Table 11-2 Development Scenario for Refinery

Fiscal Year	Demand	Existing capacity of ERL	Capacity expansion at ERL	KPC project	Product import	Product export
2015	6,206	1,500			4,706	
2016	7,070	1,500			5,570	
2017	6,633	1,500			5,133	
2018	7,575	1,500	3,000		3,075	
2019	8,770	1,500	3,000		4,270	
2020	9,453	1,500	3,000		4,953	
2021	9,224	1,500	3,000		4,724	
2022	11,149	1,500	3,000		6,649	
2023	9,928	1,500	3,000		5,428	
2024	10,112	1,500	3,000		5,612	
2025	8,370	1,500	3,000		3,870	
2026	9,503	1,500	3,000	8,000		2,997
2027	8,470	1,500	3,000	8,000		4,030
2028	8,226	1,500	3,000	8,000		4,274
2029	9,538	1,500	3,000	8,000		2,962
2030	8,022	1,500	3,000	8,000		4,478
2031	8,075	1,500	3,000	8,000		4,425
2032	8,374	1,500	3,000	8,000		4,126
2033	9,806	1,500	3,000	8,000		2,694
2034	10,280	1,500	3,000	8,000		2,220
2035	11,941	1,500	3,000	8,000		559
2036	11,520	1,500	3,000	8,000		980
2037	11,975	1,500	3,000	8,000		525
2038	11,938	1,500	3,000	8,000		562
2039	12,495	1,500	3,000	8,000		5
2040	12,479	1,500	3,000	8,000		21
2041	13,038	1,500	3,000	8,000	538	

Source: JICA South Chittagong Survey Progress Report

11.3 Outline of Oil Refinery and SPM

11.3.1 Oil Refinery

The refinery to be built at Southern Chittagong is an integrated refinery to produce both oil products and basic chemical products. Kuwait Petroleum Corporation (KPC), a Kuwaiti state-owned oil company, will be the primary operator and investor of the project. The expected completion year of the refinery is 2018. The expected outline of the refinery is shown in Table below.

Table 11-3 Outline of Refinery

Operators	Bangladesh Petroleum Corporation (BPC) and Kuwait Petroleum Corporation (KPC)
Expected completion	FY2026 (JICA team estimate)
Refinery type	Conversion type
Planned capacity	8.0 million tons per year (approx. 160,000 bbls/d)
Main products	LPG (propane and butane), naphtha, motor gasoline, kerosene, auto diesel oil, fuel oil, petrochemical products
Expected markets of product	Domestic market, Export to ASEAN countries
Crude oil source	Kuwait 100%
Expected cost	USD 6.0 billion

Source: South Chittagong Survey Team

The detailed configuration of the refining facilities has not been published by KPC as of writing this report. The following table is an expected configuration of the refinery project.

Table 11-4 Expected Configuration of Refinery

Unit	Capacity ('000 tons/y)	Duty
Crude Distillation Unit (CDU)	160	Split crude oil into various hydrocarbon fractions by distillation process
Naphtha Hydrotreating Unit (NHT)	25	Remove sulfur, chlorite, nitrogen, oxygen, metallic compounds in heavy naphtha stream distillated from CDU process to protect CCR catalyst by hydrotreating process.
Kerosene Treating Unit (KTU)	12	Remove sulfur and other inpurities from kerosene stream distillated from CDU process to meet the product specification of Jet A1.
Continuous Catalytic Reforming Unit (CCR)	25	Reform heavy naphtha straight-run from NHT to High Octane Mogas Blending components (reformate) by removing hydrogen with catalysts.
Residue Fluid Catalytic Cracking Unit (RFCC)	35	Convert heavier stream taken from CDU process to lighter stream such as naphtha and diesel oil components with catalysts.
LPG Treating Unit (LTU)	7	Remove sulfur from LPG stream taken from CDU and CCR process to meet the product specifications.
RFCC Naphtha Treating Unit (NTU)	6	Remove sulfur and other inpurities from naphtha stream taken from RFCC process to meet the product specification of motor gasoline.
Propylene Recovery Unit (PRU)	4	Recover propylene from LPG stream to produce high purity propylene.

Source: South Chittagong Survey Team

11.3.2 SPM

SPM system is planned to be built at 60 km offshore from Matarbari Island where the water depth is 27m. The purpose of building SPM is to reduce lightering costs to ship crude oil or imported oil product to a smaller tanker that can berth at Chittagong Refinery that cannot accommodate a larger tanker due to its draft restriction. According to the interview by JICA Survey Team with Bangladesh Petroleum Corporation on June 11, the expected completion year of SPM is 2018, and a Chinese company has already been awarded the construction contract. SPM system will install both crude oil
and petroleum product discharging pipelines and the capacity of the pipelines is 4.5 million tons per year each. Major components of SPM system are as shown in Table below.

Table 11-5 Major Components of SPM System

Component	Role
Floating Buoy	Floating object that is moored to seabed
Floating Hoses	Hoses to transfer crude oil and oil products from tanker to buoy
Under-buoy Flexible Hoses	Hoses to transter crude oil and oil prodccut from buoy to onshore facility
Anchors	Object to fix the location of the entire SPM sysmte
Pipe-Line End Manifold	Facility to connect flosting hoses to tanker's discharging facility

Source: JICA South Chittagong Survey Team

11.4 SPM and Refinery

Yet available in the Southern Chittagong Survey Team Progress Report

11.5 LPG

Alike other low and middle income countries, Bangladesh is increasing the reliance on LPG mainly as a proxy of modern household cooking fuel. It is in general a reasonable choice to convert to LPG from conventional solid biomass, because LPG is widely available, highly energy efficient, and less CO2 and air-polluting particles emission than combustion of conventional solid biomass and less risk of deforestation by overexploitation of forest resources[24].

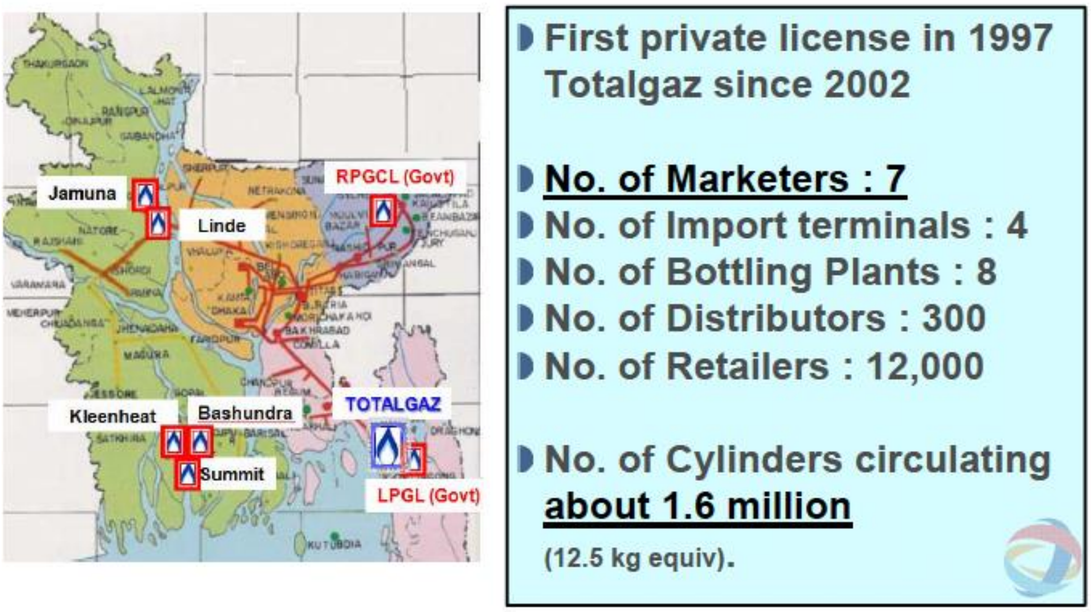
In this section, the current LPG status, issues and countermeasures of LPG promotion are discussed.

11.5.1 LPG Current Status

The official holistic statistics on LPG is not available in Bangladesh; however, based on the publically available information, the LPG consumption in the last few years approximately 110,000 ton/year, where the private sector distributes 90,000 ton and public sector (i.e. BPC) sells 20,000 ton year[25]. This volume is still quite small 2% compared to the total oil demand in Bangladesh (110,000 ton out of 5.1 million ton mentioned in the previous Section).

Since Bangladesh is facing a serious shortage of the domestic natural gas, the government has stipulated the pipelined gas access limit policy and encourages LPG alternatively (no new gas connections for new household and commercial buildings, and reducing hours for gas distribution).

In supply side, currently there are four import terminals and seven LPG private operators in Bangladesh, who deals with LPG import, shipping and distribution. For further downstream value chain, as per the TotalGas presentation, there are 12,000 retailers and about 1.6 million cylinders (12.5kg) in the market, which stands for only 4% household penetration still under 4%[26]. Also the government has guaranteed to issue licenses to thirty new private operators[27].



Source: TotalGaz Presentation (ibid.)

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[24] IEA World Energy Outlook 2006 Chapter 15, "Energy for Cooking in Developing Countries"

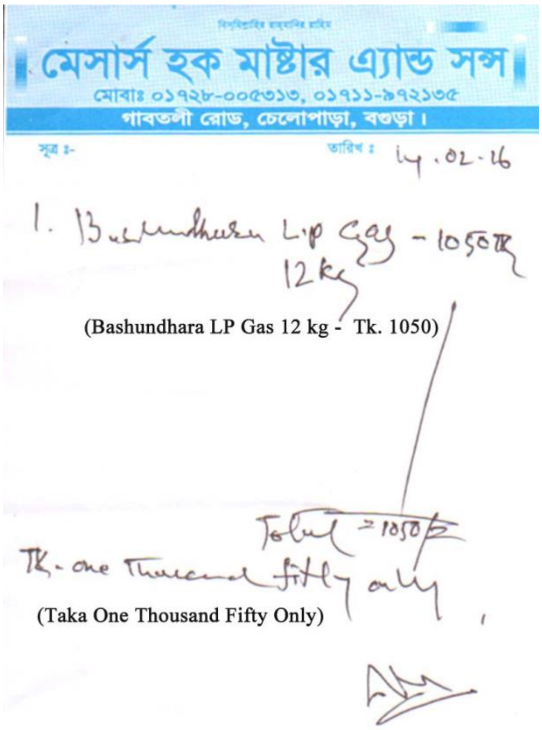
[25] Ministry of Planning, "A Paradigm Shift in Bangladesh Energy Sector towards SDG-7: A Few Insights of Energy Statistics in Bangladesh", November 2015 (http://www.unosd.org/content/documents/14698_SDGs-Incheon-2015-Bangladesh.pdf)

[26] TotalGaz Presentation in the World LPG Conference, February 2012 http://www.wlpga.org/wp-content/uploads/2015/09/Bangladesh_Renzo_Bee_Totalgaz.pdf

[2727] Financial Express "Encouraging the use of LPG by households", April 28, 2016 (http://www.thefinancialexpressbd.com/2016/04/28/28116/EncouragingtheuseofLPGbyhouseholds)

11.5.2 LPG Official and Marketed Price Gap

In Bangladesh, all fuel prices are regulated, and LPG has also an "official price", 750 Taka per 12~12.5kg cylinder. However, it is often observed that the marketed prices are 2-3 times higher than this "official price". The below figure is a sample voucher of a cylinder in Bogra, February 2016.



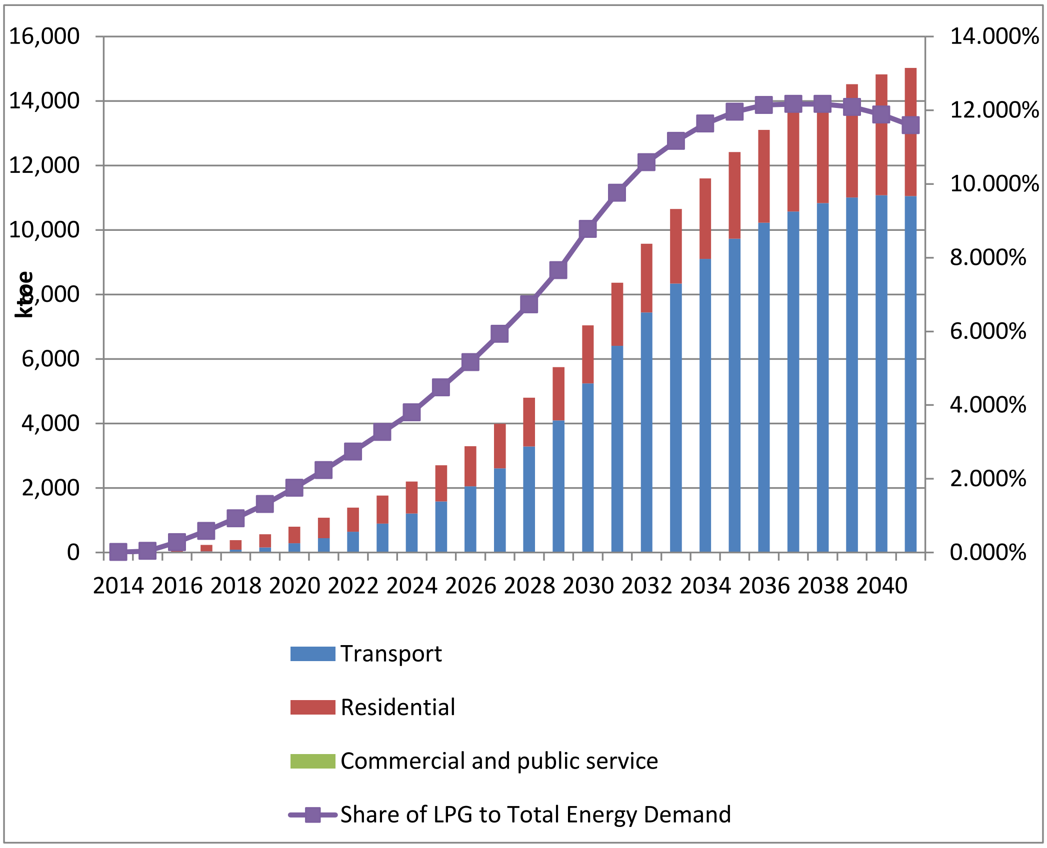
The reason of this price gap between the official rate and marketed one will be surveyed in June 2016.

11.5.3 LPG Future Demand

It should be pointed out that, although the government has policy to encourage LPG for household use, there is still no articulated policy or direction on LPG in the holistic picture of energy supply. This means that, in face of the decline of domestic natural gas and prospected sharp LNG import increase, the position of LPG to meet the growing energy demand, not only from the household but demand of all consumer sectors (especially transport sector), is yet clear.

Alternatively, for the purpose of the demand projection, the JICA Survey Team assumes that LPC will be used mainly in the household and transport sector to meet the energy demand-supply gap. More precisely, the team has taken the following assumptions; 1) as for the residential sector, the study team assumed that the natural gas supply will be maintained only for the existing customers and that new houses and apartments are obliged to use LPG instead, and 2) as for the transport sector, the current final consumption amount ratio of oil products and natural gas is roughly 2 to 1. The sharp increase of transportation fuel demand is met by oil products and natural gas (including LNG) at the same ratio (2-to-1), and the transportation fuel demand on gasoline will increase at higher pace than in the past, and the LPG meets the demand-supply gap.

As a result, the demand on LPG is projected to increase drastically at the growth rate almost 35% p.a., 15 times higher in 2041 than in 2016, as shown in the below figure.



Source: JICA Survey team

Figure 11-5 LPG Demand Projection (Household + Transport) from 2014 to 2041

This demand projection is merely the Survey team's assumption and it could largely vary depending on the policy making; however, it is still noticeable that the oil demand from transport sector – regardless of it would be gasoline, LPG or other oil products, will grow radically.

11.5.4 LPG Supply Future Plan

In order to respond to the anticipated future LPG demand growth, the Government has taken initiative to cooperate with India. It is reported that BPC and Indian Oil Corporation Limited (IOCL) had an MOU in April 2016 for a future LPG plant in Chittagong, which will be the largest plan in Bangladesh[28]. The details of the project (e.g. capacity of the terminal, or construction schedule) are yet disclosed. However, it is reported that the LPG received or produced in Chittagong will be transferred to Tripura, in the northeast India, thorough a pipeline to be developed in the Bangladesh territory. In exchange for this, oil products from a refinery in Numaligarh, Assam India will be received at Parbatipur in the northwest Bangladesh (there is some 700km distance in between).

However, in fact, in Bangladesh, some 80% of LPG is produced and delivered by private companies, including international oil companies. The government role can be, not to invest the capital intensive projects, but appropriate LPG regulation to accommodate healthy market competition and protect consumers.

[28] Financial Express, "BPC, Indian corpn sign MoU on LPG plant today", April 18, 2016 (http://www.thefinancialexpress-bd.com/2016/04/17/26591/BPC,-Indian-corpn-sign-MoU-on-LPG-plant-today)

11.5.5 Issues of LPG

(1) Absence of Strategic Position of LPG in the Energy Policy

As pointed out earlier, Bangladesh government has yet established a clear positioning of LPG in the entire energy planning. For example, a policy could place a direction on the LPG main consumer sectors, such as household and transportation, as coupled with pricing policy. Though the government has already stipulated the policy encouraging households to use LPG as alternative of pipelined gas, this is not enough.

In fact, the strategic positioning of LPG calls for the strategic positioning of LNG, which will also meet the deficient domestic natural gas supply. The new energy policy should clearly define how LNG and LPG will meet the supply shortage of domestic natural gas, and which sector should be a main consumer of each import fuel.

(2) Affordability to Households and "Unfair" Pipeline Gas Tariff

As mentioned earlier, LPG "actually marketed" price is much higher than "official rate" – For one 12kg Cylinder, some 1050 Taka to 1300 Taka, while the official one is only 700 Taka. Although the reasons behind this gap must be surveyed, but it is for sure that there is room for the government and regulatory body to take corrective actions.

Furthermore, there are striking difference between the LPG marketed price and the current pipelined natural gas- approximately 8 to 1 as seen the below Table 11-6.

Table 11-6 Unit Price Difference between LPG Marketed Price and Pipelined Gas for Household

	Fixe Price for one burner		Unit Sales Price		Heat Value per Unit		Unit Price per MJ	
Natural Gas	Tk 600	Tk/month	Tk 8.33	/m3	39.59	MJ/m3	Tk 0.21	/MJ
LPG	Tk 1,050	Tk/12 kg (1 cylinder)	Tk 87.50	/kg	50.80	MJ/kg	Tk 1.72	/MJ

Source: JICA PMSP2015 Survey Team

Even though the government intends to encourage LPG for household as an alternative of pipeline natural gas, the substantial deployment of LPG would be difficult without corrective actions for this price difference. Also, the actually expensive LPG may not be affordable for low income families, especially for the rural ones (the only 8% of pipelined gas consumers are urban centric, especially in Dhaka area). Assuming that one household consumes two cylinders a month, the fuel cost for cooking would be some 2,100 to 2,600 Taka. As per BBS's survey in 2010, the national average monthly income is 11,479 Taka, while the rural one is 9,648 Taka. According to the World Bank's study using 2005 data, Bangladesh rural households spend some 4 to 7 % of their monthly income for biomass fuels[29]. If this expenditure pattern remains almost equal today, the LPG fuel cost would be about 25 % to an average rural household, and give a big pressure to the household expenditure. As mentioned in the "Renewable Energy" Chapter, Bangladesh's access to modern energy is quite limited. According to the BBS statistics in 2014, more than 94% of the rural population in Bangladesh uses traditional solid biomass for cooking. However, LPG cannot be affordable to rural household nor contribute to the improvement of the access of the modern energy for all.

[29] World Bank, "Expenditure of Low-Income Households on Energy", June 2010, Figure E.2 Monthly Urban Household Expenditure on Biomass.

On the other hand, Bangladesh's pipeline gas for household itself has long been an issue for energy sector. It is the fixed tariff, 450 Taka for one burner for month, regardless of the actual usage, which has been pointed out in many studies including JICA's, to improve energy efficiency in Bangladesh. In fact, the Government has taken initiatives to improve the situation, and pre-paid gas meter installment supported by JICA and other development partners.

This LPG affordability issue must be addressed, not only the LPG tariff or household gas tariff issue, but also from the national energy strategy viewpoint. "LPG subsidy" maybe an easy solution to address the price issue[30], but should be analyzed carefully.

At the same time, in order to address the LPG affordability issue, biogas should be considered as a domestically and richly available resource. For detailed discussion of potential of biogas and its economic competitiveness over LPG is discussed in "Renewable Energy" Chapter.

11.5.6 Pressure to the National Coffer

To be confirmed in June 2016 Mission.

[30] Energy Bangla "LPG use to be subsidised with profit from households", July 25, 2015 (http://energybangla.com/lpg-use-to-be-subsidised-with-profit-from-households/)

PART IV POWER BALANCE

Chapter 12 Power Development Plan

12.1 Social Economic Outlook

Social economic outlooks and plans are used to forecast the power demand of Bangladesh. Population, GDP, foreign exchange, inflation rate and crude oil price are used as the preconditions for power demand forecasting.

