #2	ST	Coal-New-D	180	600	2024	2054	2118	1966	5	8	60	600	1527	0	4.17	2.85														600	600	600	600	600	600	600
B-K-D-P 3 600MW #1	ST	Coal-New-D	180	600	2023	2053	2118	1966	5	8	60	600	1527	0	4.17	2.85													600	600	600	600	600	600	600	600
B-K-D-P 3 600MW #2	ST	Coal-New-D	180	600	2024	2054	2118	1966	5	8	60	600	1527	0	4.17	2.85														600	600	600	600	600	600	600
B-K-D-P 3 600MW #3	ST	Coal-New-D	180	600	2026	2056	2118	1966	5	8	60	600	1527	0	4.17	2.85																600	600	600	600	600
B-K-D-P 4 1000 MW #1	ST	Coal-New-D	300	1000	2027	2057	2118	1966	5	8	56	600	1527	0	3.75	2.57																	1000	1000	1000	1000
B-K-D-P 4 1000 MW #2	ST	Coal-New-D	300	1000	2028	2058	2118	1966	5	8	56	600	1527	0	3.75	2.57																		1000	1000	1000
B-K-D-P 5 1000 MW #1	ST	Coal-New-D	300	1000	2028	2058	2118	1966	5	8	56	600	1527	0	3.75	2.57																		1000	1000	1000
B-K-D-P 5 1000 MW #2	ST	Coal-New-D	300	1000	2029	2059	2118	1966	5	8	56	600	1527	0	3.75	2.57																			1000	1000
B-K-D-P 6 1000 MW #1	ST	Coal-New-D	300	1000	2029	2059	2118	1966	5	8	56	600	1527	0	3.75	2.57																			1000	1000
B-K-D-P 6 1000 MW #2	ST	Coal-New-D	300	1000	2030	2060	2118	1966	5	8	56	600	1527	0	3.75	2.57																				1000
Khulna South 600 MW ST #1	ST	Coal-New-I	180	600	2016	2045	2118	1966	5	8	60	600	0	1640	4.44	3.04						600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Khulna South 600 MW ST #2	ST	Coal-New-I	180	600	2016	2046	2118	1966	5	8	60	600	0	1640	4.44	3.04						600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
Chittagong 600 MW ST #1	ST	Coal-New-I	180	600	2017	2045	2118	1966	5	8	60	600	0	1640	4.44	3.04							600	600	600	600	600	600	600	600	600	600	600	600	600	600
Chittagong 600 MW ST #2	ST	Coal-New-I	180	600	2017	2046	2118	1966	5	8	60	600	0	1640	4.44	3.04							600	600	600	600	600	600	600	600	600	600	600	600	600	600
Chittagong South 600MW #1	ST	Coal-New-I	180	600	2017	2047	2118	1966	5	8	56	600	0	1640	4.44	3.04							600	600	600	600	600	600	600	600	600	600	600	600	600	600
Matarbari 600MW #1	ST	Coal-New-I	180	600	2023	2053	2118	1966	5	8	56	600	0	1640	4.44	3.04													600	600	600	600	600	600	600	600
Matarbari 600MW #2	ST	Coal-New-I	180	600	2026	2056	2118	1966	5	8	56	600	0	1640	4.44	3.04																600	600	600	600	600
Matarbari 600MW #3	ST	Coal-New-I	180	600	2029	2059	2118	1966	5	8	56	600	0	1640	4.44	3.04																			600	600
Matarbari 600MW #4	ST	Coal-New-I	180	600	2030	2060	2118	1966	5	8	56	600	0	1640	4.44	3.04																				600
Megnagatt 600MW #1	ST	Coal-New-I	180	600	2018	2048	2118	1966	5	8	56	600	0	1640	4.44	3.04								600	600	600	600	600	600	600	600	600	600	600	600	600
Megnagatt 600MW #2	ST	Coal-New-I	180	600	2026	2056	2118	1966	5	8	56	600	0	1640	4.44	3.04																600	600	600	600	600
Mawa 600MW #1	ST	Coal-New-I	180	600	2027	2057	2118	1966	5	8	56	600	0	1640	4.44	3.04																	600	600	600	600
Mawa 600MW #2	ST	Coal-New-I	180	600	2027	2057	2118	1966	5	8	56	600	0	1640	4.44	3.04																	600	600	600	600
Zajira 600MW #1	ST	Coal-New-I	180	600	2029	2059	2118	1966	5	8	56	600	0	1640	4.44	3.04																			600	600
Siddhirgonj 210 MW ST #1	ST	Gas-Ex	89	177	2005	2034	2900	2400	5	8	60	210	3485	0	2.60	2.60	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177	177