12.1.1 Structure of demand forecast model

First, the model forecasts final energy and power demands by sector; after that, it calculates electric power, energy consumption and primary energy consumption country-wide. The outline of the model flow is as follows:

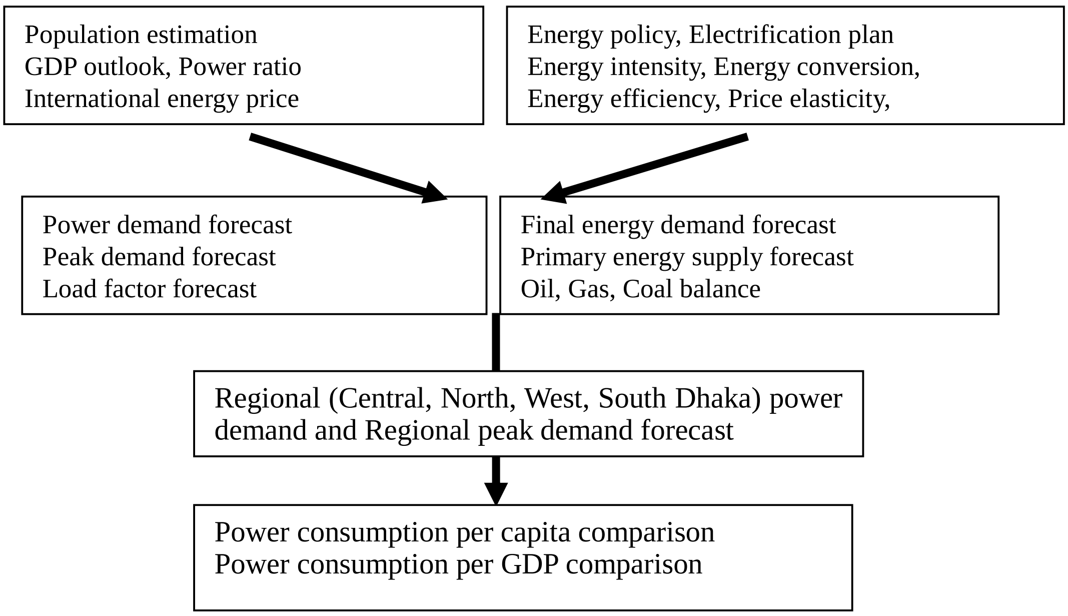


Figure 12-1 Outline of Demand Forecasting Model Flow

As the methodologies for the model building, energy demand/supply balance technology defined by the IEA, econometric model building theory for expressing economic equations, and Simple.E software to be MS-Excel add-in module as the econometric model engine are used for building the model. The model outline is as follows:

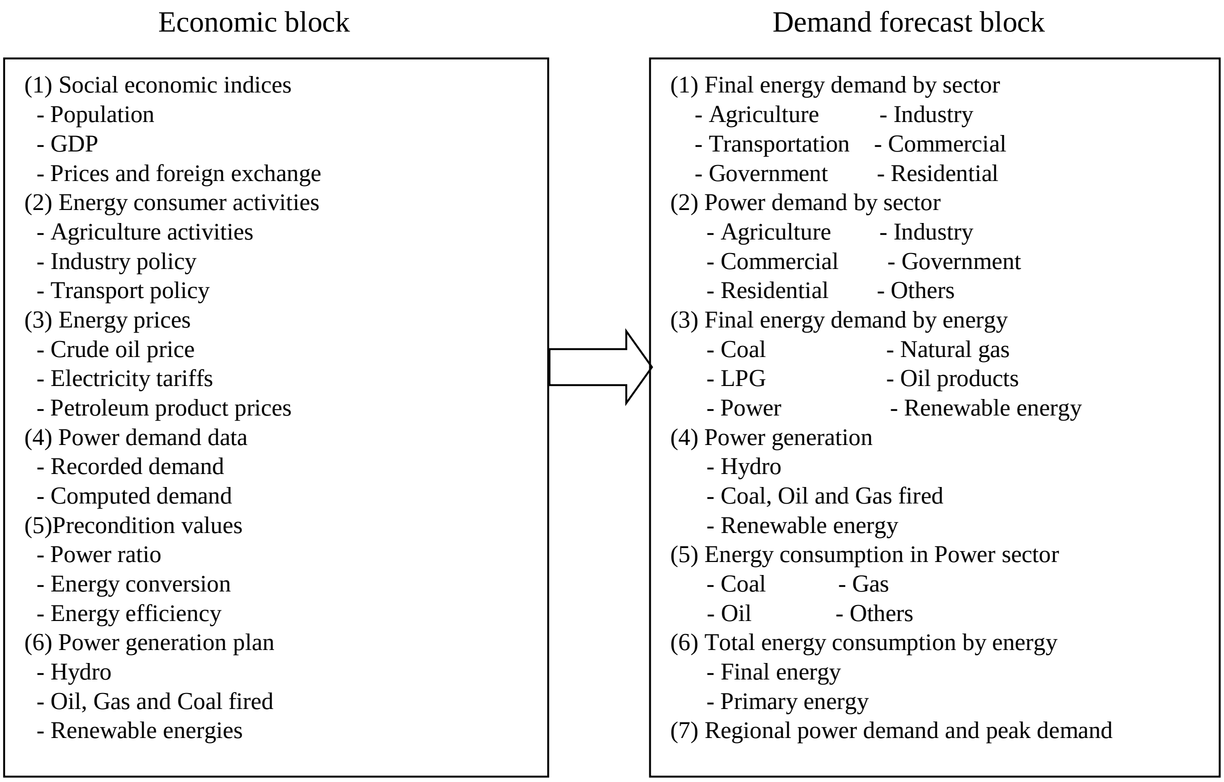


Figure 12-2 Outline of the Model Structure

Note: The procedures of the right hand block of the above figure are as the follows;

In (1), all kinds of energies used in the sectors are forecasted.

In (2), sectoral power demands are forecasted under the (1) constrain.

In (3), Fossil energies and woods and charcoal demands are forecasted under (1) and (2)

In (4), Net power demand is calculated using by load factor and T/D loss.

In (5), Fossil energies utilized to power sector are calculated.

In (6), As domestic fossil energy demand, auto mobile fuels, industry fuels and power generation fuels are smmed up.

In (7), Five block power demands in line with transmission block design are calculated. At the time, the demand plans of all substations in Bangladesh up to 2030 are referred.

(1) Procedures for power and energy demand model

To make forecasting expressions, future energy intensities are estimated by using the auto correlation analysis. The future intensities have the upper and lower limitations in order that the trends are changed up to a horizontal axis. The procedures are as follows:

Step 1 Sectoral total energy consumption by sector (A)

= Sectoral total energy consumption intensity of sector

× Sectoral GDP (Population is used for Residential sector)

Step 2 Sectoral power demand (B)

= Sectoral total energy consumption (A) × Power ratio

× Power tariff elasticity × EE&C indicator

(EE&C: Energy Efficiency & Conservation)

Step 3 Sectoral fuel demand (C)

＝(Sectoral total energy consumption (A) – Power demand)
× Energy price elasticity × EE&C indicator

Step 4 Power demand as final energy demand (D)

＝Sum Power demand of Agriculture (B), Industry (B), Commercial & service (B), Public(B) and Residential (B) sectors

Step 5 Fuel demand as final energy demand (E)

＝Sum Fuel demand of Agriculture (C), Industry (C), Commercial & service (C), Transportation (C), Public (C) and Residential (C) sectors

Step 6 Dispatched power demand (F)

＝Power demand as final energy demand (D)＋T/D loss

Step 7 Forecast Peak demand (G)

＝Dispatched power demand (F) / Load factor / 24hours / 365 days

(2) Economic scenarios

Bangladesh GDP stays at 6% from 2005 to 2013. After discussing it with Bangladesh related authorities (MOF and Bank of Bangladesh) The future GDP growth rates are assumed as follows.

i It is expected that the Sixth and Seventh five year plans are implemented with political stability after 2015.

ii It is predicted that the energy shortage (natural gas) will be resolved and the electricity import from neighboring countries are realized.

iii The targeted economic growth rate of 8% in Vision 2021 is not realized; however, it is possible that a GDP growth rate of 7% per year in the five year plans (Sixth and Seventh) can be expected. Therefore, it is assumed that future Bangladesh GDP growth rate in the JICA study is in the range of 6% to 7% per year. The following three cases, Base case, High case and Low case, are set as economic scenarios for the JICA Survey.

Table 12-1 GDP Growth Rate Scenarios for Bangladesh

Unit: %

	Case	2015/10	2020/15	2025/20	2030/25	2035/30	2040/35	2041/15
Real GDP	Base	6.2	7.4	7.4	7.0	5.3	4.4	6.1
	High	6.2	7.4	7.5	6.6	5.7	5.0	6.4
	Low	6.2	7.4	7.3	6.1	4.9	4.0	5.9
Nominal GDP	Base	13.5	12.5	11.6	9.5	7.3	6.5	9.3
	High	13.5	12.5	11.7	9.7	7.8	7.1	9.7
	Low	13.5	12.5	11.5	9.3	7.0	6.1	9.1

Source: JICAStudy Team

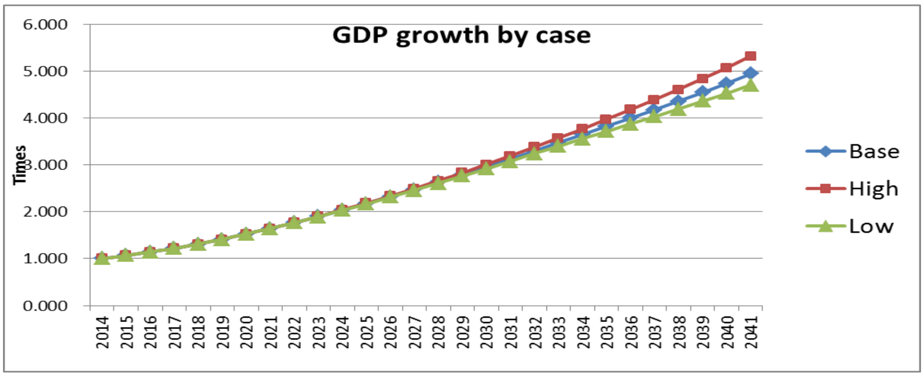


Figure 12-3 Growth Trends of GDP by Case

(3) Energy efficiency & conservation (EE&C)

When looking at other countries implementing energy efficiency policies, it is not rare to reduce by 20% of energy intensities to final energy and primary energy consumption for 20 years in comparing it to energy consumption without EE&C policy. Considering that EE&C policy will be introduced by the Bangladesh government in the near future, the effectiveness of EE&C policy is set in the following table in the model.

Table 12-2 EE&C Effectiveness Rate to Intensity by EE&C Policies

		2015to 2019	2020 to 2041
Agriculture	Power Fuel	Not affected by EE&C Not affected by EE&C	Not affected by EE&C Not affected by EE&C
Industry	Power Fuel	Not affected by EE&C Not affected by EE&C	15% reduction of intensity 20% reduction of intensity
Commercial & Services	Power Fuel	Not affected by EE&C Not affected by EE&C	15% reduction of intensity 15% reduction of intensity
Government	Power	Not affected by EE&C	15% reduction of intensity
Transportation	Fuel	Not affected by EE&C	Not affected by EE&C Not affected by EE&C
Residential (Housing)	Power Fuel	Not affected by EE&C Not affected by EE&C	Not affected by EE&C 15% reduction of intensity

Note: Actual data for auto correlation are from 2004to 2012
Note: "Not affected by EE&C" means that EE&C policy does not make any impact on the intensity trend of the sector, and the intensity is continued from the past to the future keeping growth or reduction trend.
Note: EE&C rate for fuel of government sector and power of transportation sector are not set.
Source: "Bangladesh Energy Efficiency Plan" conducted by JICA, 2015

(4) Energy price impacts on power demand

Generally, the increase of energy prices and power tariffs discourage the power demand. As the Bangladesh energy market is not a "Free competitiveness market", the price impacts on power demand are almost negligible. So the small elasticity with "-0.1" between energy price and power demand is set in the model. By doing so, the energy prices' negative impact on power and energy demands is suppressed to the minimum. (Generally, power sector liberalization indicates deregulalization of power system and open market among business entities. However, there are many cases that power tariffs to end users are decided by the Government in the developing countries.

(5) Transmission and Distribution losses

For the transmission loss rate, the current rate of 2.5 % is set as the future transmission loss rate. Although the current distribution loss is 12.5 % (Country average), the loss rate gradually decreases to 9.0 % in future. T/D loss moves to 11.5 % in the future. Distribution loss is comparatively high in developing countries. However, there is a distribution company to reduce social loss by their own efforts in Bangladesh. Therefore, distribution loss reduction is expected in Bangladesh in future. (less than 10 %)

(6) Power demand forecast by case

The peak demands (includes T/D loss) of High, Base and Low cases are as per the following figure. The average GDP growth rates for the cases are High case with 6.4%, Base case with 6.1 % and Low case with 5.9% (the growth rates are shown in GDP scenario setting session). And the peak demands of each case are 7.0% per year in High case, 6.7% per year in Base case and 6.3% per year in low case.

Table 12-3 Peak Demand Forecasts by Case

	Unit	2015	2020	2025	2030	2035	2040	2041
High	MW	8,920	13,400	20,100	28,500	38,400	49,800	52,400
Base	MW	8,900	13,400	19,900	27,700	36,400	45,700	47,800
Low	MW	8,900	13,200	19,500	26,700	34,400	42,300	44,000
	Unit	2015/10	2020/15	2025/20	2030/25	2035/30	2040/35	2041/15
High	%	7.3	8.5	8.4	7.2	6.1	5.3	7.0
Base	%	7.3	8.5	8.2	6.8	5.6	4.7	6.7
Low	%	7.3	8.5	8.1	6.5	5.2	4.2	6.3

Source: JICA Survey Team

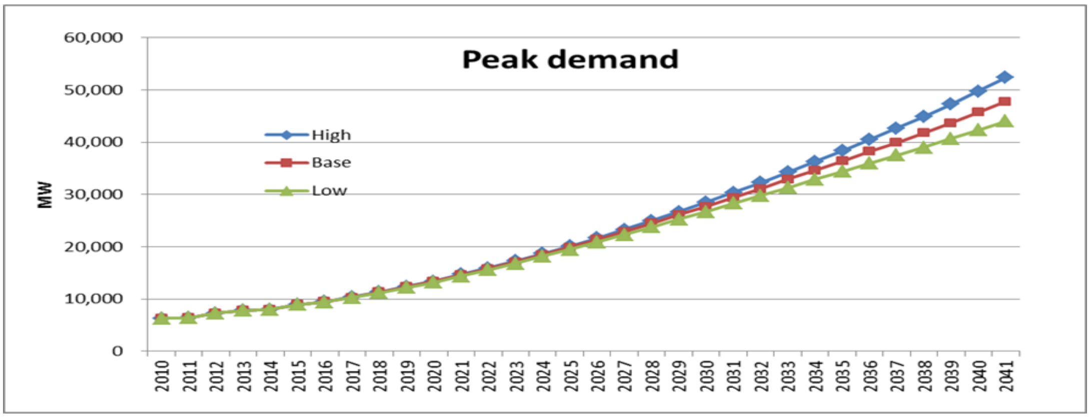


Figure 12-4 Peak Demand Trends by Case

(7) Comparison between PSMP2010 and PSMP2016

The power demand comparison between PSMP2010 and PSMP2016 is as per the following figure. When looking at both power demands until 2030, no significant differences exist in either. The GDP growth rate of PSMP2010 is 7% from 2010 to 2030 and that of PSMP2016 is 6.1 % from 2015 to 2041. In PSMP2016, the intensities to GDP and to income per capita and Power ratios are increased. The power demands are calculated by the expressions “Intensity × GDP” or “Intensity × Per capita income”

The expressions with “Elasticity×GDP growth rate” used in PSMP 2010 make power demand increase over the previous year. Changes in the elasticity cause big fluctuations in power demand. It is shown that “Intensity forecasting method” shows a straight line increase of power demand and “Elasticity forecasting method” shows an exponential curve increase of power demand.
It appears that the power demands of both in the above figures increase almost with a straight line.In terms of the results, there is no big difference in the power demands between PSMP2010 and PSMP2016, though the GDP growth rate and the methodology of the power demand forecasting are different.

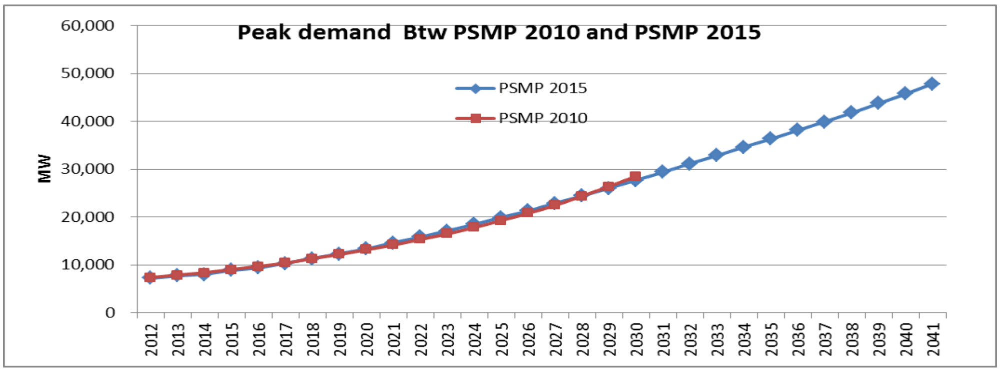


Figure 12-5 Peak Demand Comparison of PSMP2010and PSMP2016

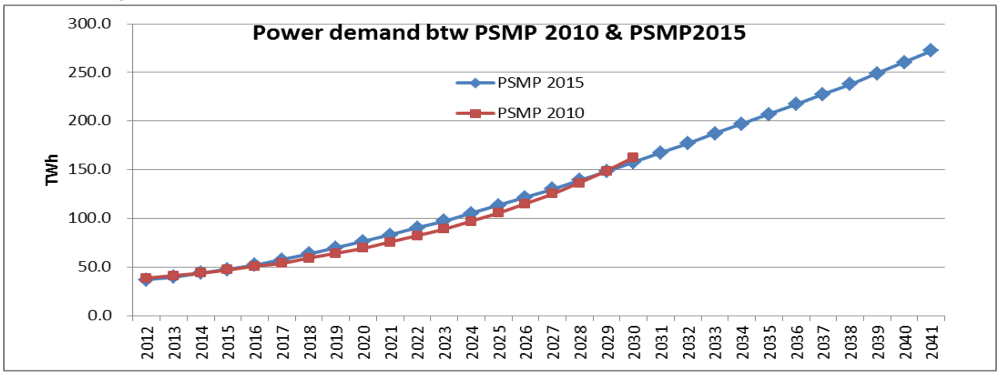


Figure 12-6 Power Demand Comparison of PSMP2010 and PSMP2016

12.1.2 Simplified Model According to Energy-GDP Elasticity

The peak demand forecast is determined by multiplying the GDP and energy-GDP elasticity determined by the economic growth scenario with the effect of energy conservation.

Table 12-4 Peak Demand Forecast According to Energy-GDP Elasticity Model

Model	Simplified Model								Macro Model
	GDP growth rate	Elastisty	Electricity growth rate	Total Demad without Energy Efficiency and Conservation (EE&C)	Effect of EE&C	Total Demand with EE&C	captivpower to the grid	Government Scenario	Macro-model case
2,015	6.5%	1.27	8.3%	8,920	0	8,920	0	8,921	8,920
2,016	7.0%	1.27	8.9%	9,713	0	9,583	0	9,583	9,500
2,017	7.2%	1.27	9.1%	10,601	0	10,318	0	10,318	10,300
2,018	7.4%	1.27	9.4%	11,597	0	11,134	0	11,134	11,300
2,019	7.6%	1.27	9.7%	12,717	0	12,039	0	12,039	12,300
2,020	8.0%	1.27	10.2%	14,009	0	13,075	149	13,223	13,400
2,021	7.8%	1.27	9.9%	15,394	0	14,163	297	14,460	14,600
2,022	7.6%	1.27	9.6%	16,875	0	15,300	446	15,746	15,800
2,023	7.4%	1.27	9.4%	18,453	0	16,485	594	17,079	17,100
2,024	7.2%	1.27	9.1%	20,129	0	17,714	743	18,456	18,500
2,025	6.9%	1.27	8.8%	21,903	0	18,983	891	19,874	19,900
2,026	6.7%	1.27	8.5%	23,776	0	20,288	1,040	21,328	21,400
2,027	6.5%	1.27	8.3%	25,744	0	21,625	1,188	22,813	22,900
2,028	6.3%	1.27	8.0%	27,806	0	22,986	1,337	24,323	24,500
2,029	6.1%	1.27	7.7%	29,959	0	24,367	1,486	25,852	26,100
2,030	5.9%	1.27	7.5%	32,198	0	25,759	1,634	27,393	27,700
2,031	5.7%	1.27	7.2%	34,520	0	27,616	1,634	29,250	29,400
2,032	5.5%	1.27	6.9%	36,916	0	29,533	1,634	31,167	31,100
2,033	5.3%	1.27	6.7%	39,381	0	31,505	1,634	33,139	32,900
2,034	5.0%	1.27	6.4%	41,906	0	33,525	1,634	35,159	34,600
2,035	4.8%	1.27	6.1%	44,483	0	35,587	1,634	37,221	36,400
2,036	4.6%	1.27	5.9%	47,101	0	37,681	1,634	39,315	38,200
2,037	4.4%	1.27	5.6%	49,750	0	39,800	1,634	41,434	39,900
2,038	4.4%	1.27	5.6%	52,526	0	42,021	1,634	43,655	41,800
2,039	4.4%	1.27	5.5%	55,436	0	44,349	1,634	45,983	43,700
2,040	4.3%	1.27	5.5%	58,486	0	46,789	1,634	48,423	45,700
2,041	4.3%	1.27	5.5%	61,681	0	49,345	1,634	50,979	47,800
Average	6.1%								

Source : JICA Survey Team and BPDB

(1) Validation of Energy-GDP elasticity

The table below shows the energy-GDP elasticity for the power demands in Bangladesh in the last 10 years and the average value is 1.27. Since the elasticity in the ASEAN countries (Thailand, Indonesia, Malaysia) is also in the range of 1.1 to 1.3, this model adopts 1.27, which is based on the track record, for all years.

Table 12-5 Actual Energy-GDP Elasticity in Bangladesh

Year	GDP at Constant Market Price (Million Taka)	GDP Growth Rate (%)	Actual Net Energy Generation (GWH)	Energy Not served	Forecasted Net Generation (GWH)		GWH Growth	Elasticity
2005	2,669,740		21,408	260	21,668	21,798		
2006	2,846,726	6.6%	22,978	843	23,821	24,243	7.3%	1.1
2007	3,029,709	6.4%	23,268	2,264	25,532	26,664	1.3%	0.2
2008	3,217,855	6.2%	24,946	1,107	26,053	26,606	7.2%	1.2
2009	3,406,524	5.9%	26,533	1,363	27,896	28,577	6.4%	1.1
2010	3,608,450	5.9%	29,247	1,829	31,076	31,991	10.2%	1.7
2011	3,850,500	6.7%	31,355	1,899	33,254	34,204	7.2%	1.1
2012	4,090,530	6.2%	35,118	1,647	36,765	37,588	12.0%	1.9
2013	4,337,200	6.0%	38,229	1,070	39,299	39,834	8.9%	1.5
2014	4,601,770	6.1%	42,195	515	42,710	42,968	10.4%	1.7
								1.27

Source : JICA Survey Team and BPDB

Table 12-6 Actual Energy-GDP Elasticity in ASEAN Countries

	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Thailand	GDP (constant 2005 US$)	170,956,863,507	181,708,833,946	189,318,499,954	198,723,685,564	209,524,501,833	213,140,198,921	211,566,627,910	227,448,322,637	229,344,519,381	246,139,191,582	
	Electricity consumption (GWh)	106,959	115,044	121,229	127,811	133,178	135,450	135,209	149,320	148,700	161,749	
	(A) GDP growth	7.2%	6.3%	4.2%	5.0%	5.4%	1.7%	-0.7%	7.5%	0.8%	7.3%	
	(B)Electricity growth	6.8%	7.6%	5.4%	5.4%	4.2%	1.7%	-0.2%	10.4%	-0.4%	8.8%	
	(A)/(B)	0.94	1.20	1.28	1.09	0.77	0.99	0.24	1.39	-0.50	1.20	
	(A') 5-year average GDP	5.2%	5.5%	5.4%	5.8%	5.6%	4.5%	3.1%	3.7%	2.9%	3.3%	
	(B') 5-year average Electricity	5.9%	7.2%	6.6%	6.7%	5.9%	4.8%	3.3%	4.3%	3.1%	4.0%	
	(A')/(B')	1.1	1.3	1.2	1.2	1.0	1.1	1.1	1.1	1.1	1.2	1.1
Indonesia	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	257,516,488,195	270,471,818,103	285,868,619,206	301,594,114,117	320,730,327,692	340,018,098,955	355,757,098,753	377,898,901,817	401,214,448,583	425,407,883,059	
	Electricity consumption (GWh)	90,441	100,097	107,705	113,415	121,614	128,810	136,053	147,972	159,867	175,329	
	(A) GDP growth	4.8%	5.0%	5.7%	5.5%	6.3%	6.0%	4.6%	6.2%	6.2%	6.0%	
	(B)Electricity growth	3.9%	10.7%	7.6%	5.3%	7.2%	5.9%	5.6%	8.8%	8.0%	9.7%	
	(A)/(B)	0.81	2.12	1.34	0.96	1.14	0.98	1.21	1.41	1.30	1.60	
	(A') 5-year average GDP	3.7%	4.6%	4.7%	5.1%	5.5%	5.7%	5.6%	5.7%	5.9%	5.8%	
	(B') 5-year average Electricity	6.7%	7.0%	6.4%	6.1%	6.9%	7.3%	6.3%	6.6%	7.1%	7.6%	
	(A')/(B')	1.8	1.5	1.3	1.2	1.3	1.3	1.1	1.1	1.2	1.3	1.3
Malaysia	items	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
	GDP (constant 2005 US$)	127,611,641,758	136,268,098,017	143,534,102,611	151,550,262,734	161,096,089,356	168,879,881,704	166,323,572,126	178,674,711,521	188,133,365,986	198,430,759,593	
	Electricity consumption (GWh)	73,420	77,252	80,755	84,573	89,358	92,881	102,920	110,853	111,852	120,637	
	(A) GDP growth	5.8%	6.8%	5.3%	5.6%	6.3%	4.8%	-1.5%	7.4%	5.3%	5.5%	
	(B)Electricity growth	6.6%	5.2%	4.5%	4.7%	5.7%	3.9%	10.8%	7.7%	0.9%	7.9%	
	(A)/(B)	1.14	0.77	0.85	0.85	0.90	0.82	-7.14	1.04	0.17	1.43	
	(A') 5-year average GDP	5.3%	5.4%	4.7%	5.8%	6.0%	5.8%	4.1%	4.5%	4.4%	4.3%	
	(B') 5-year average Electricity	6.6%	6.6%	5.7%	5.4%	5.3%	4.8%	5.9%	6.5%	5.8%	6.2%	
	(A')/(B')	1.3	1.2	1.2	0.9	0.9	0.8	1.5	1.5	1.3	1.5	1.2

Source：JICA Survey Team

(2) Setting of government power demand scenario

As a result of estimating the power demands by the "macro demand forecast model" and the "simplified model according to the energy-GDP elasticity", it was determined that the results obtained by the two models are almost at the same level, despite the difference of about 5%. Therefore, it was decided to adopt the methodology based on the "simplified model", which is more simplified and easier to function as a rolling plan, for the government value in formulating the supply plan.