Ghorasal 4x210 ST #6	ST	Gas-Ex	89	178	1999	2029	2947	2400	5	8	60	200	3485	0	2.60	2.60	178	178	178	178	178	178	178	178	178	178	178	178	178	178	178	178	178	178	178	
Ghorasal 4x210 ST #5	ST	Gas-Ex	89	178	1995	2025	2947	2400	5	8	60	200	3485	0	2.60	2.60	178	178	178	178	178	178	178	178	178	178	178	178	178	178	178					
Ghorasal 4x210 ST #4	ST	Gas-Ex	89	178	1989	2024	2947	2400	5	8	60	200	3485	0	2.60	2.60	178	178	178	178	178	178	178	178	178	178	178	178	178	178						
Ghorasal 4x210 ST #3	ST	Gas-Ex	89	178	1987	2021	2947	2400	5	8	60	200	3485	0	2.60	2.60	178	178	178	178	178	178	178	178	178	178	178									
Ashuganj 3x150 MW ST #5	ST	Gas-Ex	60	120	1988	2023	2953	2400	5	4	60	150	3485	0	2.60	2.60	120	120	120	120	120	120	120	120	120	120	120	120	120							
Ashuganj 3x150 MW ST #4	ST	Gas-Ex	60	120	1987	2022	2953	2400	5	4	60	150	3485	0	2.60	2.60	120	120	120	120	120	120	120	120	120	120	120	120								
Ashuganj 3x150 MW ST #3	ST	Gas-Ex	60	120	1987	2021	2953	2400	5	4	60	150	3485	0	2.60	2.60	120	120	120	120	120	120	120	120	120	120	120									
Raozan 2X210 ST#2	ST	Gas-Ex	88	175	1998	2028	2990	2400	5	6	60	200	3485	0	2.60	2.60	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175		
Raozan 2X210 ST#1	ST	Gas-Ex	88	175	1993	2026	2990	2400	5	6	60	200	3485	0	2.60	2.60	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175				
Ghorasal 2x55 ST #1	ST	Gas-Ex	20	40	1974	2016	3232	2400	5	10	60	60	3485	0	2.60	2.60	50	50	50	50	50	50														
Ghorasal 2x55 ST #2	ST	Gas-Ex	20	40	1976	2016	3232	2400	5	10	60	60	3485	0	2.60	2.60	30	30	30	30	30	30														
Ashuganj 2x64 MW ST #2	ST	Gas-Ex	30	60	1971	2014	3500	2232	5	7	60	60	3485	0	2.60	2.60	60	60	60	60																
Ashuganj 2x64 MW ST #1	ST	Gas-Ex	30	60	1971	2014	3500	2232	5	7	60	60	3485	0	2.60	2.60	60	60	60	60																
Chittagon (Sikalbaha) 60 MW ST	ST	Gas-Ex	18	36	1984	2019	3540	2558	5	10	60	60	3485	0	2.60	2.60	36	36	36	36	36	36	36	36	36											
NEPC, Haripur BMPP	GE	Gas-Ex	22	110	1999	2016	2000	2000		7	30	100	3485	0	-	4.00	110	110	110	110	110	110														
Jangalia, comilla SIPP	GE	Gas-Ex	7	33	2009	2024	2249	2249		4	30	30	3485	0	1.30	3.25	33	33	33	33	33	33	33	33	33	33	33	33	33	33						
Tangail SIPP (22 MW)	GE	Gas-Ex	2	22	2009	2024	2249	2249		4	30	30	3485	0	1.30	3.25	22	22	22	22	22	22	22	22	22	22	22	22	22	22						
Feni SIPP	GE	Gas-Ex	4	22	2009	2024	2249	2249		4	30	30	3485	0	1.30	3.25	22	22	22	22	22	22	22	22	22	22	22	22	22	22						
Barobkundo SIPP	GE	Gas-Ex	4	22	2009	2024	2249	2249		4	30	30	3485	0	1.30	3.25	22	22	22	22	22	22	22	22	22	22	22	22	22	22						
Kumargao 10 MW (15 Years)	GE	Gas-Ex	2	10	2009	2024	2419	2419		4	30	10	3485	0	1.30	3.25	10	10	10	10	10	10	10	10	10	10	10	10	10	10						
Ullapara, SIPP, REB	GE	Gas-Ex	2	11	2009	2024	2500	2500		4	30	20	3485	0	1.30	3.25	121	121	121	121	121	121	121	121	121	121	121	121	121	121						
Chandina,Mahdabdi,AshuliaSummit , REB	GE	Gas-Ex	7	35	2007	2024	2500	2500		4	30	30	3485	0	1.30	3.25	105	105	105	105	105	105	105	105	105	105	105	105	105	105						
Kumargoan 48MW (3 Years)	GE	Gas-Ex	2	48	2009	2011	2512	2512		4	30	50	3485	0	1.30	3.25	48																			
West Mount Baghabari BMPP	GE	Gas-Ex	14	70	1999	2016	2921	1960		6	30	100	3485	0	-	3.09	70	70	70	70	70	70														