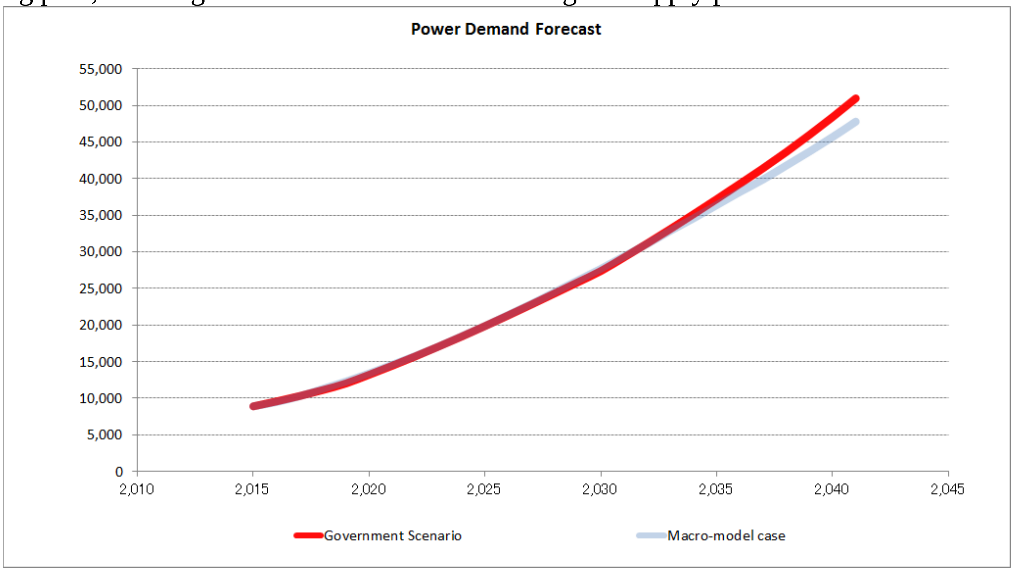


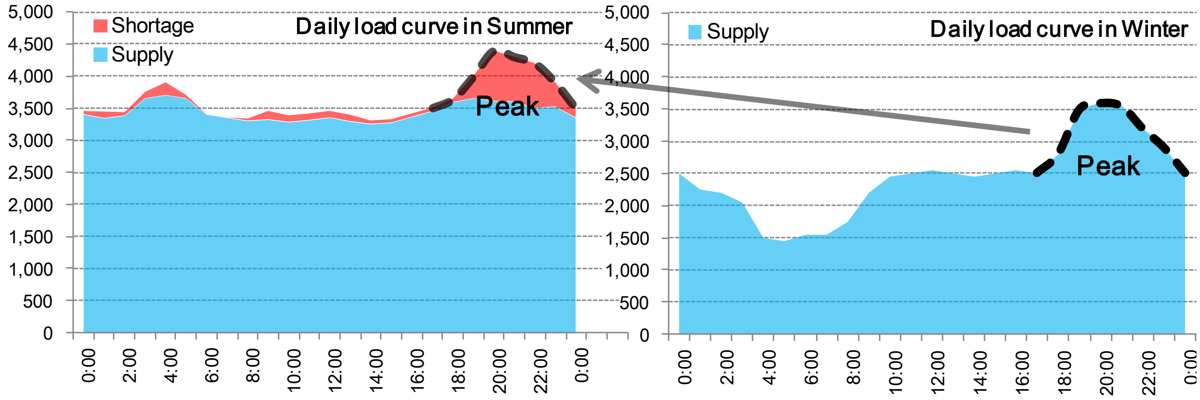
Figure 12-7 Comparision of peak power demand in both models

(3) 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 predict the maximum possible demand, including potential demand, more accurately, it is essential to estimate the daily load theoretically based on daily operation data, after considering the seasonal differences in the daily load curve and the frequency of rolling blackouts.

As shown in the figure below, rolling blackouts are carried out less frequently on holidays during the winter, and the daily load curve for such a day is extremely consistent with the actual demand during peak load hours (peak of light use). Taking into account that fact, we developed a synthesized daily load curve to estimate the power production. In doing so, the daily load curve for weekdays during the summer, which is adjusted downward by rolling blackouts, was combined with the estimated actual demand during the evening peak hours calculated based on the daily load curve for holidays in winter when no rolling blackouts are carried out.

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 estimates the maximum power energy.



Source: JICA PSMP2016

Figure 12-8 Typical daily load curves in Bangladesh in summer and winter

To estimate the maximum power that includes potential demands, PSMP adopts a method for calculating the generated power energy with which a compound daily load curve is produced by adding the evening peak demand for lighting, calculated from a daily load curve with no rotational outage on weekends and holidays in winter, to a daily load curve suppressed by rotational outage on weekdays in summer. 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 estimates the maximum power energy.

The analysis result is as shown in the table below. The actual recorded maximum load in fiscal 2015 was 7,356 MW. However, the maximum load estimated by giving consideration to latent intermediate load, peak load and actual efficiency in the assumed base load of 5,487MW is approximately 8,039MW. Accordingly, in prediction of the long-term demands up to fiscal 2041, 8,039MW reached in this study will be adopted as an initial value for fiscal 2015.

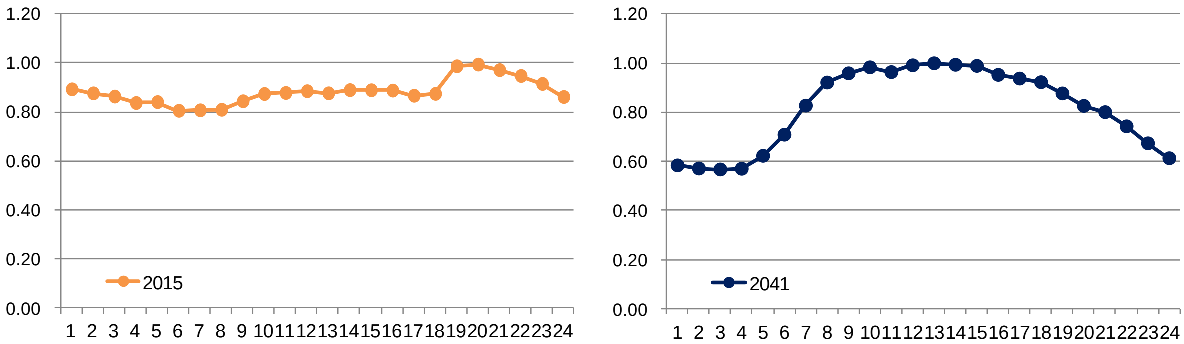
Table 12-7 Estimated maximum load for 2005-2015

Fiscal Year	Estimated Base Load (MW)	Estimated Intermediate Load (MW)	Estimated Base Over Peak Load (MW)	Estimated Peak Load (MW)	Actual Net/Gross	Estimated Net Peak Load(MW)	Growth (%)	Actual Net Peak Load (MW)	Growth (%)
2005	3,097	-	1,379	4,476	0.95	4,230		3,900	
2006	3,600	-	1,413	5,013	0.95	4,737	12.00%	4,200	7.70%
2007	4,050	-	1,063	5,113	0.95	4,832	2.00%	4,500	7.10%
2008	4,190	-	1,484	5,674	0.95	5,362	11.00%	4,600	2.20%
2009	4,150	-	1,500	5,650	0.95	5,339	-0.40%	5,050	9.80%
2010	4,300	817	1,462	6,579	0.95	6,258	16.40%	5,550	9.90%
2011	4,400	836	1,496	6,732	0.95	6,411	2.30%	5,550	0.00%
2012	5,000	950	1,700	7,650	0.96	7,326	13.60%	6,600	18.90%
2013	5,300	1,007	1,802	8,109	0.96	7,764	6.00%	6,600	0.00%
2014	5,487	1,043	1,811	8,341	0.96	8,039	2.90%	7,356	11.50%
2015	6,170	1,111	1,974	9,255	0.96	8,921	11.00%	7,500	2.00%

Source: JICA PSMP2016

12.1.3 Estimating the daily load curve

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



Source: JICA PSMP2016

Figure 12-9 Daily load curve in Bangladesh (Performance record for 2015 on the left, and estimated value for 2041 on the right)

(1) Procedure for estimating the 2015-2041 daily load curve

In the fiscal 2015 daily load curve, consideration is given to the performance value for power consumption on time-of-day basis in Bangladesh.

i) From the fiscal 2015 power consumption (performance value) on time-of-day basis in Bangladesh, the monthly Max/Average/Min data on time-of-day basis will be created where "Max" indicates the average value for highest three days for power consumption for each month, "Min" denotes the average value for lowest eight days for power consumption and "Average" represents the average value for the remaining days.
ii) According to the above-mentioned data, power consumption reaches the highest level in April. Thus, April is assumed as a "High" month. December is assumed as a "Low" month since power consumption reaches the lowest level in this month.
iii) The Max/Average/Min data will be standardized so that the Max value in April will be 1.0. This

is assumed as the 2015 daily load curve for Bangladesh.

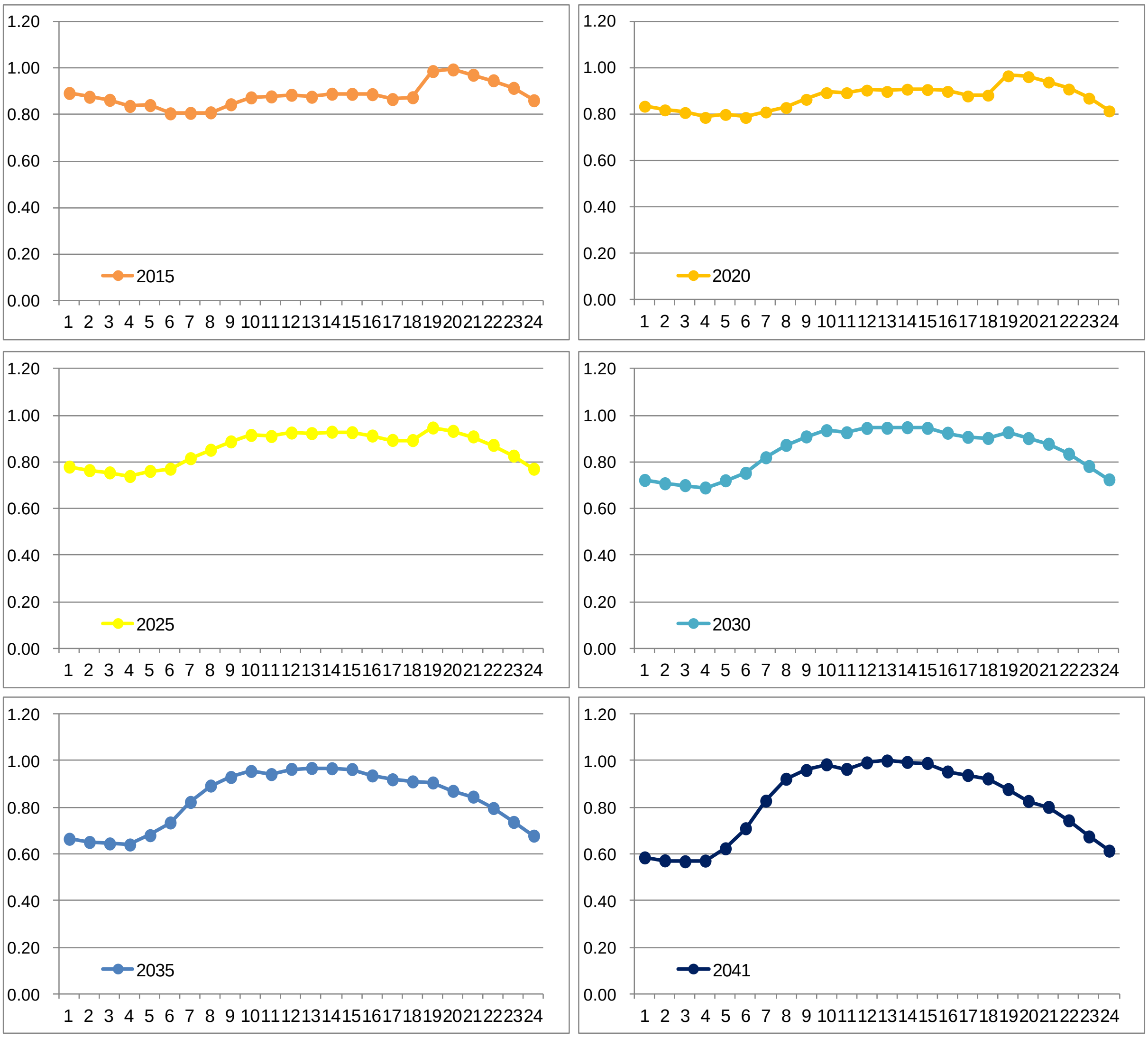
In the 2015-2041 daily load curve, there will be a gradual shift to the daily load curve of advanced countries by 2041.

i) The fiscal 2015 power consumption performance value on time-of-day basis of Japan will be used as the data of the advanced countries. Using the same procedure given in (1)-i), Max/Average/Min data on time-of-day basis for each month is created. According to the procedure given in (1)-ii), Max/Average/Min data is standardized so that the maximum value of August representing the maximum power consumption will be 1.0.
ii) "High" month in Bangladesh falls on April. Accordingly, the standardized Japan's data for August created in (2)-i) will be applied to the Bangladesh's April data for2041. Similarly, "Low" month in Bangladesh falls on December. Accordingly, the standardized Japan's data for May created in (2)-i) will be applied to the Bangladesh's December data for 2041.
iii) For the months other than December and May, there is a proportionate increase in power consumption from January to April, and a proportionate decrease in power consumption from June to November. This is assumed as an estimated daily load curve for 2041 in Bangladesh.
iv) From 2015 to 2040, there is assumed to be a proportionate increase or decrease in power consumption on time-of-day basis. This is considered to be an estimated daily load curve for the 2015-2040 period in Bangladesh.

$$H_{i,t} = H_{i-1,t} + (H_{2041,t} - H_{2015,t}) / (2041-2015+1)$$

※ i: year, t: time of the day

The estimated result is illustrated below. Observing the transition of the daily load curve at intervals of five years from 2015, the evening peak curve as a 2015 performance value represents a yearly change in the daytime peak curve of advanced countries.



Source: JICA PSMP2016

Figure 12-10 Estimated daily load curve for 2015-2041 period in Bangladesh

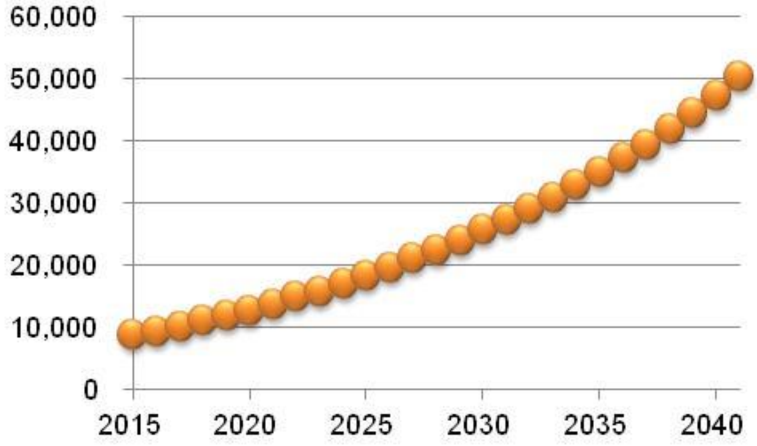
(2) Estimating the long-term power demand considering with future change of daily load curve

To estimate the long-term power demand considerting with future change of daily load curve, the daily load curve up to 2041 estimated in (2) is superimposed on the maximum power demand with consideration given to thepotentioal demand up to 2041 estimated in (1). The maximum power demand up to 2041 is estimated in another chapter. The value is shown in Table and Figure.

Table 12-8 Maximun power demand form 2015 to 2041

Power Demand	2015	2020	2025	2030	2035	2040
MW	8,921	12,949	19,191	27,434	36,634	49,034

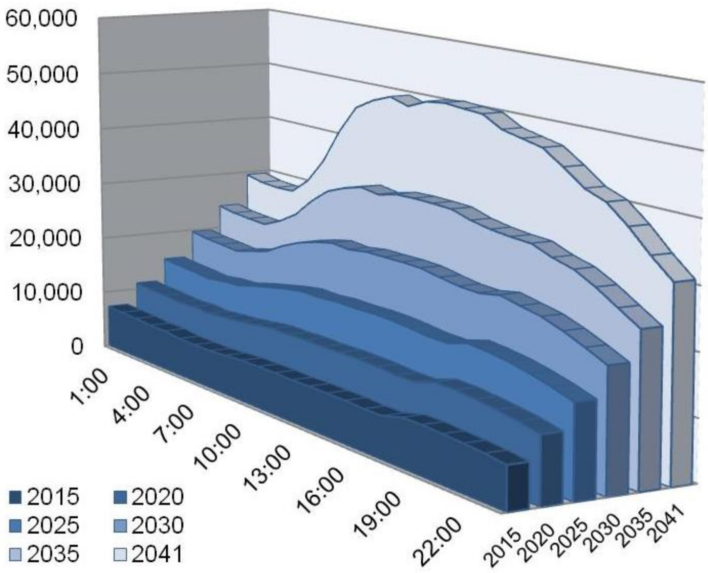
Source: JICA PSMP2016



Source: JICA PSMP2016

Figure 12-11 Maximun power demand form 2015 to 2041 (Unit: MW)

The result of estimation is illustrated below. The transition of power demand at intervals of five years from 2015 suggests that there is a rise in power demand during the 2015-2041 period, and a change from the daily power demand of evening peak to the daily power demand of daytime peak in conformity to the changes in daily load curve.



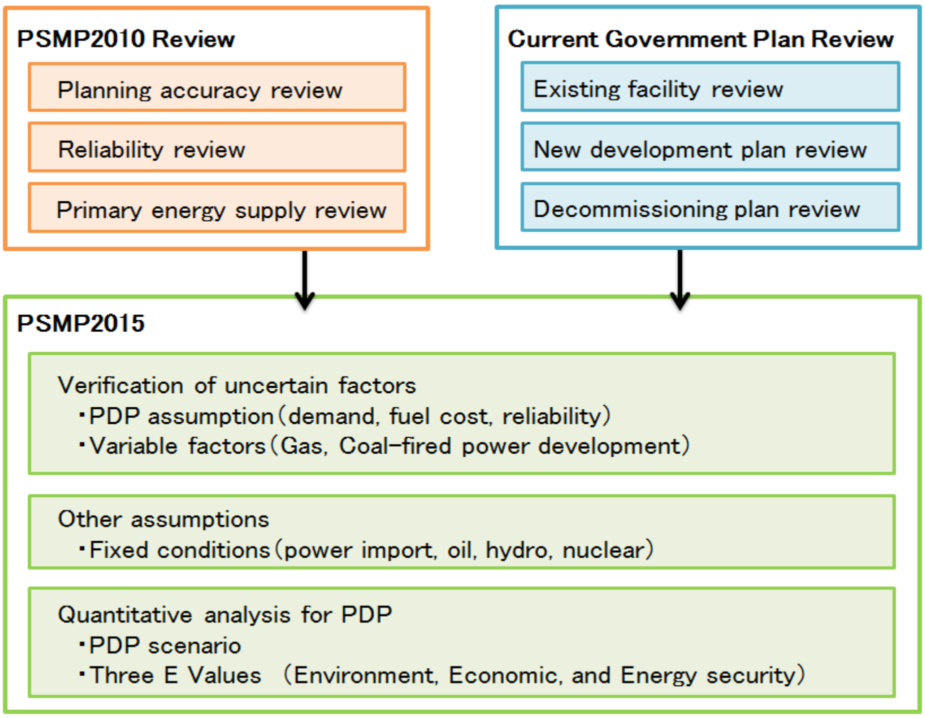
Source: JICA PSMP2016

Figure 12-12 Transition of estimated power demand during 2015-2041 period in Bangladesh (Unit: MW)

12.2 PSMP2010 Review

12.2.1 Study flow

To draw up a future power development plan over a long time, it is essential to review and verify the appropriateness of events with low uncertainty over a short term (existing facility and plan) and forge a long-term plan by piling up middle- to long-term plans with high uncertainty. The concrete study flow is as shown below.