Sahzibazar RPP (3 Years)	GE	Gas-Ex	2	50	2009	2011	3028	3028		4	30	50	3485	0	1.30	3.25	50																			
Sahzibazar RPP (15 Years)	GE	Gas-Ex	2	86	2009	2024	3158	3158		4	30	100	3485	0	1.30	3.25	86	86	86	86	86	86	86	86	86	86	86	86	86	86						
Tongi 100 MW GT	CT	Gas-Ex	30	100	2005	2025	3064	2408		7	30	100	3485	0	1.30	3.25	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100					
Baghabari 100 MW CT	CT	Gas-Ex	30	99	2002	2022	3064	2408		4	30	100	3485	0	1.30	3.25	99	99	99	99	99	99	99	99	99	99	99	99								
Baghabari 71 MW CT	CT	Gas-Ex	21	70	1991	2016	3057	3057		4	30	100	3485	0	1.30	3.25	70	70	70	70	70	70														
Shahjibazar GT 7 units	CT	Gas-Ex	11	38	1968	2009	3062	3062		10	30	60	3485	0	1.30	3.25																				
Shahjibazar2x35 MW CT #2	CT	Gas-Ex	10	34	2001	2023	3062	3062		10	30	60	3485	0	1.30	3.25	34	34	34	34	34	34	34	34	34	34	34	34	34							
Shahjibazar2x35 MW CT #1	CT	Gas-Ex	10	34	2000	2023	3062	3062		10	30	60	3485	0	1.30	3.25	34	34	34	34	34	34	34	34	34	34	34	34	34							
Chittagon (Sikalbaha) BMGT	CT	Gas-Ex	10	10	1987	2019	3540	2558	5	10	60	60	3485	0	2.60	2.60																				
Haripur 3x33 CT #3	CT	Gas-Ex	9	31	1988	2014	3835	3835		5	30	30	3485	0	1.30	3.25	31	31	31	31																
Haripur 3x33 CT #2	CT	Gas-Ex	9	31	1988	2014	3835	3835		5	30	30	3485	0	1.30	3.25	31	31	31	31																
Haripur 3x33 CT #1	CT	Gas-Ex	9	31	1988	2014	3835	3835		5	30	30	3485	0	1.30	3.25	31	31	31	31																
Sylhet 20 MW CT	CT	Gas-Ex	6	19	1987	2014	3969	3969		8	30	20	3485	0	1.30	3.25	19	19	19	19																
Ashuganj CT 56 MW	CT	Gas-Ex	12	40	1986	2014	4258	4258		15	30	40	3485	0	1.30	3.25	40	40	40	40																

Station Name	Type	Fuel Type	Min Unit Net Capacity (MW)	Max Unit Net Capacity (MW)	In Service FY	Retirement FY	Net Heat Rate (kCal/kWh) Min. Load	Net Heat Rate (KCal/KWh) Incremental	Sping Resv (%)	Forced Outage (%)	Maint. Req'd D/yr	Maint. Class Size (MW)	Fuel Cost (Cents/10^6 KCal) Domst /	Foreign	Fixed O&M ($/KW-mon)	Variable O&M ($/MWh)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CDC, Haripur	CC	Gas-Ex	144	360	2002	2027	2027	1479	5	6	45	400	3485	0	1.85	1.43	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360			
CDC, Meghnaghat	CC	Gas-Ex	180	450	2003	2028	1900	1850	5	6	45	500	3485	0	0.70	1.34	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450		
Mymenshing (RPC) 210 MW CC	CC	Gas-Ex	70	175	2006	2031	2000	1900	5	6	45	200	3485	0	6.50	1.30	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
Fenchuganj CC	CC	Gas-Ex	35	88	1994	2022	2090	1950	5	6	45	90	3485	0	1.63	1.69	88	88	88	88	88	88	88	88	88	88	88	88								
Ashuganj 90 MW CC	CC	Gas-Ex	23	56	1984	2014	3483	2400	5	15	45	60	3485	0	1.63	1.69	56	56	56	56																
Ghorasal, Dual Fuel, Peaking Plant	GE	Gas-New	40	290	2013	2033	2019	1902		6	40	200	3485	0	2.60	1.14			290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290	290
Kaliakair, Dual Fuel, Peaking Plant	GE	Gas-New	20	100	2014	2029	2019	1893		6	40	100	3485	0	2.60	1.14			0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Savar, Dual Fuel, Peaking Plant	GE	Gas-New	20	100	2014	2029	2019	1893		6	40	100	3485	0	2.60	1.14			0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Ashuganj – 3 yrs Rental, commissioned	GE	Gas-New	11	55	2010	2013	2019	1893		4	30	60	3485	0	2.60	1.14	55	55	55																	