Source: PSMP research group

Figure 12-13 Flow for Drawing Up Power Development Plan

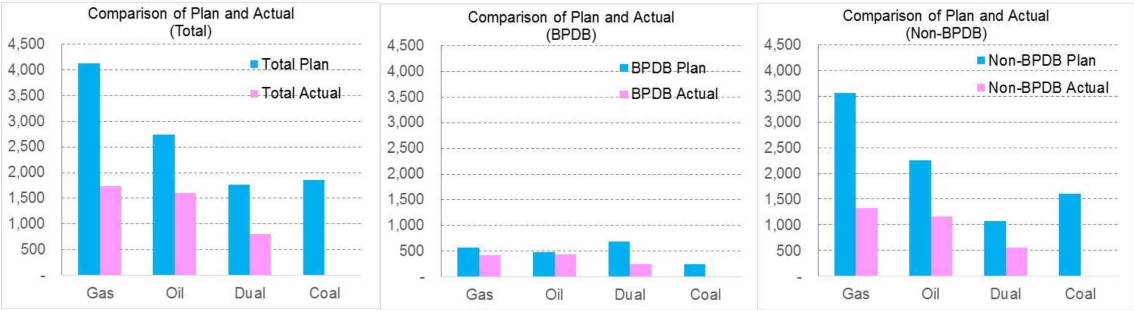
12.2.2 Plan reliability review

The following table shows the number of power development plans for PSMP2010 and the number of power plants constructed as of 2015. As of 2015, about 40% of the plan by BPDP and other plans combined is proceeding.

Table 12-9 Power Development Plans and Results by Fuel Type

			Gas	Oil	Dual	Coal	Total
BPDB	MW	Plan	568	486	692	250	1,996
		Actual	418	440	252	-	1,110
		%	74%	91%	36%	0%	56%
Non-BPDB	MW	Plan	3,558	2,257	1,075	1,600	8,490
		Actual	1,321	1,158	555	-	3,034
		%	37%	51%	52%	0%	36%
Total	MW	Plan	4,126	2,743	1,767	1,850	10,486
		Actual	1,739	1,598	807	-	4,144
		%	42%	58%	46%	0%	40%

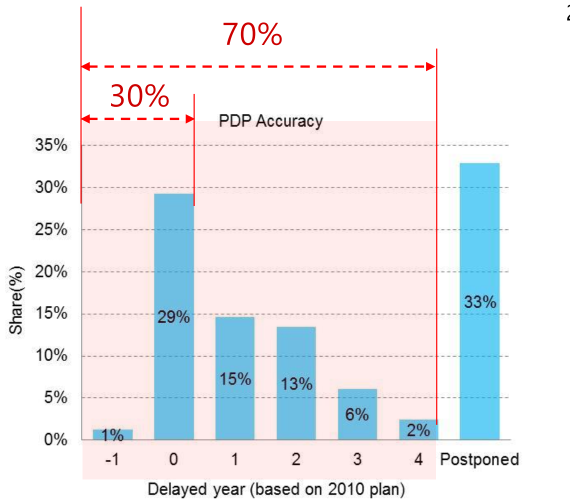
Source：JICA PSMP2016



Source：JICA PSMP2016

Figure 12-14 Power Development Plans and Results by Operator

Of the power plants already constructed, about 30% was completed as scheduled. On the other hand, 70% was constructed 1 to 4 years behind schedule. It is therefore assumed that 70% of the existing power development plan for PSM2015 will be delayed and a power development plan will be crafted taking the delay into consideration.



Source：JICA PSMP2016

Figure 12-15 Delay in Power Development Plan

12.2.3 Exisitng generation capacity and retirement plan

The installed capacity of existing plants was determined as described below after discussions with concerned organizations in Bangladesh. The installed capacity of existing plants is 10,895MW as of 2015. Lists of existing plants for each fuel type are shown below.

Table 12-10 Exisitng generation capacity in 2015

Gas	Existing	6,780
Oil	Existing	3,202
Coal	Existing	182
Sub Total	Existing	10,165
Hydro	Existing	230
Power Import	Existing	500
Ground Total	Existing	10,895

Source：JICA PSMP2016

(1) Gas-based

The list of existing gas-fired power plants is as follows and the total capacity is 6,780MW.

Table 12-11 Existing gas-based generation capacity

No.	Gas Plant (Existing)	Type			COD	Retirement	Operation Period	Output (MW) net 送電端出力
1	Rauzan 210 MW S\T (1st)	Public	ST	Gas	1993	2023	31	166
2	Rauzan 210 MW S\T (2nd)	Public	ST	Gas	1993	2023	31	166
3	Chittagong 1x60 MW Steam Turbine	Public	ST	Gas	N/A	2016	-	39
4	Shikalbaha 150 MW Peaking PP	Public	GT	Gas	2010	2030	21	147
5	Ashuganj 2x64 MW Steam Turbine	Public	ST	Gas	1970	2017	48	89
6	Ashuganj 3x150 MW Steam Turbine	Public	ST	Gas	1986	2021	36	366
7	Ashuganj GT 2 *	Public	CC	Gas	1986	2017	32	39
8	Ashuganj 50 MW	Public	RE	Gas	2011	2031	21	44
9	Ashuganj 225 MW CCPP	public	GT	Gas	N/A	2040	-	218
10	Chandpur 150 MW CCPP	Public	CC	Gas	2012	2038	27	158
11	Ghorasal 2x55 MW Steam Turbine	Public	ST	Gas	1974	2019	46	78
12	Ghorasal 210 MW S/T (5+6th Unit)	Public	ST	Gas	1986	2018	33	672
13	Siddhirganj 210 MW Steam Turbine	Public	ST	Gas	2004	2035	32	138
14	Siddhirganj 2x120 MW G/T	Public	GT	Gas	2012	2032	21	206
15	Haripur 3x33 MW Gas Turbine	Public	GT	Gas	1987	2017	31	59
16	Haripur 412 MW CCPP	Public	CC	Gas	2014	2039	26	400
17	Tongi 100 MW Gas Turbine	Public	GT	Gas	2005	2025	21	103
20	Sylhet 1x150 MW Gas Turbine	Public	GT	Gas	2012	2018	7	139
21	Fenchuganj C.C. (Unit #1)	Public	CC	Gas	2011	2020	10	165
22	Baghabari 71 MW Gas Turbine	Public	GT	Gas	1991	2020	30	69
23	Baghabari 100 MW Gas Turbine	Public	GT	Gas	2001	2025	25	98
24	Sirajgonj 150 MW Gas Turbine	Public	GT	Gas	N/A	2037	-	204
25	RPCL	Private		Gas	2006	2031	26	202
26	CDC, Haripur	Private		Gas	2001	2026	26	360
27	CDC, Meghnaghat	Private		Gas	2002	2027	26	450
28	Ghorashal 108 MW (Regent Power)	Private		Gas	2014	2029	16	108
29	Ashuganj modular 195 MW (United Power)	Private		Gas	N/A	2035	-	195
30	Bibiyana 2 (Summith) 341 MW	Private		Gas	N/A	2040	-	341
31	Bogra Rental (15 Years)	Private		Gas	2009	2023	15	22
32	Kumargoan (3 Years)	Private		Gas	N/A	2018	-	50
33	Sahzibazar RPP (15 Years)	Private		Gas	2009	2024	16	86
34	Sahzibazar RPP (3 Years)	Private		Gas	2008	2017	10	50
35	Tangail SIPP (22 MW)	Private		Gas	2008	2024	17	22
36	Feni SIPP (22 MW)	Private		Gas	2009	2024	16	22
37	Kumargao 10 MW (15 Years)	Private		Gas	2009	2024	16	10
38	Barabkundu	Private		Gas	2009	2024	16	22
39	Bhola RPP (34.5 MW)	Private		Gas	2009	2017	9	33
40	Jangalia , Comilla (33 MW)	Private		Gas	2009	2024	16	33
41	Fenchugonj 51 MW Rental (15 Yrs)	Private		Gas	2009	2024	16	51
42	Ashugonj 55 MW 3 Years Rental	Private		Gas	2010	2018	9	55
43	Fenchugonj 50 MW Rental (Energy Prima)	Private		Gas	2012	2017	6	44
44	Ghorashal 45 MW RPP (Aggreko)	Private		Gas	2010	2018	9	45
45	Ghorashal 100 MW RPP Aggreko)	Private		Gas	2012	2018	7	100
46	B.Baria 70 MW QRPP (3 Yrs Aggreco)	Private		Gas	2011	2017	7	85
47	Ghorashal 78 MW QRPP (3 Yrs Max Power)	Private		Gas	2011	2020	10	78
48	Ashugonj 80 MW QRPP (3 Yrs Aggreco)	Private		Gas	2011	2016	6	95
49	Ashugonj 53 MW Q. Rental PP (3 Years, United)	Private		Gas	2011	2019	9	53
50	Shajahanullah Power Com. Ltd.	Private		Gas	2010	2020	11	25
51	Summit Power(REB)	Private		Gas	1984	2022	39	105
52	Bogra RPP (Energy Prima)	Private		Gas	2011	2024	14	20
53	Lump SIPP Gas (Hobiganj SIPP (REB) (Confi-Energypac)	Private		Gas	2011	2024	14	11
54	Ullapara SIPP (REB) (Summit)	Private		Gas	2009	2024	16	11
55	Narsindi SIPP (REB) (Doreen)	Private		Gas	2008	2024	17	22
56	Feni SIPP (REB) (Doreen)	Private		Gas	2008	2024	17	11
57	Mouna, Gazipur SIPP (REB) (Summit)	Private		Gas	2009	2024	16	33
58	Rupganj , Narayanganj SIPP (REB) (Summit)	Private		Gas	2009	2024	16	33
59	Ashugonj 51 MW IPP (Midland)	Private		Gas	N/A	2028	-	51
							Total MW	6,780

Source：JICA PSMP2016

(2) Oil-based

The list of existing oil-fired power plants is as follows and the total capacity is 3,202MW.

Table 12-12 Existing oil-based generation capacity

No.	Oil Plant (Existing)	Type			COD	Retirement	Operation Period	Output (MW) net 送電端出力
1	Hathazari 100 MW Peaking PP	Public	RE	F.oil	2011	2032	22	96
2	Sangu, Dohazari 100 MW PPP	Public	RE	F.oil	2012	2033	22	99
3	RPCL Raozan 25 MW	Public	RE	F.oil	2013	2033	21	25
4	RPCL Gazipur 52 MW	Public	RE	F.oil	2012	2032	21	51
5	Titas (Doudkandi) 50 MW RE	Public	RE	F.oil	2011	2031	21	51
6	Khulna 1x110 MW Steam Turbine	Public	ST	F.oil	1984	2016	33	50
7	Barisal 2x20 MW Gas Turbine	Public	GT	HSD	1984	2016	33	30
8	Bheramara 3x20 MW Gas Turbine	Public	GT	HSD	1976	2016	41	46
9	Khulna 150 MW (NWPGCL)	Public	GT	HSD	2013	2017	5	155
10	Faridpur 50 MW Peaking PP	Public	RE	F.oil	2011	2031	21	52
11	Gopalgonj 100 MW Peaking PP	Public	RE	F.oil	2011	2032	22	107
12	Baghabari 50 MW RE	Public	RE	F.oil	2011	2031	21	51
13	Bera 70 MW RE	Public	RE	F.oil	2011	2032	22	70
14	Rangpur 20 MW Gas Turbine	Public	GT	HSD	1988	2016	29	19
15	Saidpur 20 MW Gas Turbine	Public	GT	HSD	1987	2016	30	19
16	Santahar 50 MW PP	Public	RE	F.oil	2012	2032	21	49
17	Katakhali 50 MW PP	Public	RE	F.oil	2012	2032	21	49
18	KPCL	Private		F.oil	1998	2018	21	110
19	NEPC	Private		F.oil	1999	2019	21	110
20	Natore, Rajshahi 50 MW PP	Private		F.oil	2014	2029	16	52
21	Meghnagat power Co. (summit)	Private		HSD	2015	2040	26	305
22	Gogonnogor 102 MW PP	Private		F.oil	2014	2029	16	102
23	Baraka-Potengga 50 MW PP	Private		F.oil	2014	2029	16	50
24	Potiya, Chittagong 108 MW (ECPV)	Private		F.oil	2015	2030	16	108
25	Comilla 52 MW (Lakdhanvi Bangla)	Private		F.oil	N/A	2030	-	52
26	Katpotti,Munshigonj 50 MW (Sinha peoples)	Private		F.oil	2015	2030	16	51
27	Shikalbaha 55 MW Rental (3 Years)	Private		F.oil	2014	2018	5	40
28	Thakurgaon 50 MW 3 Years Rental	Private		HSD	2015	2018	4	40
29	Khulna 55 MW RPP 3 yrs (Aggreko)	Private		HSD	2010	2018	9	55
30	Pagla 50 MW (DPA)	Private		HSD	2010	2018	9	50
31	Bheramara 110 MW 3 Yrs Rental (Quantum)	Private		HSD	2010	2018	9	105
32	Shiddirgonj 100 MW Q. Rental 3 Yrs	Private		HSD	2011	2019	9	98
33	Madangonj 100 MW QRPP (5 Yrs Summit)	Private		F.oil	2011	2021	11	100
34	Khulna 115 MW QRPP (5 Yrs Summit)	Private		F.oil	2011	2021	11	115
35	Noapara 40 MW QRPP (5 Yrs Khan Jahan Ali)	Private		F.oil	2011	2029	19	40
36	Noapara 105 MW RPP (5 Yrs Quantum)	Private		F.oil	2011	2016	6	101
37	Meghnagat 100 MW QRPP (5 Yrs) IEL	Private		F.oil	2011	2021	11	100
38	Shiddirgonj 100 MW QRPP (5 Yrs) Dutch Bangla	Private		F.oil	2011	2021	11	100
39	Amnura 50 MW QRPP (5Yrs, Sinha Power)	Private		F.oil	2012	2018	7	50
40	Keranigonj 100 MW QRPP (5 Yrs) Power Pac	Private		F.oil	2012	2017	6	100
41	Julda 100 MW QRPP (5Yrs, Acron Infra)	Private		F.oil	2012	2018	7	100
42	Katakhali 50 MW QRPP	Private		F.oil	2012	2019	8	50
							Total MW	3,202

Source：JICA PSMP2016

(3) Coal-based

The Barpapukuria Plant with the capacity of 182MW is the only existing coal-fired power plant. It uses domestic coal.

Table 12-13 Existing coal-based generation capacity

No.	Coal Plant (Existing)	Type	COD	Retirement	Operation Period	Output (MW) net 送電端出力
1	Barpapukuria 250MW (Unit 1&2)	Coal Domestic	2000	2036	37	182

Source：JICA PSMP2016

(4) Hydropower

The Kaptai Hydro Power Plant with the capacity of 230MW is the only existing hydropower plant.

Table 12-14 Existing hydropower generation capacity

No.	Hydro Plant (Existing)	Type	COD	Retirement	Operation Period	Output (MW) net 送電端出力
1	Kaptai Hydro Power Plant	Hydro	2000	9999	-	230

Source：JICA PSMP2016

(5) Existing power import generation capacity

Current power import is only 500MW by Bheramara-Bharampur HVDC (phase 1).

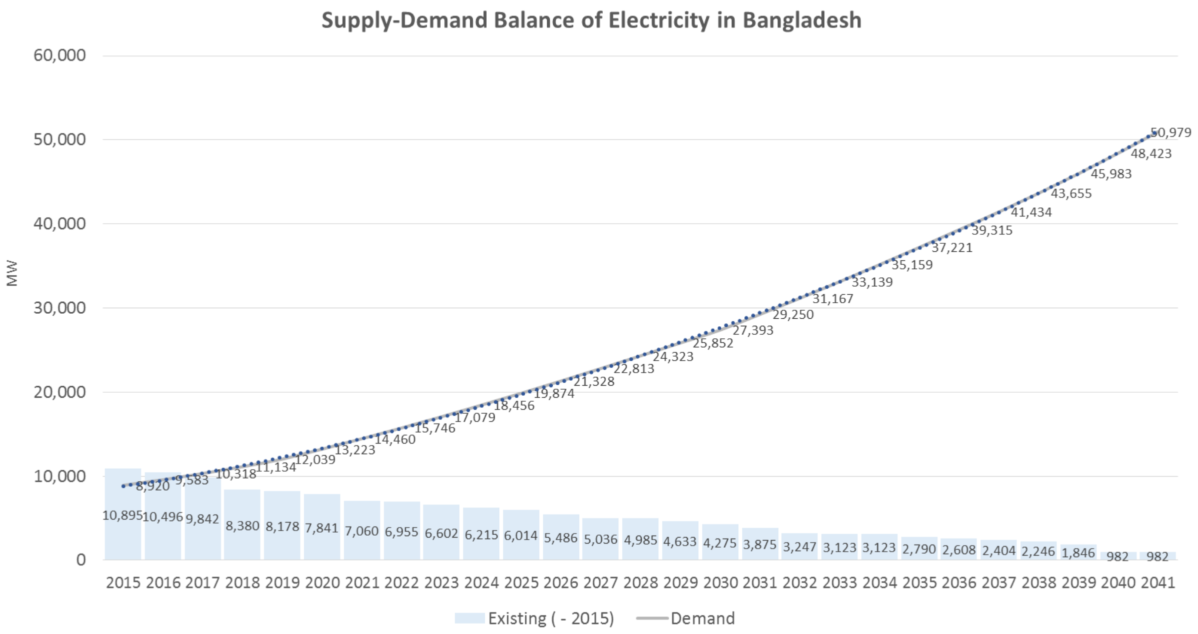
Table 12-15 Existing coal-based generation capacity

No.	Coal Plant (Existing)	Type	COD	Retirement	Operation Period	Output (MW) net 送電端出力
1	Bheramara-Bharampur	HDVC	2013	9999	-	500

Source：JICA PSMP2016

12.2.4 Retirement plan

Based on the lists of existing plant capacity described above, the COD, retirement year and years of operation are evaluated. Since the average years of operation are about 20 years, the retirement plan is determined to be valid.



Source: JICA PSMP2016

Figure 12-16 Existign capacity changes with retirement plan from2015-2041

12.2.5 Candidate plan

The plants to be newly built are divided into those that the construction has been already committed and confirmed with concerned organizations in Bangladesh (described later) and those that are not yet committed and are still subject to change. The installed capacity of the committed plants was confirmed as follows. As shown in the table below, the total installed capacity of the committed plants is 14,213MW. Lists of candidate plants for each fuel type are shown below.

Table 12-16 Fuel-wise comitted capacity in 2015

Comitted		
Gas	comitted	5,126
Oil	comitted	2,545
Coal	comitted	6,543
Sub Total	comitted	14,213

Source：JICA PSMP2016

(1) Gas based

The list of candidate gas-fired power plants is as follows and the total capacity is 5,126MW.

Table 12-17 Candidate gas-fired power plants

No.	Gas Plant (Candidate)	Type		COD	Retirement	Output (MW) net 送電端出力
1	Bhola 225 MW CCPP: SC GT Unit	BPDB	Gas	2016	2041	189
2	Siddirganj 335 MW CCPP: SC GT Unit	EGCB	Gas	2016	2041	328
3	Ashuganj (South) 450 MW CCPP	APSCL	Gas	2017	2042	370
4	Ashuganj (South) 450 MW CCPP	APSCL	Gas	2016	2041	361
5	Ghorasal 363 MW (7th Unit) CCPP	BPDB	Gas	2017	-	352
6	Shajibazar CCPP	-	Gas	2016	2041	322
7	Shikalbaha 225 MW CCPP	-	Gas	2017	-	218
8	Bibiana South CCPP BPDB	-	Gas	2019	-	372
9	Bibiana III CCPP BPDB	-	Gas	2019	-	388
10	Bheramara 414 MW CCPP	NWPGC	Gas	2018	2042	402
11	Fenchugonj 50 MW Power Plant	IPP/NRB	Gas	2019	2034	50
12	Sylhet 150 MW PP Conversion (Additional 75MW)	BPDB	Gas	2018	2042	221
13	Ghorasal 3rd Unit Repowering (Capacity Addition)	BPDB	Gas	2018	2042	776
14	Kusiara 163 MW CCPP	IPP	Gas	2018	-	163
15	Bagabari 100 MW PP Conversion	BPDB	Gas	2020	2042	102
16	Sirajganj 414 MW CCPP (4th unit)	-	Gas	2020	2043	414
17	Shahajibazar 100 MW	-	Gas	2038	-	98
					Total MW	5,126

Source：JICA PSMP2016

(2) Oil based

Table 12-18 Candidate oil-fired power plants

No.	Oil Plant (Candidate)	Type	COD	Retirement	Output (MW) net 送電端出力
1	Kodda Gazipur 150 MW (PDB-RPCL)	Oil	2016	2035	147
2	Chapai Nababganj 104 MW PP	Oil	2017	2032	102
3	Keranigonj 100 MW PP (Re from Khulna))	Oil	2019	2034	100
4	Bosila, Keranigonj 108 MW PP (CLC Power)	Oil	2017	2032	108
5	Jamalpur 100 MW Power Plant	Oil	2017	2032	95
6	Barisal 100 MW PP (Re. from Syedpur)	Oil	2016	2031	110
7	Lump HFO Private New ~50 MW (Madangonj 50 MW Peaking Plant (Re. from Shantahar)	Oil	2016	2031	55
8	Manikgonj 55 MW PP	Oil	2016	2031	50
9	Kamalaghat 50 MW PP)	Oil	2017	2032	55
10	Nababgonj 55 MW PP	Oil	2016	2031	55
11	Satkhira 50 MW PP	Oil	2019	2034	50
12	Bhairab 50 MW PP	Oil	2019	2034	50
13	Upgradation of Khulna 150 MW to 225 MW	Oil	2017	2037	221
14	Khulna 200-300 MW CCPP	Oil	2019	2039	196
15	Patiya 100 Mw BOO FO power plant	Oil	2020	2035	100
16	Anwara 300 MW HFO plant	Oil	2020	2035	300
17	Julda 100 Mw BOO FO power plant	Oil	2020	2035	100
18	Sirajgonj 225 MW CCPP (2nd Unit)	Oil	2019	2039	216
19	Sirajgonj 225 MW CCPP (3rd Unit)	Oil	2020	2040	216
20	Bhola 220 MW CCPP Dual Fuel BOO power plant	Oil	2020	2040	220
				Total MW	2,545

Source：JICA PSMP2016

(3) Coal based

The list of candidate coal-fired power plants is as follows and the total capacity is 6,543MW.

Table 12-19 Candidate coal-fired power plants

No.	Coal Plant (Candidate)	Type				COD	Retirement	Output (MW) net 送電端出力
1	Matarbari#1,2	Public	CPGCBL	USC	Imp Coal	2023	-	1,104
2	Rampal#1,2	Public	BIFPCL	SC	Imp Coal	2020	-	1,214
3	Payra#1,2	Public	NWPGCL	SC	Imp Coal	2020	-	1,214
4	Khulna	IPP	Orion Group	SC	Imp Coal	2020	-	630
5	Maowa	IPP	Orion Group	SC	Imp Coal	2020	-	522
6	Dhaka	IPP	Orion Group	SC	Imp Coal	2020	-	635
7	Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-1				Imp Coal	2020	-	612
8	Chittagong 612 MW Coal Fired Power Project(S.Alam Group)-2				Imp Coal	2020	-	612
							Total MW	6,543

Source：JICA PSMP2016

(4) Technical evaluation

The JICA Study Team assessed the candidate plan suggested by the government from the following viewpoints. As a result, although it was technically determined that some of the plants may not be able to achieve the assumed commissioning of date (COD), respecting the government spirit of taking challenges, even though the target may be difficult, in formulating the long-term power generation plan, the Team decided to adopt the government committed plan.

12.2.6 Fuel cost scenario

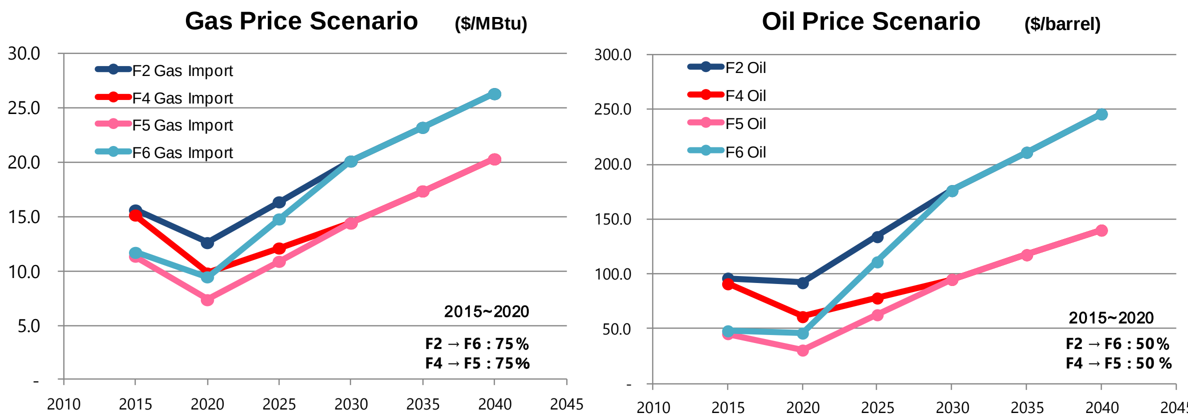
To assess the economic efficiency, some scenarios for fuel prices were considered for each fuel type. Fuel gas is very cheap in Bangladesh compared with the international price. The controlled price for fuel gas in the country is 1/16th the international price. Demand for primary energy is significantly increasing in tandem with economic growth, and Bangladesh is expected to be forced to import primary energy sources from other countries in the future. Considering that situation, the following five scenarios numbered F1 to F5 were considered. While the long-term estimate of the international price by the IEA was used under F1 to F4, the current conditions in Bangladesh were taken into account based on the F4 scenario when making an estimate under F5.

F1: IEA's New Policies Scenario
F2: IEA's Current Policies Scenario
F3: IEA's 450 Scenario
F4: IEA's Low Oil Price Scenario
F5: Revised F4 Scenario considering current status in Bangladesh
F6: Revised F2 Scenario considering current status in Bangladesh

The following are notes for the F5 and F6 scenarios.

- The oil prices are set at the value equivalent to 50 percent those for F4 and F2 for the period until 2020. The oil prices are estimated to gradually increase so that they will catch up with the levels under the F4 and F2 scenarios by 2030.
- The imported gas prices are set at the value equivalent to 75 percent those for F4 and F2 for the period until 2020. The prices are estimated to gradually increase so that they will catch up with the levels under the F4 and F2 scenarios by 2030.

The domestic gas prices represent the price as of 2014 in Bangladesh and are estimated to gradually increase so that they will catch up with the levels under the F4 and F2 scenarios by 2030.



Source: JICA PSMP2016

Figure 12-17 Gas and oil prices under F5 and F6 scenarios

For the forecast of future fuel prices, relevant fuel scenarios are calculated with the oil price as the standard in principle. For the oil price, oil price 2015-2040, which is estimated based on the world supply-demand balance scenario released by the International Energy Agency (IEA), is adopted. With respect to the natural gas price, although it is usually determined based on relative transactions linked to the oil price based on long-term contracts, it is also widely known to be 1/6 of the oil price. As such, the long-term gas price in Bangladesh was estimated by taking these factors as well as the gas price scenario shown by the IEA and the current market price into consideration. In addition, long-term coal price scenario has been established based on the assumption that Australian and Indonesian coal will be procured based on the supply-demand balance scenario, which is described in detail in the chapter relating to coal. Moreover, scenarios for products deriving from oil should also be established based on the oil price as shown in the following table.

Table 12-20 Fuel Scenari conditions

Exchange Rate (Taka/$)						
Discount rate	12%					
GJ to Million Kcal	418					
1. EIA 2009 Energy Outlook (price at refineries)						
Exchange Rate (Taka/$)						
3. LS diesel 1.20, and high sulfur diesel 1.15 for fuel oil price						
4. Natural gas price is 0.75 of estimated fuel oil price						
5. EIA 2005 Energy Outlook (exported price FAS of US coal)						
6. Assumes 80% of Imported coal cost in $/Ton						
7. LPG price is assumed at 130% of Natural Gas						
					Rationale	
Crude has 40.14 MJ/kg			40.14			
Import	6000	kcal/kg		25.0	MJ/kg	
Domestic	6100	kcal/kg		25.5	MJ/kg	
Fuel oil price as % of Crude			0.80		Historical data for ratios HFO vs. crude #2 distillate	
Low Sulfur Diesel as % of crude			1.20		Historical data for #2 diesel vs. #2 fuel oil	
High Sulfur Diesel as % of crude			1.15		Historical data for #2 distillate vs. crude	
Natural gas price as % of fuel oil price			0.75		EIA forecast, 75% of singapore HFO	
Domestic coal as % of imported coal			80%			
$/Ton for coal transport and handling			15			
						for WASP
Natural Gas 950 Btu/scf or 35,375 kJ/cubic meter				950		239.396 Kcal/scf

12.2.7 Supply reliability

The following figures show expected reserved margine.

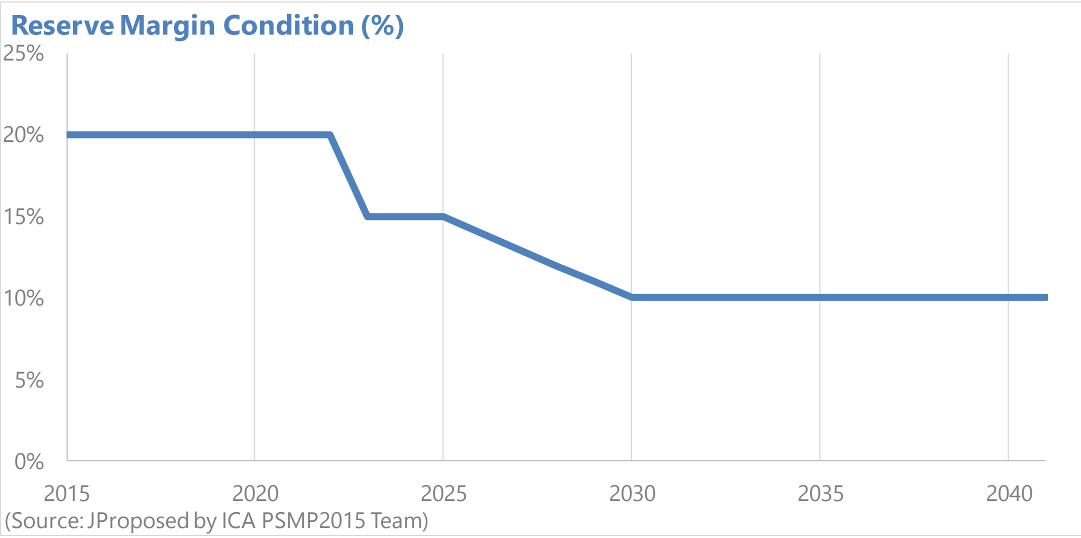


Figure 12-18 Reserved Supply Capability

12.2.8 CO2 emissions by fuel type

To assess the impact on the environment, the emissions of carbon dioxide (CO_2) by fuel were estimated based on the calculation formula below. The results are summarized in the following table.

CO_2 emissions (kg/Mcal)
= carbon content per heating value (t-CO_2/TJ) / consumed calories per heating value (kcal/MJ)

Table 12-21 Estimated CO2 emissions by fuel

Item	CO2 emissions (kg/Mcal)
COAL (Domestic)	0.39615
COAL (Import)	0.40229
HSD	0.30095
OIL	0.30709
GAS	0.23492

Source: JICA PSMP2016

12.3 Power demand and supply simulation

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

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

- P1 (Coal Max)：Coal55%、Gas15%
- P2：Coal 45%、Gas 25%

- P3：Coal 35%、Gas 35%
- P4：Coal 25%、Gas 45%
- P5 (Gas Max)：Coal 25%、Gas 45%

After determining the optimum share of gas and coal in the enrgy mix, as Step2, changing the share of other fuels than the thermal power and nuclear power in the energy mix should be considered.

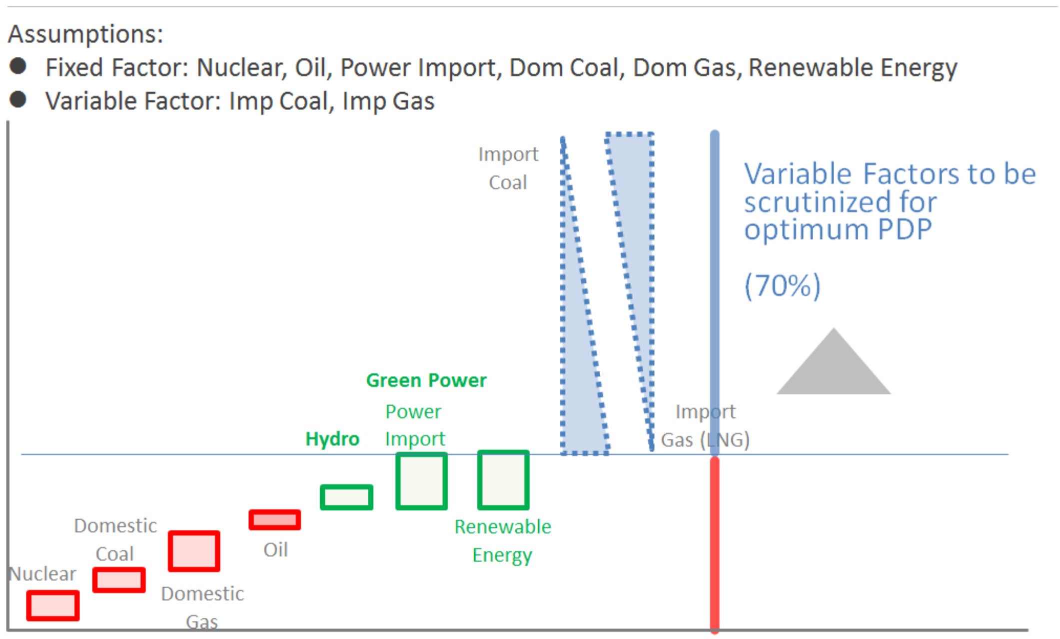
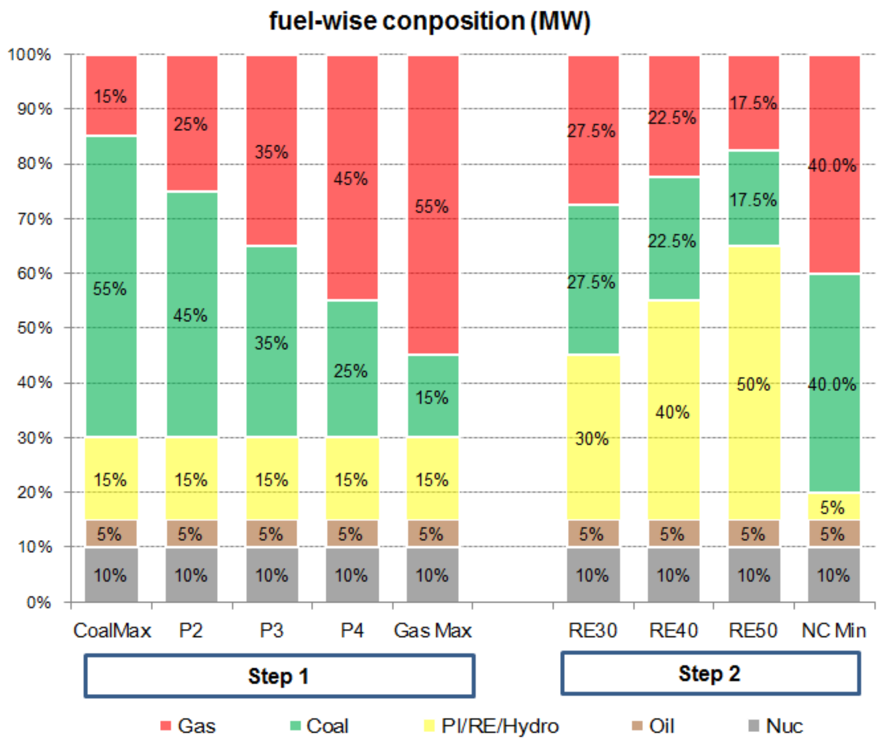
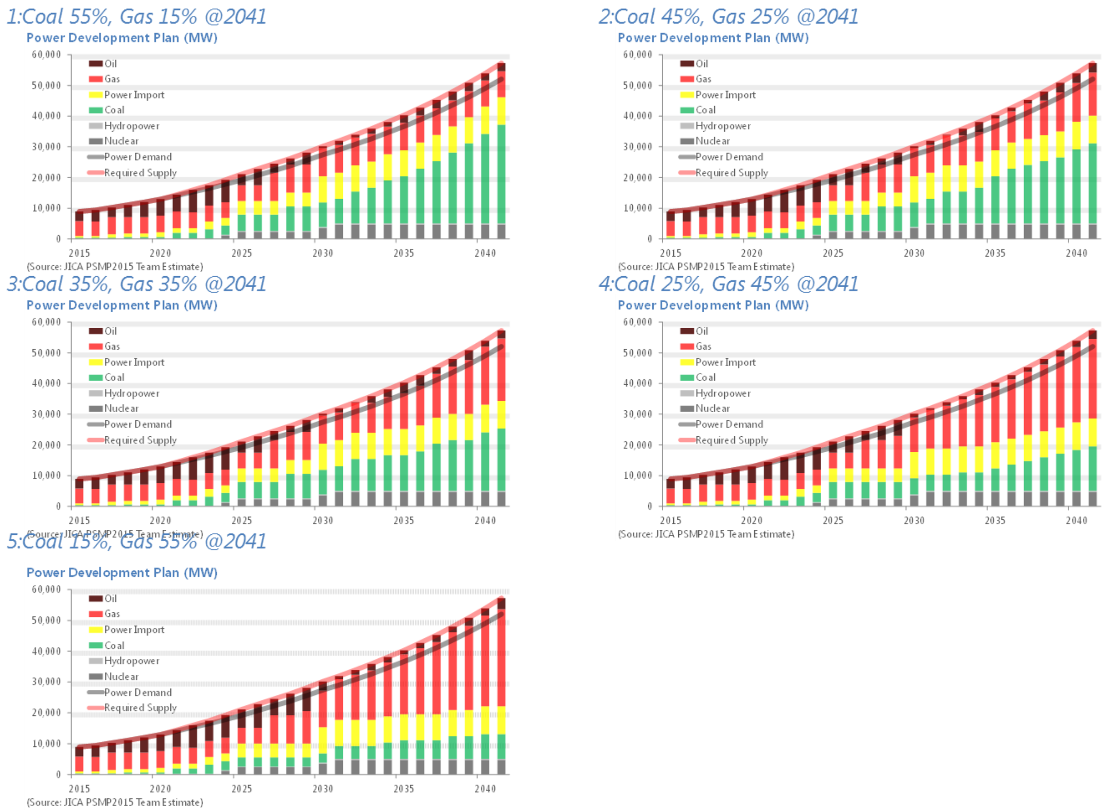


Figure 12-19 Methodology for demand and supply simulation



Source：JICA PSMP2016

Figure 12-20 Generation pattern in 2041



Source：JICA PSMP2016

Figure 12-21Annual Trend of Energy Mix in Different Scenarios

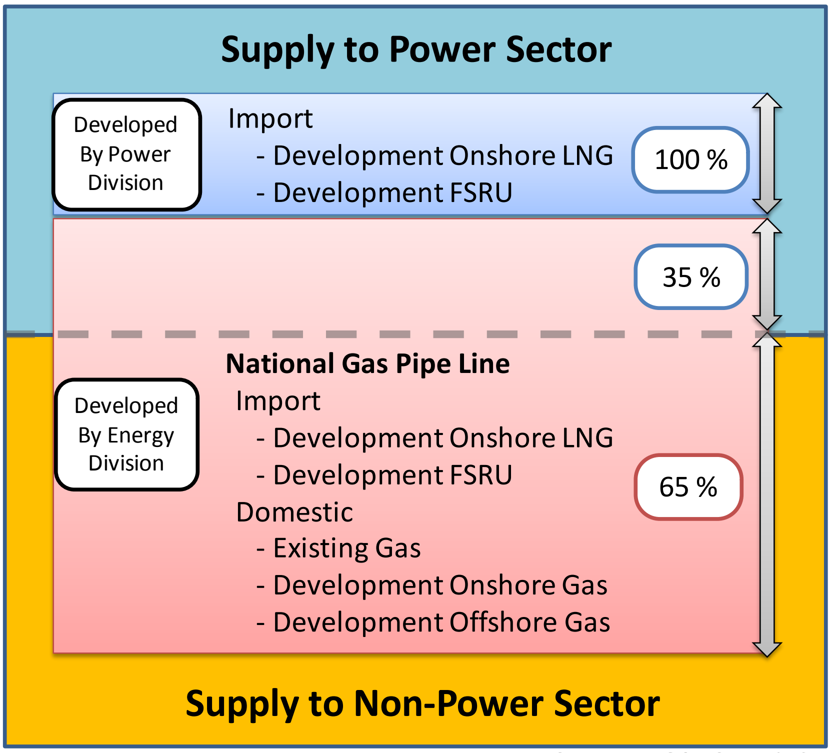
12.3.1 Scenario fluctuating condition

(1) Gas development plan scenario

(a) Gas supply scheme

The following figure shows a scheme to develop natural gas in Bangladesh. The supply scheme is as follows. The gas facilities are divided into domestic gas facilities developed through energy division, domestic on-shore and off-shore facilities to be developed in the future, on-shore LNG and off-shore FSRU facilities to be developed through power division for imported gas.

Of the gas supplied through energy division, 35% is supplied to the power sector and 65% to the non-power sector. The gas supplied through power division is supplied 100% to the power sector.



Source：JICA PSMP2016

Figure 12-22 Natural Gas Supply Scheme

(b) Conditions to be studied

The scenario studied by JICA's southern Chittagong MP research will be employed for an LNG development plan scenario. Development of LNG terminals in the Matarbari area is planned according to the following policy:

a) For the following reasons, LNG should be imported at receiving terminals to be constructed in the Matarbari area as much as possible.

There are no other projects that are identified as "on-going" except FSRU by Petrobangla.

It can be said that, except in the Matarbari area, it is difficult to find a suitable site for developing a deep sea port that is required for receiving a large scale LNG carrier.

It is economical to develop LNG receiving terminals in conjunction with the development of commercial ports and/or industrial ports.

b) Onshore terminals generally require about four years for construction (not including land reclamation) and it is difficult to achieve early development considering the periods required for other activities such as FS, permits, design, tender, land reclamation, etc. Therefore, for FY2019 to FY2026 when the gas supply deficit emerges, FSRUs that require relatively short period of time by the operation start should be, in addition to the import from India through a pipeline, introduced to correspond to the deficit.

c) LNG receiving terminals should be developed in stages corresponding to the increase of demand. 500 mmcfd should be adopted as a standard capacity in each development stage.

d) Storage of LNG should be adequately planned considering the influence of bad weather, accidents, etc.

(c) Development scenario

The figure below shows LNG development scenario.

Table 12-22 LNG Development Scenario

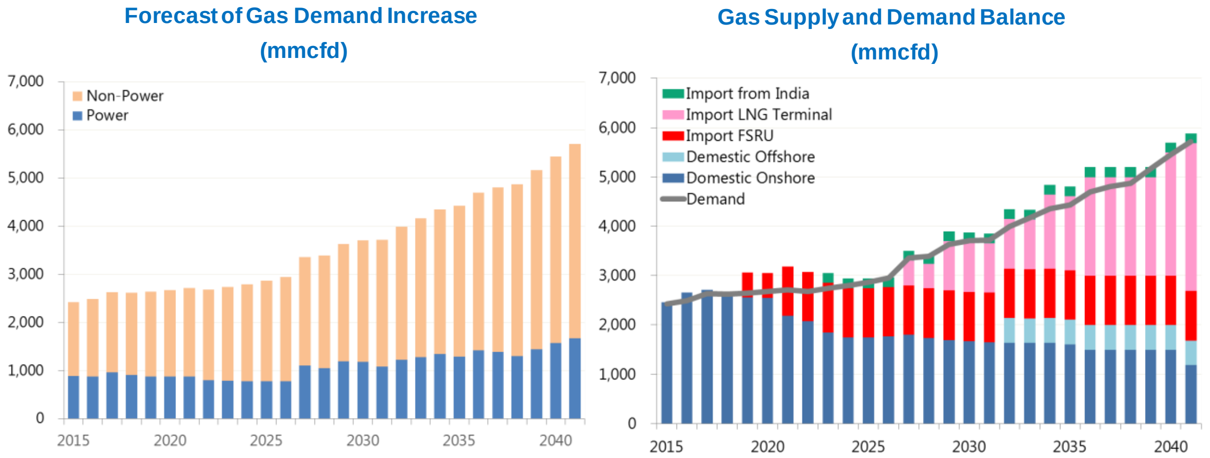
	3	7	8	9	10	11	12	13	14	15
	Demand	Supply		New LNG Terminal						Balance
				FSRU		Onshore Terminal				
	Total	**Total**	**Shortage**	Energy Div		Energy Div	Power Div.		Total of New LNG Terminal	New LNG Terminal - Shortage
Source			**3 - 7**						9 to 13	8 + 14
FY	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd
2015	**2,425**	**2,464**	**40**							40
2016	**2,488**	**2,653**	**166**	**By Petrobangla**			**Pipeline from India**			166
2017	**2,632**	**2,716**	**84**							84
2018	**2,624**	**2,662**	**37**							37
2019	**2,645**	**2,563**	**-82**	500					500	418
2020	**2,679**	**2,547**	**-132**	500					500	368
2021	**2,716**	**2,188**	**-528**	500	500				1,000	472
2022	**2,682**	**2,075**	**-607**	500	500				1,000	393
2023	**2,742**	**1,851**	**-891**	500	500		200		1,200	309
2024	**2,796**	**1,747**	**-1,049**	500	500		200		1,200	151
2025	**2,870**	**1,741**	**-1,128**	500	500		200		1,200	72
2026	**2,948**	**1,766**	**-1,183**	500	500		200		1,200	17
2027	**3,358**	**1,805**	**-1,553**	500	500		200	**500**	1,700	147
2028	**3,388**	**1,740**	**-1,648**	500	500		200	500	1,700	52
2029	**3,628**	**1,696**	**-1,932**	500	500	**500**	200	500	2,200	268
2030	**3,707**	**1,671**	**-2,036**	500	500	500	200	500	2,200	164
2031	**3,724**	**1,653**	**-2,071**	500	500	500	200	500	2,200	129
2032	**3,990**	**2,142**	**-1,848**	500	500	500	200	500	2,200	352
2033	**4,165**	**2,133**	**-2,031**	500	500	500	200	500	2,200	169
2034	**4,352**	**2,137**	**-2,214**	500	500	**1,000**	200	500	2,700	486
2035	**4,428**	**2,104**	**-2,324**	500	500	1,000	200	500	2,700	376
2036	**4,701**	**1,996**	**-2,705**	500	500	**1,500**	200	500	3,200	495
2037	**4,804**	**1,996**	**-2,808**	500	500	1,500	200	500	3,200	392
2038	**4,868**	**1,996**	**-2,872**	500	500	1,500	200	500	3,200	328
2039	**5,164**	**1,997**	**-3,167**	500	500	1,500	200	500	3,200	33
2040	**5,455**	**1,999**	**-3,457**	500	500	2,000	200	500	3,700	243
2041	**5,715**	**1,684**	-4,030	500	500	2,500	200	500	4,200	170

To be planned in the Matarbari Area (columns 10, 11 and 13)

On-going FSRU at Maheshkhali [note] (column 9)

Note: According to the information from Petrobangla, the on-going FSRU may start its operation from March 2017 (FY2017). However, the above table assumes that the operation starts from FY2019 when the gas supply deficit emerges.