Fenchuganj (15 Years), commissioned	GE	Gas-New	10	51	2010	2025	2019	1893		4	30	50	3485	0	2.60	1.14	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51					
Ashuganj 50	GE	Gas-New	10	52	2012	2032	2019	1894		4	30	50	3485	0	2.60	1.14		52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
Comilla Peaking, Dual Fuel, Peaking Plant	GE	Gas-New	10	50	2013	2028	2019	1893		6	40	50	3485	0	2.60	1.14			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50		
Fenchuganj – 3 Yrs rental, U/C	GE	Gas-New	10	50	2011	2014	2019	1893		4	30	50	3485	0	2.60	1.14	50	50	50	50																
Bhola (3 Years), Commissioned	GE	Gas-New	7	33	2010	2013	2019	1893		4	30	40	3485	0	2.60	1.14	33	33	33																	
Bogra –3 yrs rental, U/C	GE	Gas-New	4	20	2011	2014	2019	1893		4	30	20	3485	0	2.60	1.14	20	20	20	20																
Siddhirgonj 2X150 MW CT(450CC)	CC	Gas-New	180	450	2014	2039	1877	2984	5	5	45	500	3485	0	1.43	0.98			0	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Ashuganj 150 MW (150CC)	CC	Gas-New	59	150	2015	2040	1877	2972	5	5	45	150	3485	0	1.95	1.34				0	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Khulna 150MW , Dual Fuel, Peaking Plant	CT	Gas-New	45	150	2013	2033	3177	2269		6	40	150	0	4647	0.73	0.50			150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Sikalbaha 150MW Peaking Plant, U/C	CT	Gas-New	45	149	2011	2031	3177	2269		4	30	150	3485	0	0.73	0.50	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149
Sirajganj 150MW , Dual Fuel, Peaking Plant	CT	Gas-New	45	150	2013	2033	3177	2269		6	40	150	0	4647	0.73	0.50			150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Siddhirgonj 2X120 MW Peaking Plant (U/C)	CT	Gas-New	31	104	2011	2031	3738	2670		4	30	100	3485	0	0.88	0.61	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208	208
Keraniganj, 750 MW, CC	CC	Gas-New	300	750	2018	2043	1877	1408	5	5	45	750	3485	0	0.92	0.63								750	750	750	750	750	750	750	750	750	750	750	750	750
Meghnaghat Large #1, 750 MW, CC	CC	Gas-New	300	750	2017	2042	1877	1408	5	5	45	750	3485	0	0.92	0.63						0	750	750	750	750	750	750	750	750	750	750	750	750	750	750
Meghnaghat Large #2, 750 MW, CC	CC	Gas-New	300	750	2020	2044	1877	1408	5	5	45	750	3485	0	0.92	0.63										750	750	750	750	750	750	750	750	750	750	750
Ashuganj 450 MW CCPP	CC	Gas-New	179	450	2017	2041	1877	1410	5	5	45	450	3485	0	1.43	0.98					0	0	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Bibiana 450 MW CCPP(Ist Unit)	CC	Gas-New	180	450	2015	2040	1877	1408	5	5	45	500	3485	0	1.43	0.98				0	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Bibiana 450 MW CCPP(2nd Unit)	CC	Gas-New	180	450	2015	2040	1877	1408	5	5	45	500	3485	0	1.43	0.98				0	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Meghnaghat CCPP (2nd unit) Dual Fuel	CC	Gas-New	180	450	2015	2040	1877	1408	5	6	50	500	3485	0	2.18	1.49				0	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