Source: 1) Demand and supply: JICA PSMP2016 and EECMP
2) New LNG terminals: Petrobangla, Power Div., NWPGC, JICA Survey Team



Source：JICA PSMP2016

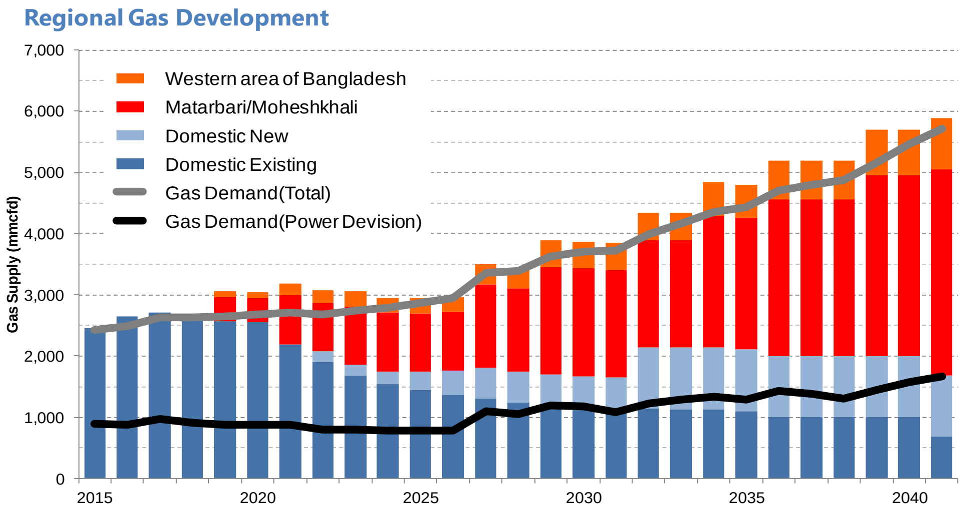
Figure 12-23 Gas Supply Scheme

From the above table, it is found that the amount of 4,000 mmcfd (2 x 500 mmcfd FSRU + 2,500 mmcfd onshore terminals by Energy Div. + 500 mmcfd onshore terminal by Power Div.) among the total demand of about 5,700 mmcfd in FY2041 should be supplied from the new LNG terminals and if these terminals constructed in the Matarbari area, a quite large portion of the total gas demand has to rely on one supply base. This situation is not preferable from a viewpoint of energy security. There may be operational problems in the existing gas supply network as well. Considering these points, it has been arbitrarily judged that the maximum supply capacity in the Matarbari area should be limited to more or less 50% of the total demand in FY2041 and thus, the last two onshore terminals (2 x 500 mmcfd capacity) in FY2040 and FY2041 should be constructed at different locations.
Consequently, the new LNG terminals to be developed in the Matarbari area are as summarized below:
The above plan should be further discussed with concerned organizations in Bangladesh and if necessary, the proposed development plan should be re-examined.

Table 12-23 LNG Terminals Planned to be Developed in Matarbari Area

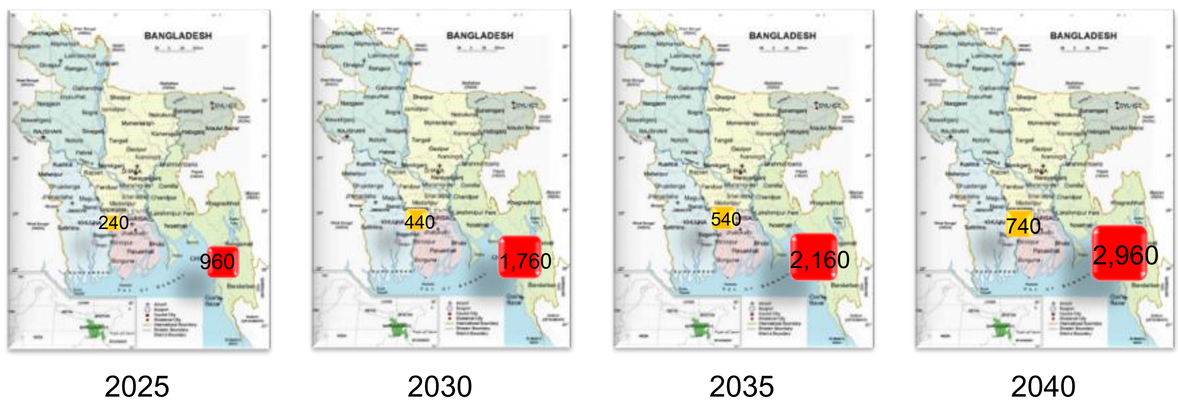
FY	Type of Terminal	Capacity (mmcfd)	Remarks
2019	*FSRU*	*500*	*On-going project by Petrobangla*
2021	FSRU	500	To be planned
2027	Onshore	500	To be planned
2029	Onshore	500	To be planned
2034	Onshore	500	To be planned
2036	Onshore	500	To be planned
Total Capacity		3,000	

Source: JICA Survey Team



(Source: JICA PSMP2015/South Chittagong Team Estimated)

Figure 12-24 Scenario to Develop Imported Gas in Each Region



Source：JICA PSMP2016

Figure 12-25 Scenario to Develop Imported Gas in Each Region (Unit: mmctd)

(2) Coal development scenario

(a) Existing development scenario
Domestic coal production in Bangladesh is only from Barapukuria coal mine (underground mine), which produces at present approx. 1 million tonnes annually and supplies to Barapukuria power station, etc., and will produce only approx.1.5 million tonnes annually for Barapukuria power station, etc. even after implementation of expansion plan. Although Phulbari coal mine has a huge reserve, the development of Phulbari coal mine was cancelled by current government because many people need to be resettled for the development. As production of domestic coal will not increase against surge of power demand in the future, imported coal will be necessary.

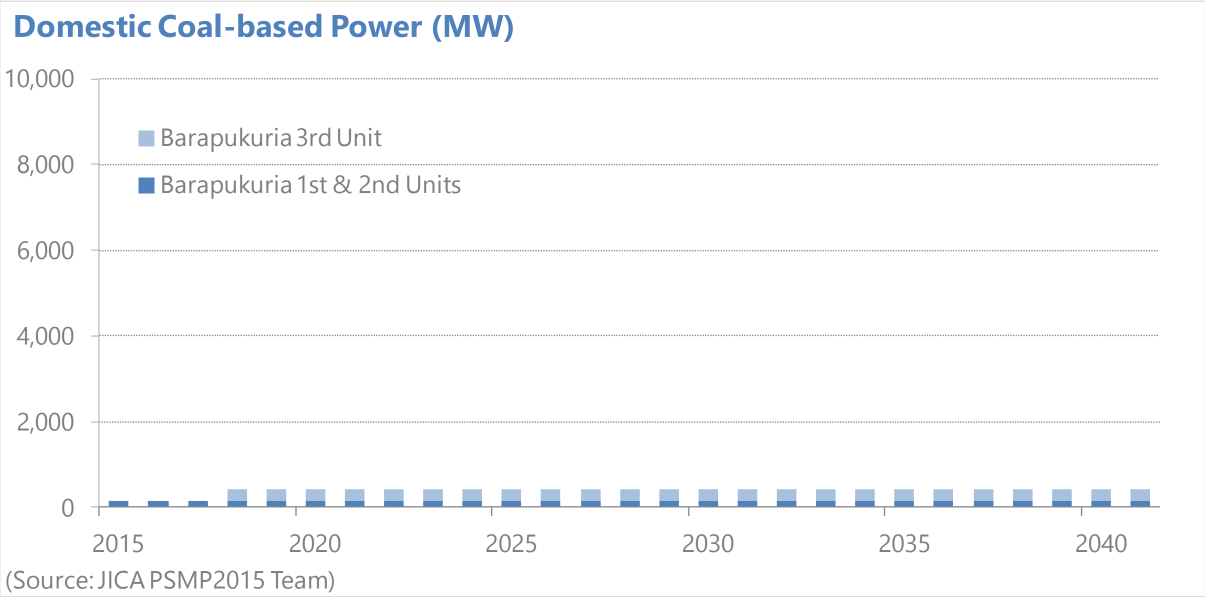


Figure 12-26 Existing Coal-fired Power Plant Scenario

(b) New development scenario
As for coal transportation from coal production country such as Australia, Indonesia and South Africa to Bangladesh, using larger vessel is cost effective transportation method. Panamax vessel (80,000DWT) can access near Matarbari #1-6 and Maheshkhali projects sites, if a commercial port at Maheshkhali island is constructed. On the other hand, the vessel can't access near Maowa, Khulna, Rampal, Payra and Matarbari # 7-12 project sites, because of very shallow bay around these project sites. These projects may use onshore coal terminals or offshore coal trans-shipment stations to reduce fuel transportation costs.
According to discussions with power companies, that is, BIFPCL, CPGCPL, NWPGC and Orion Group, etc., following information was supplied.

a) Rampal projects
Rampal projects will use an off shore coal trans-shipment station. 8,000DWT-10,000DWT barge from the station to projects sites has been considered. However these projects will use CTT, in case that COD of CTT is earlier than COD of Rampal projects and tariff of the terminal is cheaper than operation costs of the off shore coal trans-shipment station.

b) Payra projects
Deep sea port will be constructed at Payra, which also have a coal terminal.

c) Maowa and Khulna projects
Maowa and Khulna projects will use imported coal using 5,000DWT barge via Chittagong port, whose maximum draft is 9.1m. Panamax vessel cannot access Chittagong port because of shallow waterway.
d) Matarbari North projects
Matarbari North projects will use CTT.

e) Brick manufactures (Non-Power)
Brick manufactures at the north of Dhaka, use imported coal using 5,000DWT barge via Chittagong port. It is possibility that Rampal projects, Payra projects, Maowa and Khulna projects and brick manufactures also use a coal terminal, which Panamax vessel can access, because of cheaper fuel transportation costs. The estimated annual trading volume of CTT is depending on the development progress of the Payra deep sea port.

(c) Development Scenario
c) Maowa and Khulna projects
Maowa and Khulna projects will use imported coal using 5,000DWT barge via Chittagong port, whose maximum draft is 9.1m. Panamax vessel cannot access Chittagong port because of shallow waterway.
d) Matarbari North projects
Matarbari North projects will use CTT.

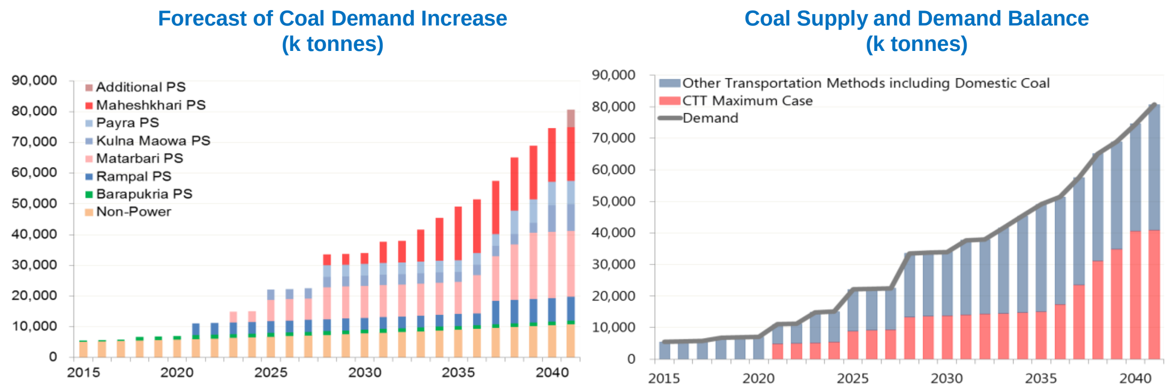
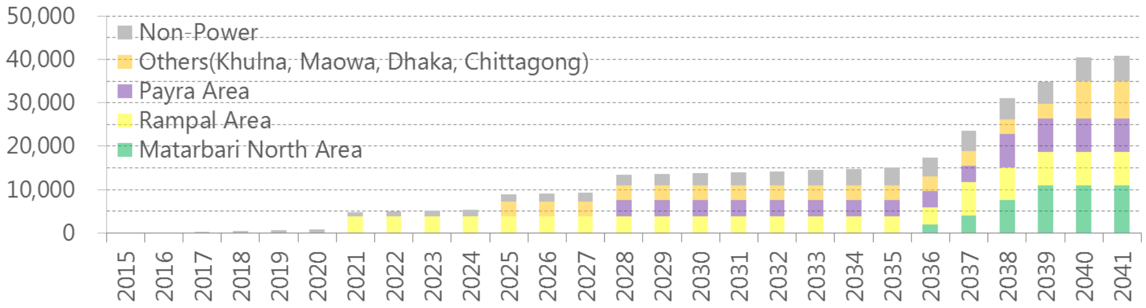


Figure 12-27 Coal Demand and Supply

(d) Assumption for plotting plan of CTT

a) Estimated annual trading volume
Currently transportation methods of imported coal for each project except for Matarbari and Maheshkhali projects have not yet fixed, maximum estimated annual trading volume of CTT is adopted for plotting plan. As brick manufactures have used Chittagong port, only increment of coal consumption volume of non-power since 2015 is added to trading volume of CTT. The Table below shows the estimated trading volume at CTT. The estimated annual trading volumes at CTT in FY 2026, FY 2031 and FY 2041 would be approx. 9 tonnes, approx. 14 million tonnes and approx. 41 million tonnes respectively. The Table below shows estimated annual trading volume at CTT in FY 2026, FY 2031 and FY 2041. It is recommended that an additional coal terminal should be considered to avoid a lots of power stations' shut down simultaneously.



Source: JICA Survey Team

Figure 12-28 Estimated Trading Volume at CTT (k tonnes)CTT

Table 12-24 Estimated Trading Volume at CTT

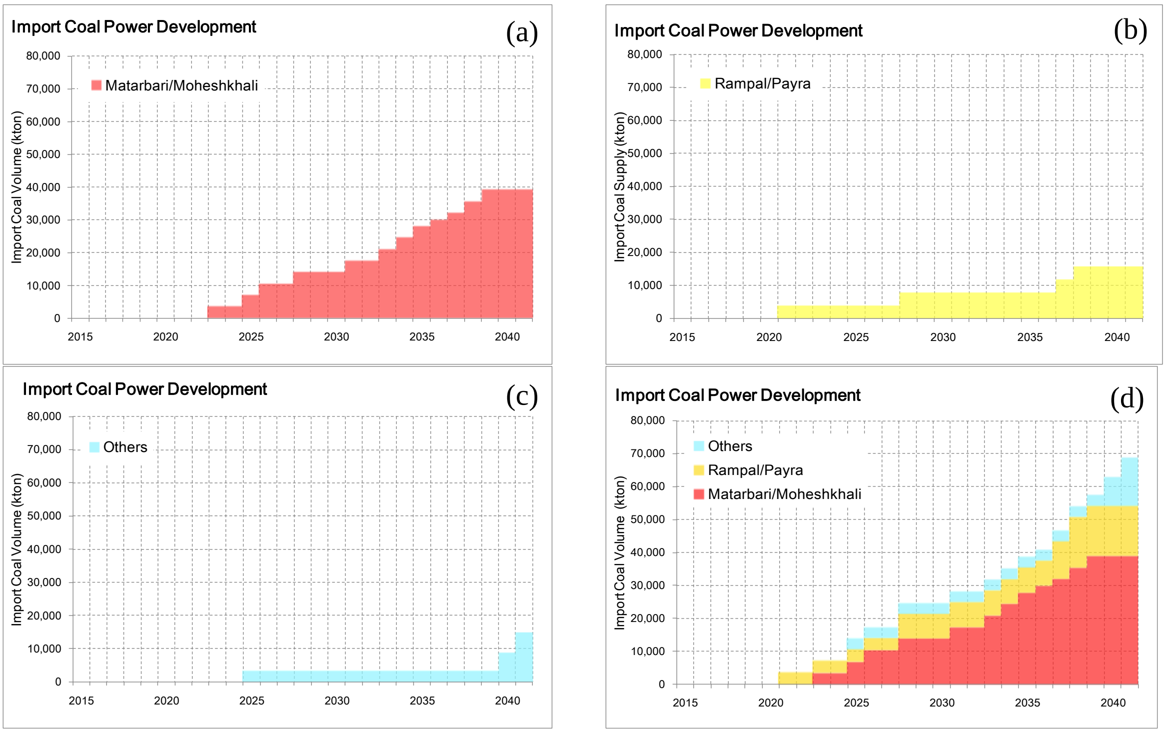
Projects	Category	Generation Capacity	Coal Consumption(k tonnes)		
			FY 2026	FY 2031	FY 2041
Power Sector(North Area)			**7,169**	**10,997**	**24,044**
Rampal#1,2	Public(BIFPCL)	660MW×2units	3,828	3,828	3,828
Rampal#3,4	Public(BIFPCL)	660MW×2units			3,828
Payra#1,2	Public(NWPGCL)	660MW×2units		3,828	3,828
Payra#3,4	Public(NWPGCL)	660MW×2units			3,828
Khulna	IPP(Orion Group)	630MW	1,827	1,827	1,827
Maowa	IPP(Orion Group)	522MW	1,514	1,514	1,514
Dhaka	IPP(Orion Group)	635MW			1,842
Chittagong	IPP(S Alam Group)	612MW			1,775
Chittagong	IPP(S Alam Group)	612MW			1,775
Power Sector(South Area)			**0**	**0**	**11,020**
Matarbari North#7	Public(CPGCBL)	700MW			2,030
Matarbari North#8	Public(CPGCBL)	700MW			2,030
Matarbari North#9,10	Public(EGCB)	600MW×2units			3,480
Matarbari North#11,12	Public(EGCB)	600MW×2units			3,480
Non-Power Sector			**1,921**	**3,024**	**5,783**
Total			**9,090**	**14,020**	**40,847**

Source: JICA Survey Team

b) Stock pile capacity
JICA CTT Team has considered that storage capacity is specified to meet coal consumption for approx. 30 days with continuous operation on the assu mption that stock pile capacities at CTT for customers such as power stations operators and non-power sector operators are not necessity, as customers have enough coal storage capacity at each site.

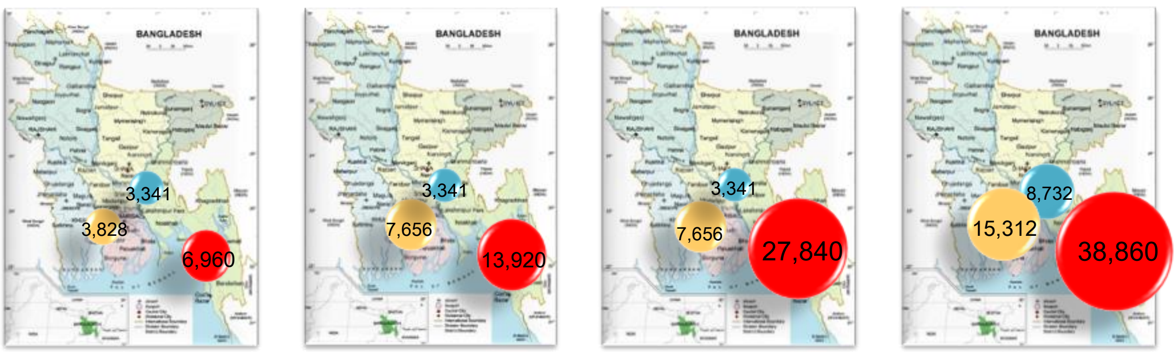
c) Further consideration
As above mentioned, assumptions are considered only for plotting plan, trading volume and required stock pile capacity should be reviewed in accordance with negotiations with each power plant operator and non-power operator. And also after COD of CTT, expansion plan should be reviewed.

(e) Region-wise coal import scenario
The figure below indicats region-wise coal supply scenario. Main ports will be in Matabari, Moheshkali, Rampal, and Payla area. It is expected that approximatelt 40,000kton of coal will be imported in both Matabari and Moheshkali area by 2040. In Rampal and Payla area, around 15,000kton of coal will be imported. Total coal volume of import will be 70,00kton by 2040.



Source：JICA PSMP2016

Figure 12-29 Region-wise Coal Import



(a) 2025 (b) 2030 (c) 2035 (d) 2040

Source：JICA PSMP2016

Figure 12-30 Coal Supply (2025-2040) (Unit: kTon))

Source：JICA PSMP2016

12.3.2 Fixed conditions

(1) Power Imports

The existing plan by the government and the new development plan proposed through this study are shown in the figure below. The current power import is only 500MW from Barapkuria, but power imports from neighboring countries, such as Nepal, Bhutan and India, are expected in the future. The development plan of the capacity has been created with the aim of covering about 15% of the total transmission network capacity in Bangladesh.