North Dhaka 450MW CCPP	CC	Gas-New	179	450	2016	2040	1877	1410	5	5	45	450	3485	0	1.43	0.98					0	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Serajganj 450 MW CCPP	CC	Gas-New	180	450	2015	2040	1877	1408	5	5	45	500	3485	0	1.43	0.98					450	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Bheramara 360 MW CCPP (NWPGC)	CC	Gas-New	143	360	2015	2040	1877	1410	5	5	45	400	3485	0	1.58	1.08					360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
Haripur 360 MW CCPP (EGCB)	CC	Gas-New	143	360	2014	2039	1877	1410	5	5	45	400	3485	0	2	1.08				360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
Bhola 150MW CCPP(Ist unit), BPDB	CC	Gas-New	59	150	2015	2040	1877	1413	5	5	45	150	3485	0	1.95	1.34				0	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Chandpur 150 MW CCPP (BPDB), U/C	CC	Gas-New	59	150	2013	2038	1877	1413	5	5	45	150	3485	0	1.95	1.34			150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Sylhet 150 MW CCPP (BPDB), U/C	CC	Gas-New	59	150	2013	2038	1877	1413	5	5	45	150	3485	0	1.95	1.34			150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Fenchuganj CC(2nd Phase), U/C	CC	Gas-New	43	108	2011	2036	1877	1629	5	5	45	100	3485	0	1.95	1.34	103	103	103	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108
Bhola CCPP(2nd unit)	CC	Gas-New	90	225	2014	2039	2086	1564	5	5	45	200	3485	0	1.95	1.34				225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Madanganj,Keraniganj CCPP Dual Fuel	CC	Gas-New	90	225	2014	2039	2086	1564	5	6	50	300	0	4647	1.95	1.34				225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Sikalbaha 225 MW Dual Fuel, CC	CC	Gas-New	90	225	2014	2039	2086	1564	5	6	50	400	0	4647	1.95	1.34				225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225	225
Khulna 60 MW ST	ST	FO-Ex	17	33	1973	2016	3540	2558	5	10	60	60	0	4647	2.60	3.00	33	33	33	33	33	33														
khulna 110 MW ST	ST	FO-Ex	27	54	1985	2019	3437	2487	5	10	60	100	0	4647	2.60	3.00	54	54	54	54	54	54	54	54	54											
Syedpur Peaking Plant	GE	FO-New	20	100	2012	2030	2172	2037		6	40	100	0	4647	2.51	1.72		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Jamalpur Peaking Plant	GE	FO-New	20	100	2012	2030	2172	2037		6	40	100	0	4647	2.51	1.72		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Chapai Nababgonj Peaking Plant	GE	FO-New	20	100	2012	2030	2172	2037		6	40	100	0	4647	2.51	1.72		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Khulna Peaking Plant	GE	FO-New	20	100	2012	2030	2172	2037		6	40	100	0	4647	2.51	1.72		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		
Dohazari Peaking Plant	GE	FO-New	20	100	2012	2032	2172	2037		6	40	100	0	4647	2.51	1.72		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Hathazari Peaking Plant	GE	FO-New	20	100	2012	2032	2172	2037		6	40	100	0	4647	2.51	1.72		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
FaridpurPeaking Plant	GE	FO-New	10	50	2012	2032	2172	2037		6	40	50	0	4647	2.51	1.72		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Baghabari Peaking Plant	GE	FO-New	10	50	2012	2032	2172	2037		6	40	50	0	4647	2.51	1.72		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Katakhali Peaking Plant	GE	FO-New	10	50	2012	2032	2172	2037		6	40	50	0	4647	2.51	1.72		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Santahar Peaking Plant	GE	FO-New	10	50	2012	2032	2172	2037		6	40	50	0	4647	2.51	1.72		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
BPDB & RPCL, 150MW	GE	FO-New	30	150	2014	2034	2172	2037		6	40	150	0	4647	2.51	1.72			0	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Khulna(quick rental)	GE	FO-New	23	115	2011	2017	2172	2037		4	40	115	0	4647	2.51	1.72	115	115	115	115	115	115														
Modanganj(quick rental)	GE	FO-New	20	102	2011	2017	2172	2037		4	40	102	0	4647	2.51	1.72	102	102	102	102	102	102														
Gopalgonj Peaking Plant	GE	FO-New	20	100	2012	2032	2172	2037		6	40	100	0	4647	2.51	1.72		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Julda(quick rental)	GE	FO-New	20	100	2011	2017	2172	2037		4	40	100	0	4647	2.51	1.72	100	100	100	100	100	100														
Kadda, Meghna(quick rental)	GE	FO-New	20	100	2011	2017	2172	2037		4	40	100	0	4647	2.51	1.72	100	100	100	100	100	100														
Kadda, Sidhirganj(quick rental)	GE	FO-New	20	100	2011	2017	2172	2037		4	40	100	0	4647	2.51	1.72	100	100	100	100	100	100														
Keranigong(quick rental)	GE	FO-New	20	100	2011	2017	2172	2037		4	40	100	0	4647	2.51	1.72	100	100	100	100	100	100														
Meghnagat(quick rental)	GE	FO-New	20	100	2011	2017	2172	2037		4	40	100	0	4647	2.51	1.72	100	100	100	100	100	100														
Noapara, Jessore, Rental, U/C	GE	FO-New	20	100	2011	2017	2172	2037		4	40	100	0	4647	2.51	1.72	100	100	100	100	100	100														
Bera, Pabna, Peaking Plant	GE	FO-New	14	70	2012	2032	2172	2037		6	40	100	0	4647	2.51	1.72		70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Shikalbaha – 3 yrs rental, commissioned	GE	FO-New	11	55	2010	2013	2172	2037		4	40	60	0	4647	2.51	1.72	55	55	55																	
Barisal, Rental,U/C	GE	FO-New	10	50	2011	2017	2172	2037		4	40	50	0	4647	2.51	1.72	50	50	50	50	50	50														
Chapai Nawabgonj(quick rental)	GE	FO-New	10	50	2011	2017	2172	2037		4	40	50	0	4647	2.51	1.72	50	50	50	50	50	50														
Doudkandi	GE	FO-New	10	50	2012	2032	2172	2037		6	40	50	0	4647	2.51	1.72		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Gazipur 50 MW	GE	FO-New	10	50	2013	2033	2172	2037		6	40	50	0	4647	2.51	1.72			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Katakhali(quick rental)	GE	FO-New	10	50	2011	2017	2172	2037		4	40	50	0	4647	2.51	1.72	50	50	50	50	50	50														
Katakhali, Rajshahi, Peaking Plant	GE	FO-New	10	50	2013	2028	2172	2037		6	40	50	0	4647	2.51	1.72			50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50		
Noapara(quick rental)	GE	FO-New	8	40	2011	2017	2172	2037		4	40	40	0	4647	2.51	1.72	40	40	40	40	40	40														
Raujan 20 MW	GE	FO-New	4	20	2013	2033	2172	2038		6	40	20	0	4647	2.51	1.72			20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Station Name	Type	Fuel Type	Min Unit Net Capacity (MW)	Max Unit Net Capacity (MW)	In Service FY	Retirement FY	Net Heat Rate (kCal/kWh) Min. Load	Net Heat Rate (KCal/KWh) Incremental	Sping Resv (%)	Forced Outage (%)	Maint. Req'd D/yr	Maint. Class Size (MW)	Fuel Cost (Cents/10^6 KCal) Domst	Fuel Cost (Cents/10^6 KCal) Foreign	Fixed O&M ($/KW-mon	Variable O&M ($/MWh)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tangail 20 MW	GE	FO-New	4	20	2013	2028	2172	2037		6	40	20	0	4647	2.51	1.72			20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20		
Chandpur 15 MW	GE	FO-New	3	15	2013	2028	2172	2037		6	40	20	0	4647	2.51	1.72			15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15		