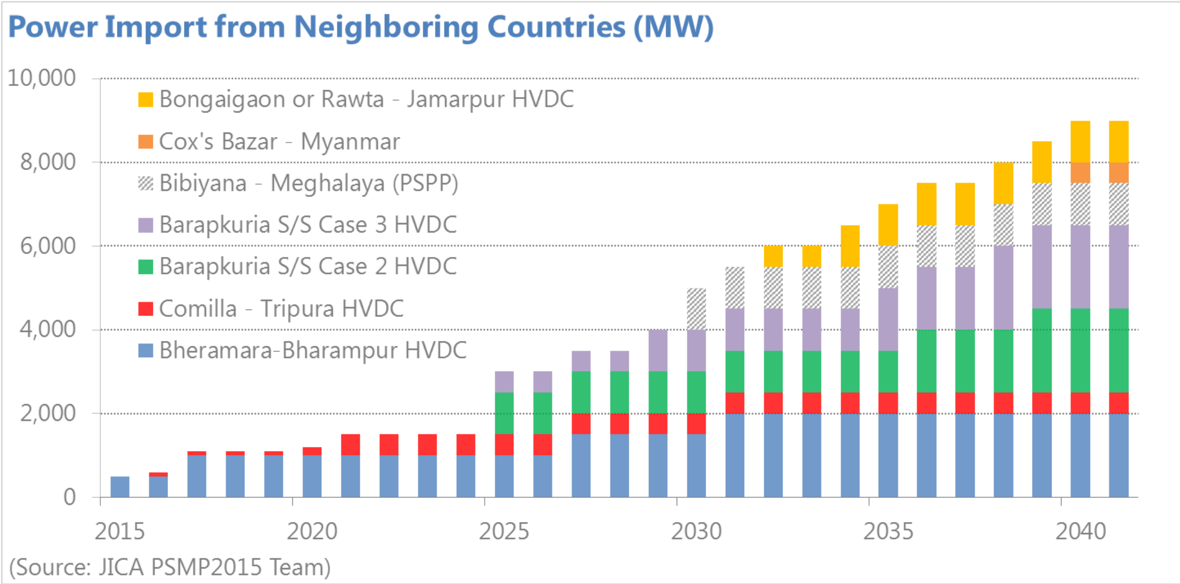


Figure 12-31 Trends of Power Imports from Neighboring Countries

Table 12-25 Power import scenario

Power Import Scenario	Type	Output	COD	Unit	2015	2020	2025	2030	2035	2040	2041
Bheramara-Bharampur HVDC	BPDB	1500		MW	500	1000	1000	1500	2000	2000	2000
Phase 1		500	2013	MW	500	500	500	500	500	500	500
Phase 2		500	2017	MW	0	500	500	500	500	500	500
Phase 3		500	2027	MW	0	0	0	500	500	500	500
Phase 4		500	2031	MW	0	0	0	0	500	500	500
Comilla - Tripura HVDC	BPDB	500		MW	0	200	500	500	500	500	500
Phase 1-1 (100MW)		100	2016	MW	0	100	100	100	100	100	100
Phase 1-2 (100MW)		100	2020	MW	0	100	100	100	100	100	100
Phase 2 (300MW)		300	2021	MW	0	0	300	300	300	300	300
Barapkuria S/S Case 2 HVDC	BPDB	1500		MW	0	0	1000	1000	1000	2000	2000
Phase I		1000	2025	MW	0	0	1000	1000	1000	1000	1000
Phase II		500	2036	MW	0	0	0	0	0	500	500
Phase III		500	2039	MW	0	0	0	0	0	500	500
Barapkuria S/S Case 3 HVDC	BPDB	2000		MW	0	0	500	1000	1500	2000	2000
Phase I		500	2025	MW	0	0	500	500	500	500	500
Phase II		500	2029	MW	0	0	0	500	500	500	500
Phase III		500	2035	MW	0	0	0	0	500	500	500
Phase IV		500	2038	MW	0	0	0	0	0	500	500
Bibiyana - Meghalaya (PSPP)	BPDB	1000	2030	MW	0	0	0	1000	1000	1000	1000
Cox's Bazar - Myanmar	BPDB	500	2040	MW	0	0	0	0	0	500	500
Bongaigaon or Rawta - Jamarpur HVDC	BPDB	1000		MW	0	0	0	0	1000	1000	1000
PhaseI		500	2032	MW	0	0	0	0	500	500	500
PhaseII		500	2034	MW	0	0	0	0	500	500	500
Total		**5500**		**MW**	**500**	**1200**	**3000**	**5000**	**7000**	**9000**	**9000**

Source: JICA PSMP2016

(2) Nuclear power development

The government has cuurent nuclear power development scenario as follows.

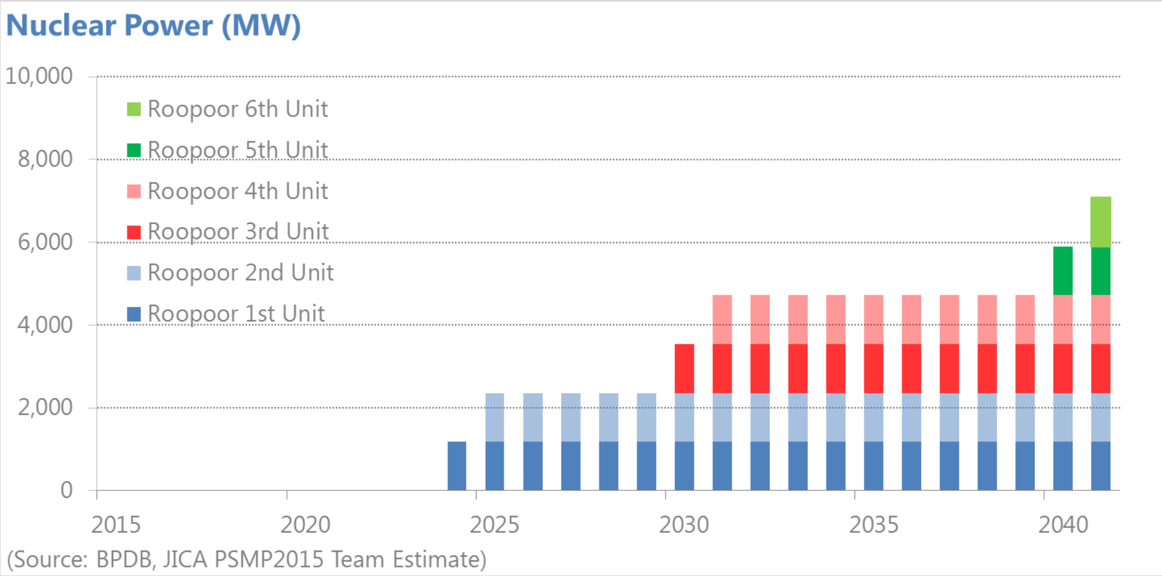


Figure 12-32 Nuclear Power Development

(3) Hydropower development
The government has cuurent hydro-power development scenario as follows.

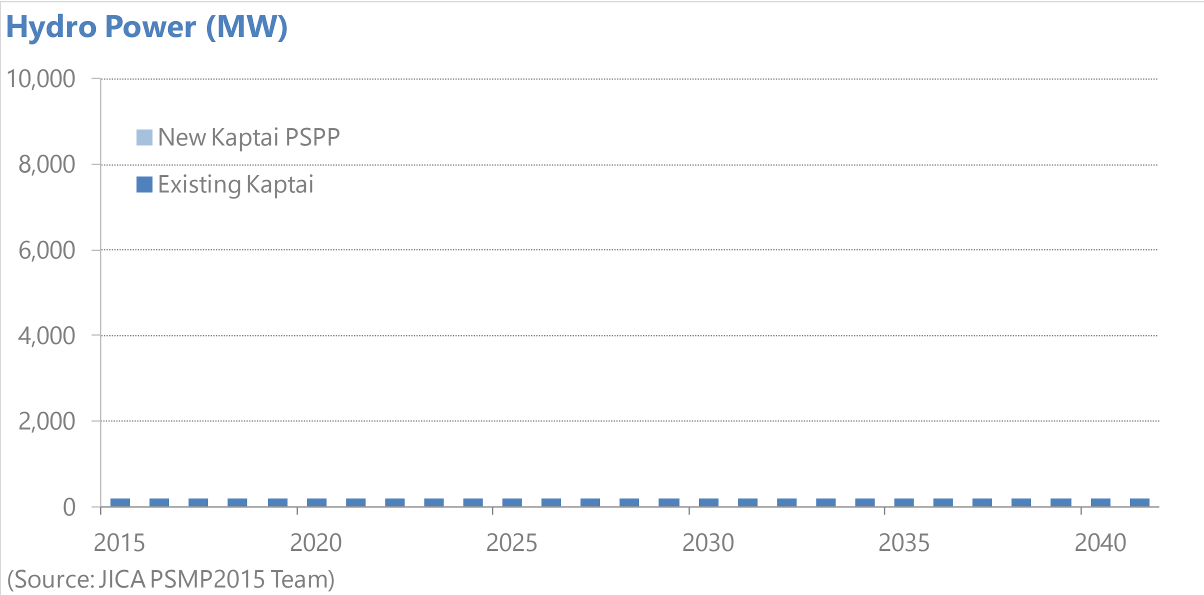
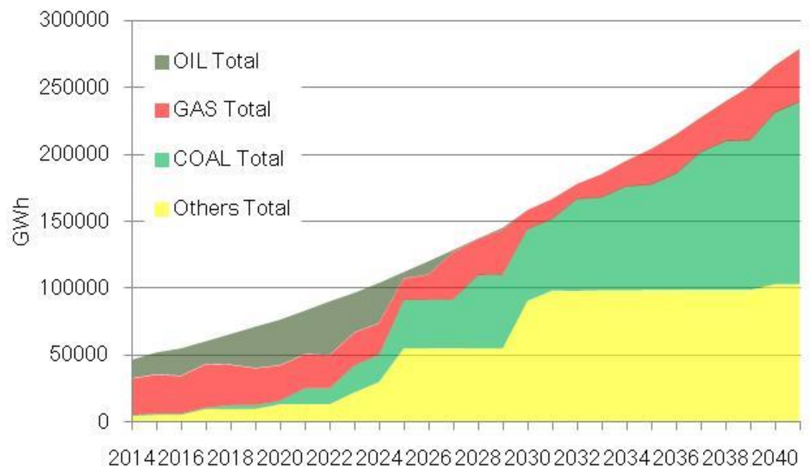


Figure 12-33 Hydropower Development

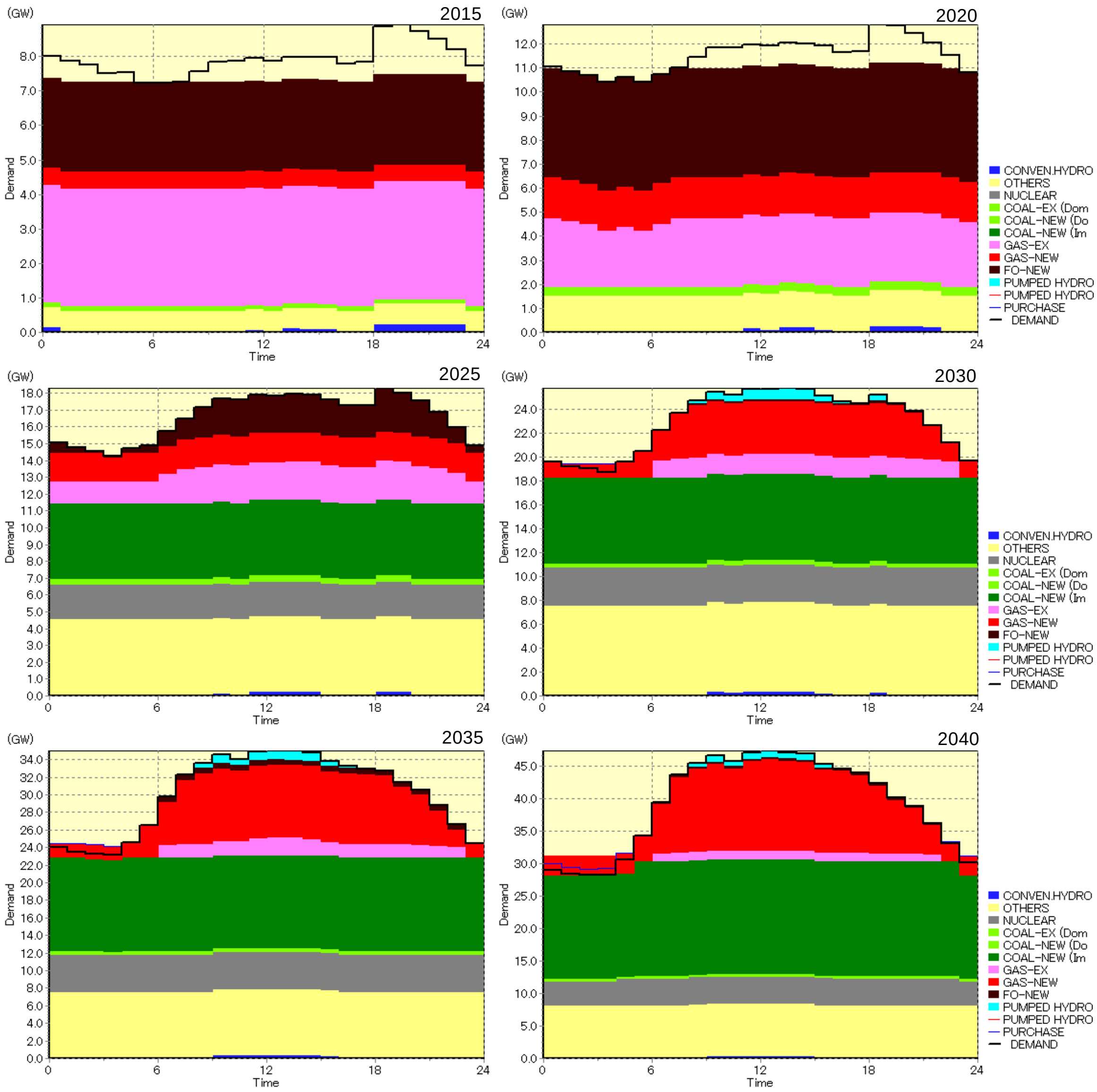
12.3.3 Result of consideration of Power Development Plan

The breakdown of power production by fuel (GWh) under the F5-P3 scenario is shown below. Meanwhile, the following figure shows the daily load curve during the summer for the 2015-2040 period. The daily load was estimated at intervals of five years.



Source: JICA PSMP2016

Figure 12-34 Change in power production over tim

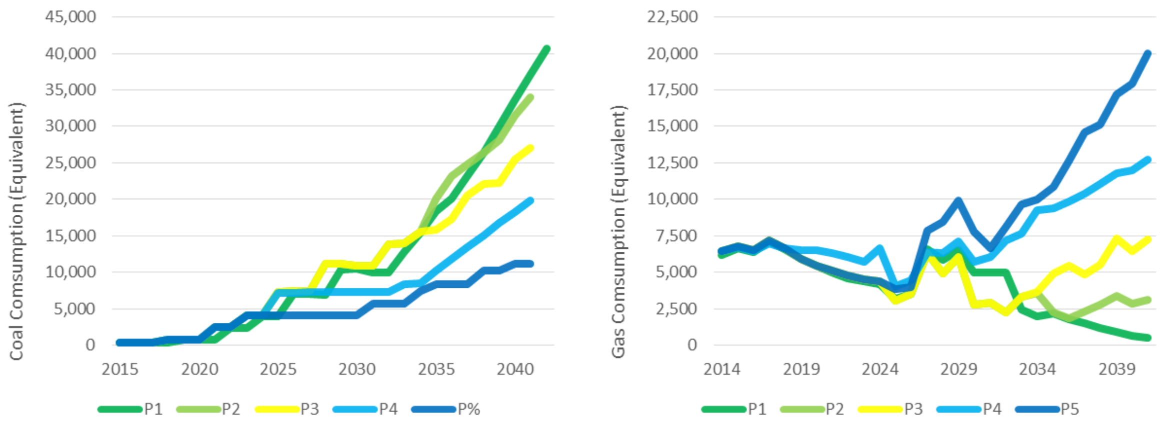


Source: JICA PSMP2016

Figure 12-35 Daily load curve

12.3.4 Comparison of scenarios for energy source ratio

The figure below shows the fuel consumption in different scenarios. The coal consumption is the highest in Scenario P1 and the lowest in Scenario P5. On the other hand, the gas consumption is the highest in Scenario P5 and the lowest in Scenario P1.

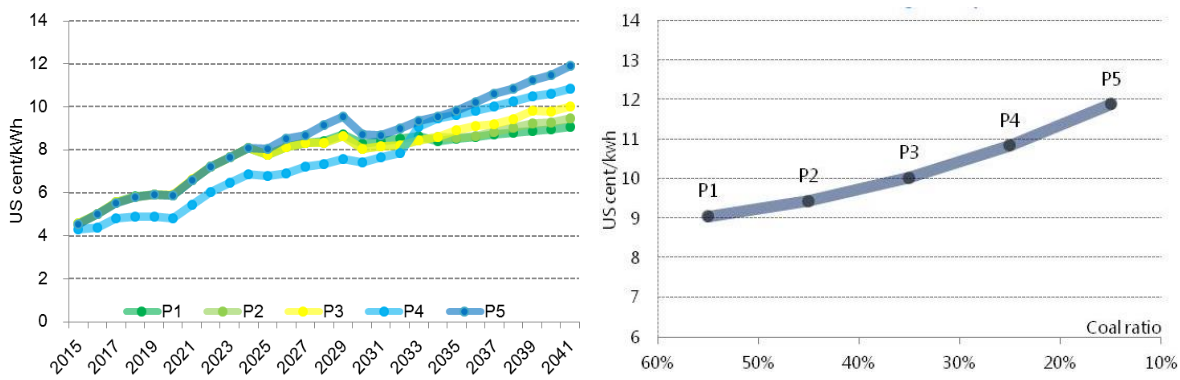


Source: JICA PSMP2016

Figure 12-36 Sneratio-wise gas and coal consumption

12.3.5 Changes in generation cost for all fuel sources

The power generation cost is expected to increase gradually in the future. It is the lowest in Scenario P1 with the high share of coal in the energy mix, and in Scenario P5 with the high share of gas in the energy mix. As the use of coal spreads in stages, the fuel expense will be slashed, helping curve increases in power generation cost. Thus, the power generation cost is estimated at 9 to 12 US cents/kWh for 2040. Meanwhile, comparison of the power generation cost between the five scenarios for energy source ratio (P1 to P5) shows the power generation cost becomes higher as the ratio of coal to all the energy sources becomes smaller.



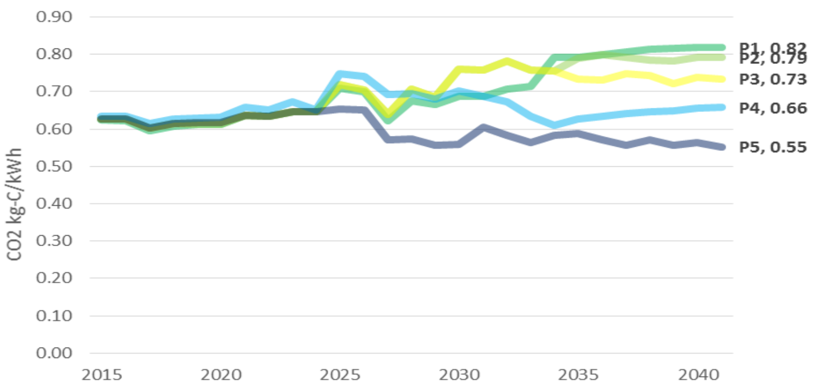
Source: JICA PSMP2016

Figure 12-37 Power generation cost under each scenario and Ratio of coal

12.3.6 Changes in CO2 emssions

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

(0.55 CO2 kg-C/kWh) in Scenario P5 with a low share of coal in the energy mix.



Source: JICA PSMP2016

Figure 12-38 Scenario-Wise CO2 Emissions

12.3.7 Efficiency setting

(1) WASP data

The heat rate, output and efficiency should be extracted for each power plant in accordance with the WASP data.

(2) Grouping

Power plants with similar output and efficiency should be grouped together. There should be 48 groups.

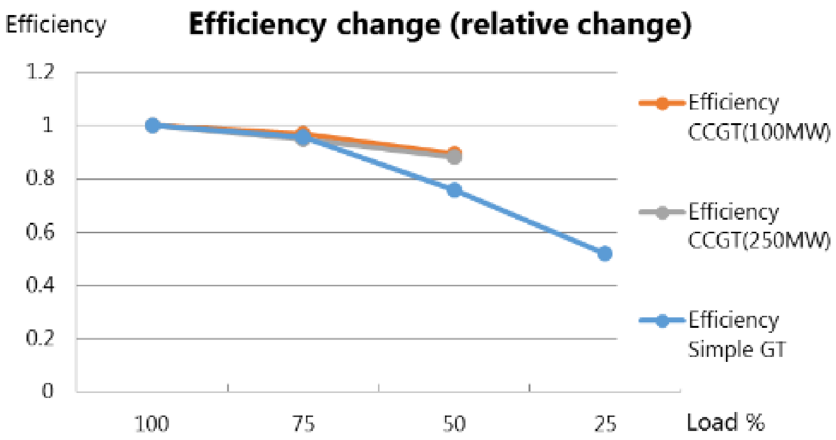
Table 12-26 Gouping for efficiency calculation (part of list)

WASP	Name of plant		Plant Type	Heat Rate min	Heat Rate Incremental	Output (MW)	Efficiency (%)	Group
	OIL Existing Group 6-15							
26	Hathazari 100 MW Peaking PP	RE	F.oil	2,208	2,208	96	0.40	**6**
26	Sangu, Dohazari 100 MW PPP	RE	F.oil	2,208	2,208	99	0.41	6
27	RPCL Raozan 25 MW	RE	F.oil	2,154	2,154	25	0.40	**7**
27	RPCL Gazipur 52 MW	RE	F.oil	2,154	2,154	51	0.40	**8**
27	Titas (Doudkandi) 50 MW RE	RE	F.oil	2,154	2,154	51	0.38	8
19	Khulna 1x110 MW Steam Turbine	ST	F.oil	4,793	3,834	50	0.22	**9**
23	Barisal 2x20 MW Gas Turbine	GT	HSD	6,518	4,237	30	0.19	**7**
23	Bheramara 3x20 MW Gas Turbine	GT	HSD	2,473	2,473	46	0.20	9
20	Khulna 150 MW (NWPGCL)	GT	HSD	4,769	3,100	155	0.34	**10**
27	Faridpur 50 MW Peaking PP	RE	F.oil	2,154	2,154	52	0.40	8
26	Gopalgonj 100 MW Peaking PP	RE	F.oil	2,208	2,208	107	0.40	**6**
27	Baghabari 50 MW RE	RE	F.oil	2,154	2,154	51	0.39	8
26	Bera 70 MW RE	RE	F.oil	2,208	2,208	70	0.39	8
23	Rangpur 20 MW Gas Turbine	GT	HSD	2,473	4,237	19	0.24	**11**
23	Saidpur 20 MW Gas Turbine	GT	HSD	2,473	4,237	19	0.25	11
27	Santahar 50 MW PP	RE	F.oil	2,154	2,154	49	0.40	8
27	Katakhali 50 MW PP	RE	F.oil	2,154	2,154	49	0.40	8
30	KPCL		F.oil	2,126	2,126	110	0.39	**12**
30	NEPC		F.oil	2,126	2,126	110	0.40	12
31	Natore, Rajshahi 50 MW PP		F.oil	2,084	2,084	52	0.38	**13**
41	Meghnagat power Co. (summit)		HSD	2,416	1,933	305	0.38	**14**
30	Gogonnogor 102 MW PP		F.oil	2,126	2,126	102	0.38	12

①WASPデータの整理

②Output(MW)と効率を考慮した48Groupの分類

(3) Calculation of efficiency
For each group, output (min) is calculated based on the heat rate and the calculation formula below and efficiency reduction is estimated by referring to the efficiency change curve.



$$\text{Incremental heat rate} = \frac{\text{Heat rate at max. output} \times \text{Max. output} + \text{Heat rate at min. output} \times \text{Min. output}}{\text{Max. output} - \text{Min. output}}$$

Figure 12-39 Efficiency curve model for calculation

(4) Calcuation of heat rate curve
Based on the efficiency and output determined above, the coefficients of the heat rate curve, a, b and c,

are calculated.