Narayanganj 30MW	GE	FO-New	3	30	2013	2028	2172	2052		6	40	20	0	4647	2.51	1.72			30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30		
Keraniganj Peaking	GE	FO-New	20	100	2026	2041	2172	2037		4	45	100	0	4647	2.51	1.72																200	200	200	200	200
Bogra Peaking	GE	FO-New	20	100	2025	2040	2172	2037		4	45	100	0	4647	2.51	1.72															100	100	100	100	100	100
Comilla Peaking	GE	FO-New	20	100	2019	2033	2172	2037		4	45	100	0	4647	2.51	1.72								-	100	100	100	100	100	100	100	100	100	100	100	100
Daudkandi Peaking	GE	FO-New	20	100	2028	2043	2172	2037		4	45	100	0	4647	2.51	1.72																		100	100	100
Jessore Peaking	GE	FO-New	20	100	2019	2034	2172	2037		4	45	100	0	4647	2.51	1.72									100	100	100	100	100	100	100	100	100	100	100	100
Jhenaidah Peaking	GE	FO-New	20	100	2023	2038	2172	2037		4	45	100	0	4647	2.51	1.72													100	100	100	100	100	100	100	100
Halishahar Peaking	GE	FO-New	20	100	2022	2037	2172	2037		4	45	100	0	4647	2.51	1.72												100	100	100	100	100	100	100	100	100
Khulna Center Peaking	GE	FO-New	20	100	2021	2036	2172	2037		4	45	100	0	4647	2.51	1.72											100	100	100	100	100	100	100	100	100	100
Ashuganj Peaking	GE	FO-New	20	100	2020	2035	2172	2037		4	45	100	0	4647	2.51	1.72										200	200	200	200	200	200	200	200	200	200	200
Mymensingh Peaking	GE	FO-New	20	100	2029	2044	2172	2037		4	45	100	0	4647	2.51	1.72																			100	100
Rajshahi Peaking	GE	FO-New	20	100	2027	2042	2172	2037		4	45	100	0	4647	2.51	1.72																	100	100	100	100
Rangpur Peaking	GE	FO-New	20	100	2029	2044	2172	2037		4	45	100	0	4647	2.51	1.72																			100	100
Khulna Rental (3 Years)	GE	HSD-Ex	8	40	2008	2011	1972	1972		4	30	40	0	7125	1.50	4.00	40																			
KPCL, Khulna BMPP	GE	HSD-Ex	21	106	1999	2016	2205	2205		6	40	100	0	7125		4.50	106	106	106	106	106	106														
Rangpur 20MW CT	CT	HSD-Ex	5.7	19	1989	2016	4000	4000		8	30	20	0	7125	1.50	4.00	19	19	19	19	19	19														
Saidpur 20MW CT	CT	HSD-Ex	5.7	19	1988	2016	4000	4000		8	30	20	0	7125	1.50	4.00	19	19	19	19	19	19														
Barisal 2x20MW CT #1	CT	HSD-Ex	4.5	15	1985	2016	4000	4000		8	30	20	0	7125	1.50	4.00	15	15	15	15	15	15														
Barisal 2x20MW CT #2	CT	HSD-Ex	4.5	15	1988	2016	4000	4000		8	30	20	0	7125	1.50	4.00	15	15	15	15	15	15														
Bheramara 3x20 MW CT #1	CT	HSD-Ex	5	17	1977	2014	3772	3772		6	30	20	0	7125	1.50	4.00	17	17	17	17																
Bheramara 3x20 MW CT #2	CT	HSD-Ex	5	17	1976	2014	3772	3772		6	30	20	0	7125	1.50	4.00	17	17	17	17																
Bheramara 3x20 MW CT #3	CT	HSD-Ex	5	17	1980	2014	3772	3772		6	30	20	0	7125	1.50	4.00	17	17	17	17																
Barisal Diesel (9 units)	GE	HSD-Ex			1975	2009							0	7125	1.50	4.00																				
Bhola Diesel	GE	HSD-Ex		2	1989	2013							0	7125	1.50	4.00	2	2	2																	
Bhola Diesel (New)	GE	HSD-Ex		2	1989	2013							0	7125	1.50	4.00	2	2	2																	
Ghorashal (quick rental)	GE	HSD-New	29	145	2011	2014	2172	2037		4	30	145	0	7125	2.51	1.72	145	145	145	145																
Bheramara, Rental , U/C	GE	HSD-New	20	100	2011	2014	2172	2037		4	30	100	0	7125	2.51	1.72	100	100	100	100																
Siddirganj(quick rental)	GE	HSD-New	20	100	2011	2014	2172	2037		4	30	100	0	7125	2.51	1.72	100	100	100	100																
Khulna(quick rental)	GE	HSD-New	11	55	2011	2014	2172	2037		4	30	55	0	7125	2.51	1.72	55	55	55	55																
Pagla, Narayaganj(quick rental)	GE	HSD-New	10	50	2011	2014	2172	2037		4	30	50	0	7125	2.51	1.72	50	50	50	50																
Thakurgao, Rental, U/C	GE	HSD-New	10	50	2011	2014	2172	2037		4	30	50	0	7125	2.51	1.72	50	50	50	50																
Karnafuli hydro power plant #1	HY	Hydro/RE-Ex	25	40	1962	2040	-	-	-	-	-	230	-	-	2.60	-	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Karnafuli hydro power plant #2	HY	Hydro/RE-Ex	25	40	1963	2040	-	-	-	-	-	230	-	-	2.60	-	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Karnafuli hydro power plant #3	HY	Hydro/RE-Ex	25	50	1983	2040	-	-	-	-	-	230	-	-	2.60	-	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Karnafuli hydro power plant #4	HY	Hydro/RE-Ex	25	50	1989	2040	-	-	-	-	-	230	-	-	2.60	-	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Karnafuli hydro power plant #5	HY	Hydro/RE-Ex	25	50	1989	2040	-	-	-	-	-	230	-	-	2.60	-	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Karnafuli Hydro (#6&7, 2x50 MW)	HY	Hydro/RE-New	20	100	2016	2066									2.60	-	-	-	-	-	-	-	-	-	-	-	100	100	100	100	100	100	100	100	100	100
Sarishabari, Jamalpur(Solar)	SP	Hydro/RE-New	0	3	2013	2063													3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Rajabarihat Goat Development Firm(Solar)	SP	Hydro/RE-New	0	3	2013	2063													3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Kaptai Power Plant(Solar)	SP	Hydro/RE-New	0	5	2013	2063													5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Patenga Offshore, Chittagong(Wind)	WP	Hydro/RE-New	0	100	2013	2063													100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Rooppur Nuclear # 1, 1000 MW	Nuclear	Nuclear	500	1000	2018	2058	2300	2896	5	8	60	1000											0	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
Rooppur Nuclear # 2, 1000 MW	Nuclear	Nuclear	500	1000	2020	2061	2300	2896	5	8	60	1000														1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Rooppur Nuclear # 3, 1000 MW	Nuclear	Nuclear	500	1000	2024	2064	2300	2896	5	8	60	1000																	0	1000	1000	1000	1000	1000	1000	1000
Rooppur Nuclear # 4, 1000 MW	Nuclear	Nuclear	500	1000	2025	2065	2300	2896	5	8	60	1000																			1000	1000	1000	1000	1000	1000
PALLATANA to COMILLA	IC	Int-conect		250	2025	2075																	-	-	-	-	-	-	-	-	250	250	250	250	250	250
SILCHAR to FENCHUGANJ 1	IC	Int-conect		750	2022	2072																						750	750	750	750	750	750	750	750	750
BAHARAMPUR to BHERAMARA Phase-1	IC	Int-conect		500	2013	2063													500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
BAHARAMPUR to BHERAMARA Phase-2	IC	Int-conect		500	2021	2071																				-	500	500	500	500	500	500	500	500	500	500
Hydro from Nepal (Kishanganj (PURNIA) to Bogra	IC	Hydro/RE-New		500	2023	2073																				-	-	-	500	500	500	500	500	500	500	500
Hydro from Bhutan (Alipurduar to Bogra)	IC	Hydro/RE-New		500	2023	2073																				-	-	-	500	500	500	500	500	500	500	500
Myanmmer to Bangladesh (should refer from PGC	IC	Hydro/RE-New		500	2018	2068																		500	500	500	500	500	500	500	500	500	500	500	500	500

Source: PSMP Study Team