Table 12-27 Gouping for efficiency calculation (part of list)

$y = a x^2 + b x + c$

WASP	Name of plant	Group	Efficiency-100% (%)	Efficiency-75% (%)	Efficiency-50% (%)	a	b	c
	OIL Existing Group 6-15							
26	Hathazari 100 MW Peaking PP	6	0.40	0.39	0.36	1.529	1728.86	28,108
26	Sangu, Dohazari 100 MW PPP	6						
27	RPCL Raozan 25 MW	7	0.40	0.39	0.37	7.610	1720.55	5,595
27	RPCL Gazipur 52 MW	8	0.40	0.39	0.36	3.048	1722.50	14,002
27	Titas (Doudkandi) 50 MW RE	8						
19	Khulna 1x110 MW Steam Turbine	9	0.22	0.22	0.20	5.422	3064.78	24,914
23	Barisal 2x20 MW Gas Turbine	7						
23	Bheramara 3x20 MW Gas Turbine	9						
20	Khulna 150 MW (NWPGCL)	10	0.34	0.33	0.31	1.201	2036.84	49,673
27	Faridpur 50 MW Peaking PP	8						
26	Gopalgonj 100 MW Peaking PP	6						
27	Baghabari 50 MW RE	8						
26	Bera 70 MW RE	8						
23	Rangpur 20 MW Gas Turbine	11	0.24	0.23	0.22	12.880	2911.98	9,469
23	Saidpur 20 MW Gas Turbine	11						
27	Santahar 50 MW PP	8						
27	Katakhali 50 MW PP	8						
30	KPCL	12	0.39	0.38	0.35	1.579	1784.75	29,017
30	NEPC	12						
31	Natore, Rajshahi 50 MW PP	13	0.38	0.37	0.35	3.184	1799.57	14,629
41	Meghnagat power Co. (summit)	14	0.38	0.37	0.35	0.531	1799.57	87,773
30	Gogonnogor 102 MW PP	12						

③Efficiencyの計算　④Heat Rate Curveの計算

12.4 3E Evaluation of Power Development Scenarios

Power supply has close relationship with economic activities and environmental problems. Sustainable energy supply should meet Three "E" conditions (3E), which stand for Environment value, Economic value, and Energy security value. Japanese energy policy is also based on 3E concepts as expressed in its "Basic Energy Plan".
In this chapter, we quantified 3E values in 2041 for power development scenarios presented previous clouse to choose the most preferable scenario.

12.4.1 Economic Value

In long-term, Bangladesh will not owe much its economy on domestic energy mining industry nor plant manufacture industry. This means that lower power supply cost will bring lower burden to Bangladeshi economy as whole.
Thus, we simply employed power generation cost (cost per unit electricity generated) to evaluate economic value of each power development scenario. Power generation cost consists of fixed price and fuel price. Fuel price projection in 2014 is shown in the previous clouse.

12.4.2 Environmental Value

As we reviewed international environmental policy in the previous environment, climate change is one of the most critical issues among environmental impacts of power supply. Bangladesh also submitted INDC to UNFCCC in 2015 and projected greenhouse gases emission reductions in the power sector by 2030.
Thus, environmental value of each power development scenario should be evaluated focusing CO2 emission. This study employed CO2 cost per unit electricity generated to evaluate environmental value of each power development scenario. CO2 cost is calculated by multiplying CO2 emission and CO2 price. We used 125 USD/tCO2 for CO2 price referring assumption in 450 scenario of IEA World Energy Outlook 2015.

Table 12-28 CO2 Price Assumption in IEA WEO 2015

(USD 2014 per tonne)

Region		Sectors	2020	2030	2040
450 Scenario	United States and Canada	Power and industry	20	100	140
	European Union	Power, industry and aviation	22	100	140
	Japan	Power and industry	20	100	140
	Korea	Power and industry	22	100	140
	Australia and New Zealand	Power and industry	20	100	140
	China, Russia, Brazil and South Africa	Power and industry	10	75	125

Source) IEA World Energy Outlook 2015

12.4.3 Methodologies of 3E Evaluation in Bangladesh: Energy Security Value

Energy security covers many concepts and there are no common approaches to evaluate it unlike previous two values. Here we presented the overview of energy security evaluation and reviewed past studies and then explained the methodology we employed.

12.4.4 Overview of Energy Security Evaluation

Risk assessment is a theory of decision-making that was established in the field of engineering study. Risks consist of two factors, i.e. the probability of risk realization and the impact of the consequence.

It needs to be noted that studying on the risks concerning energy security covers a broad range of issues. According to International Energy Agency (IEA), energy security is defined as “the uninterrupted availability of energy sources at an affordable price”.

An example of energy supply interruption was the case that European countries were faced with in 2006. At that time the natural gas supply from Russia was reduced because of soured relationship between Russia and Ukraine. In addition to the political incidents like that, economical incident and accidental event can bring about a problem of energy supply shortage. We also experienced a turbulent change in energy price recently when oil price rose to 150 USD per barrel in 2007 due to the turbulence in the Middle East, which then dropped to 40 USD per barrel after the Global Financial Crisis. Such high volatility is considered to be caused by the influx of speculative money in the energy market.

On a longer-term basis, the effect of continuous growth of energy demand and the depletion of fossil fuel needs to be taken into account. Uncertainty about the international policy on climate change can be also considered a kind of risk. The measurement for energy security may also change depending on the targeted period.

Furthermore, in discussing the availability of energy resources, it needs to be clarified who is the beneficiary as the precondition of the discussion. Energy availability can be discussed either as the availability at nation-level or as the availability for end-consumers. When we discuss the availability for the end-consumers, the channels of energy supply to them such as the conditions of domestic energy markets and energy supply network also need to be considered. Sometimes the accessibility to energy supply is regarded as one of the performance indicators of energy security.

Table 12-29 is one example to classify the risks concerning energy security from the aspect of different types of impact. Any kinds of risk related to energy security can be evaluated using risk assessment theory if they can be plotted with the axes of probability and impact.

A realistic approach to quantify the risks is the empirical approach. For example, it is empirically understood that, if we diversify the sources of energy supply, the possibility that all of them are suspended at once can be reduced. So the degree of diversification of energy sources can be an empirical index to measure energy security. In fact, most of the trials to quantify energy security were made based on the empirical approaches like that. Specific examples are discussed in the following section.

Table 12-29 An Example of Classifying Risks of Energy Security

Impact to what	Price (hike, volatility) Quantity (shortage)
Impact of when	Short-term Long-term
Impact to whom	Nation (consumers are also affected in the end) Consumers (risks in the course of energy distribution)

12.4.5 Past Studies on the Quantitative Evaluation of Energy Security

A standard methodology to evaluate the degree of diversification is to use “Herfindahl-Hirschman Index” (HHI). HHI was originally established to measure the status of market competition, and is formulated as the sum of the square of each business entity’s market share. When this index is applied to energy supply, this can be used as a measure to evaluate the diversification of energy supply. That is, the smaller the index is, the more diversified the status of energy supply is.

Table 12-30 is the list of past studies to address the quantitative evaluation of energy security. HHI is applied in some of these studies such as IEA (2007), METI (2010) and IMF (2011), to evaluate the degree of diversification of energy suppler countries and/or primary energy sources. These studies concluded that HHI is too simple as a tool to express energy security, so they modified HHI by adding weights to parameters. For example, country risks of energy supplier countries are employed to weigh the suppliers’ market share. Hence the index becomes smaller when the energy sources for a country rely on the supplier countries with lower country risk. This weighted HHI is utilized as an index to measure the risks for national-level energy supply on a short-term basis.

However, these studies did not provide clear explanation how the weight is determined quantitatively. Another drawback is that the proximity among supplier countries is not taken into account. That is, if a country relies on the energy import from two adjacent countries, this situation is considered to be riskier than importing from two distant countries.

The study of METI (2015) tried to address these issues. This METI study adopted a portfolio theory to evaluate the diversification of supplier countries and primary energy sources. The theory originally derives from the field of finance for deciding the portfolio of assets to gain expected return while minimizing risk. If this is applied to energy supply, return from each asset corresponds to energy import from a supplier country. Actually, weighted HHI can be interpreted as one specific situation of composite risks under the portfolio theory.

American Chamber of Commerce (ACC) takes a different approach to express various aspects of energy security. They employed no less than 37 indices that are considered to be related to energy security. Making use of empirically formulated weights, these indices are integrated into a single index called Index of U.S. Energy Security Index (see Figure 12-40). ACC also provides evaluations of the energy security of other countries (though Bangladesh is not covered), which is called International Energy Security Risk Index, where 29 indices are used. A previous study of METI (2010) also devised several indices for evaluating the entire supply chain of energy, besides the evaluation using HHI (see Figure 12-41).

A study of IEA (2011) ranked countries using a performance indicator combining various statistic data such as energy import ratio, number of energy-import ports and oil storage, on a highly empirical basis. A remarkable point of this study is that it distinguishes between risk and resilience in evaluating energy security (see Figure 12-42). Evaluating not only the extent of remaining risks but also the intensity of resilience can contribute to the effective evaluation of energy security.

Table 12-30 Past Studies on Quantitative Evaluation of Energy Security

Literature	Approach
IEA “Energy Security and Climate Policy” , 2007	An index of market concentration is formulated considering the diversification of supply sources. The adopted index, which is a sort of weighted Herfindahl-Hirschman Index. Here the extent of concentration of each energy source is defined as the square sum of each supplier country’s share in the energy supply, weighted by the country risk. Then the weighted average of each energy source’s index is formulated considering the share of each energy source in the total primary energy supply.
METI (Japan), “2010 Annual Report on Energy (Energy white paper 2010)”, 2010	Here energy security is defined as being able to secure energy in the “quantity” necessary for people’s live, economic and social activities, and national defense etc. at affordable “price”. National energy security is evaluated using 8 indices across energy supply chain, including primary energy self-sufficiency, diversification of countries from which energy is imported, diversification of energy source and reduction of dependency on choke points. Herfindahl-Hirschman Index is employed to evaluate the diversification.
IMF working paper, “Measuring Energy Security :Trends in the Diversification of Oil and Natural Gas Supplies ”, 2011	Diversification of primary energy supplier is evaluated using the squared sum of the shares of energy suppliers, which are weighted with country risk of each supplier, proxy to each supplier, and the share of energy import of evaluated country (smaller import share means more flexibility in supply).
METI (Japan), “Toward the Stable Assurance of Fuel Resources ~ Energy Risk Index (Security Index) ~”, 2015	The stability of energy supply is evaluated by focusing on the supply chain from supplier countries to Japan. Suppliers’ country risk, sea-lane risk, and the effect of diversification of suppliers and sources are considered in an integrated way.
American Chamber of Commerce (ACC), “Index of US Energy	US’s national energy security is evaluated using 37 different indices including geopolitical factor (ex. production of fossil fuel,

Literature	Approach
Security Risk", annually updated	import of US), economic factor (ex. energy price, energy consumption per GDP), reliability factor (ex. Electricity reserve rate), environmental factor (CO2 emission, R&D investment to renewable energy) etc.
IEA "Measuring Short-term Energy Security" , 2011	Energy security on each energy source is evaluated, taking into account the "risk"-related data and the "resilience"-related data. Countries are experientially ranked using these statistics data. The extent of energy source mix is not considered.

Figure 12-40 Diagram of Indices that Form ACC's "Index of US Energy Security Risk"

Source) American Chamber of Commerce (ACC), "Index of US Energy Security Risk 2014", 2014

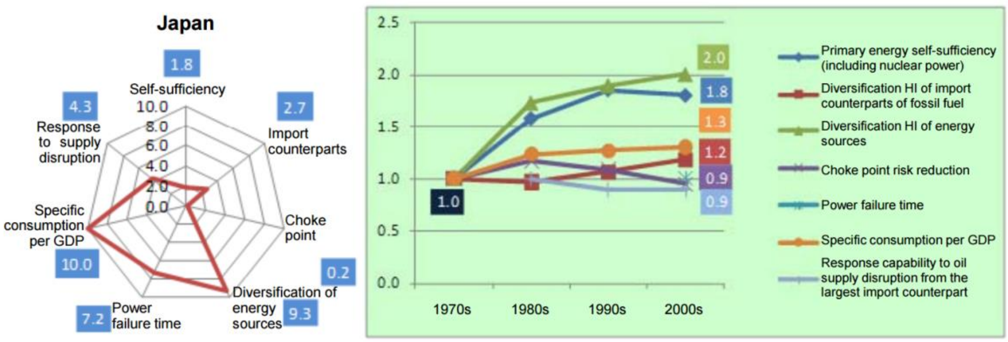


Figure 12-41 METI's Evaluation on the Status of Energy Security in Japan

Source) METI (Japan), "2010 Annual Report on Energy (Energy white paper 2010)", 2010

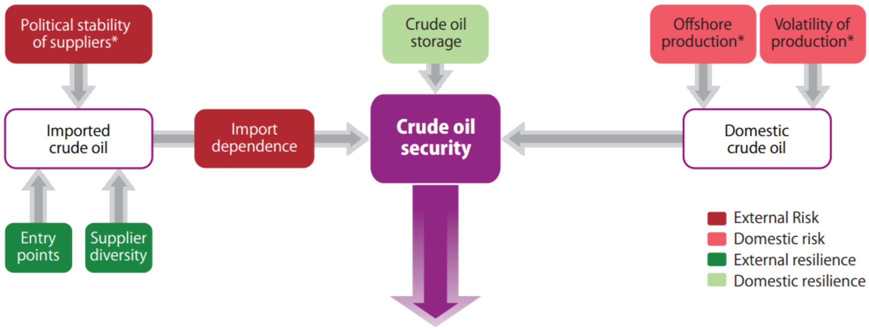


Figure 12-42 IEA's Schematic Diagram for Analyzing the Energy Security of Crude Oil

Source) IEA "Measuring Short-term Energy Security", 2011

12.4.6 Key Issues in Considering the Energy Security in Bangladesh

Because there is no agreed or standardize approach to evaluate energy security, this study recommends that a methodology of quantitative evaluation of energy security in Bangladesh should be devised by considering the characteristics of Bangladesh's energy supply and demand besides referring to the aforementioned approaches.

There are several studies on energy security in Bangladesh as shown in Table 12-31. These studies focus on relatively nation-side long-term energy supply. They commonly mention the importance stable expansion of energy supply capacity to achieve the economic growth target.

Figure 12-43 illustrates current energy supplier to Bangladesh. In 2013, around 80% of Bangladeshi energy was supplied by itself. India supplies coal by land. Southeast Asian countries supply oil products by sea, much of which is originally from Middle East. In the future, increase of energy import of Bangladesh is inevitable along with economic development. Which energy sources and from which countries Bangladesh can import are the key concerns in Bangladesh.

To evaluate energy security in this 3E evaluation, we focused on risk of sudden shortage in energy supply quantity, which would directly damage Bangladesh economic activities. The difference ratio of coal and gas among power development scenarios brings different dependence on supplier countries and delivery routes, and thus different shortage risks. This energy shortage risk can be quantified in monetary value as potential loss value of economic production.

There are of course other approaches to evaluate energy security. Energy price stability and predictability are other important aspects for energy security. We considered such aspects regrading price in "Economic viability" among 3E. Feasibility of these scenarios can be another aspect to ensure long-term energy security. We judged that these scenarios have similar feasibility and need equally intense policies, so considering this aspect will not be information for making a decision.

Table 12-31 Past Studies on Energy Security in Bangladesh

Literature	Approach
Unnayan Onneshan, "Energy Security: Trends and Challenges - Bangladesh Economic Update", 2014	It discusses current energy security situation using related data like below: ・ Power ➢ Availability (Consumption per capita, electricity access, load shedding) ➢ Reliability (Ownership, use of fuel) ➢ Affordability (Tariff and subsidy, system loss, cost) ・ Other energy ➢ Reserve, production, import ➢ Price, import cost
T. Ishtiaque (Bangladesh University) et al., "Energy Sector Development and Energy Security in Bangladesh", 2013	Energy sector development to 2050 is discussed. It points out that long-term energy policy is crucial to sustainable development of Bangladesh. As for energy security, it mentions the importance of cooperation with other countries to ensure energy supply, especially hydropower from Bhutan and Nepal.
ANM Obaidullah, Energy Security & Climate Change: Challenge for Bangladesh, Energy & Power	Uninterrupted energy supply is essential for stable economic growth in Bangladesh. It focuses on primary energy mix to ensure such energy supply. It consists coal is the most stable commodity in Bangladesh in spite of high CO_2 emission. LNG, nuclear and renewables are other prospective commodities.

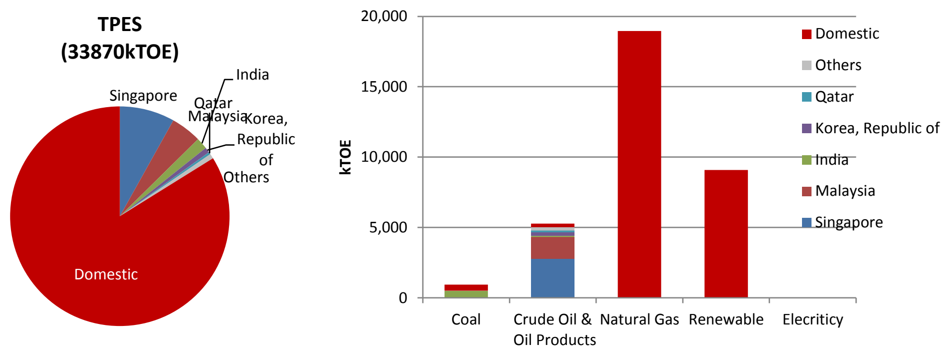


Figure 12-43 Current energy suppliers to Bangladesh in 2013

12.4.7 Methodologies of Evaluaion

As discussed above, we focused on risk of sudden shortage in energy supply to evaluate energy security. Proposed index is calculated using the formula below.

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

To calculate "possible non-delivery rate", we modeled physical energy delivery routes to Bangladesh and assumed the blockage probability of each point on the routes. Figure 12-44 illustrates the model concept. Among many kinds of risk on the energy delivery routes, we focused on three risks: export suspension risk, blockage risk on land route, and blockage risk on sea route. We ignored the risks to deliver domestic energy.

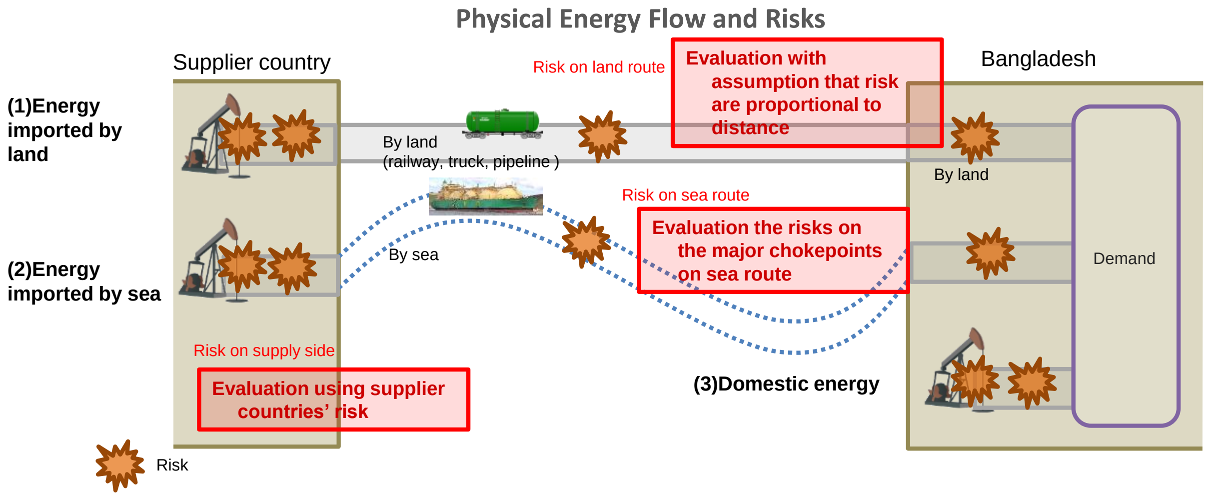


Figure 12-44 Physical Energy Delivery Routes and Risks

With the model, energy delivery rate to Bangladesh can be expressed in the form of probability density function as shown in Figure 12-45, considering many different combinations of risk realization. This curve itself reflects the risk situation of the physical energy delivery of the country. Using the parameter of the expectation (μ) and the standard deviation (σ) of this distribution curve, we can calculate a value of (μ– σ) which shows minimum delivery rate with 84% confident interval mathematically. In the other word, 1– (μ– σ) shows maximum non-delivery rate. This number is that we call "Possible non-delivery rate" here.

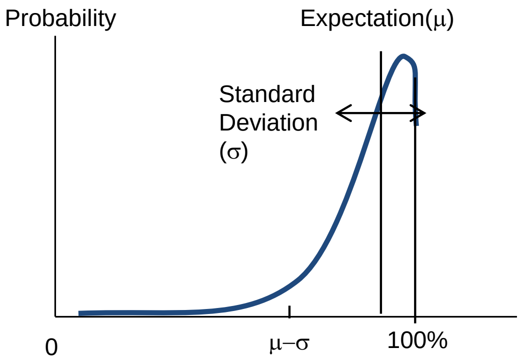


Figure 12-45 An Example of Probability Density of Energy Delivery

To calculate the number, we need portfolio of energy sources import for each scenario and blockage probability of each point on the routes.

Based on analysis for natural gas, LNG, coal and oil supply in the previous chapters, we assumed the maximum domestic supply potential and export potential from neighbor countries. Insufficient energy sources are assumed to be imported from the major energy exporters referring current supplier to Asian countries. Australia and Indonesia can be possible candidates of coal suppliers. Crude oil and oil products will come from Middle East countries like UAE and Saudi Arabia. As for LNG, Qatar can be the supplier.

Table 12-32 Assumption of Energy Suppliers and their Potential

	Coal	Crude oil and oil products	Natural gas
Imported by land	India 5,000 ktoe	—	India 9,500 ktoe
Imported by sea	Indonesia: 50% of remains Australia: 50% of remains	UAE:50% of remains Saudi Arabia: 50% of	Qatar: remains

		remains	
Domestic	15,000 ktoe	—	19,000 ktoe

Though accurate quantization of routes' blockage probabilities is hardly possible, this study tried to assume the risk as follows in order to serve for quantitative analysis of 3E. As for export suspension risk, we referred country risk classification by OECD and attributed it with the assumed probability as shown in Table 12-33. Blockage probability of land route is calculated by multiplying the route distance and a constant factor. Blockage probability of sea route is calculated by multiplying the number of major chokepoints on the route and another constant factor.

Table 12-33 Assumption of Export Suspension Risk

Energy	Supplier	Classification by OECD	Assumed export suspension risk
Coal	India	3	5%
	Indonesia	3	5%
	Australia	(High Income OECD Country not reviewed or classified)	0.1%
Oil	UAE	2	1%
	Saudi Arabia	2	1%
Gas	India	3	5%
	Qatar	3	5%
Electricity	India	3	5%

Note) Classifying countries into 7 grades (from 1(best) to 7(worst))
Source) OECD Country Risk Classification

12.4.8 3E Evaluation Result in Bangladesh

The 3E indices in 2041 following above methodologies are shown in Table 12-34. All indices are expressed in monetary value and they indicate better energy composition when the value is small. Furthermore, they can be totaled to indicate final 3E evaluation.
Economy index becomes larger as the ratio of coal to all the energy sources becomes smaller. Environmental index becomes smaller as the ratio of coal to all the energy sources becomes smaller. Energy Security index is the smallest when the ratio of coal and gas is balanced. As total of those, the 3E

Table 12-34 3E Evaluation Result of Each Power Development Scenario

	Composition (MW base)	**Economy** [US cent/kWh]	**Environment** [US cent/kWh]	**Energy Security** [US cent/kWh]	**Total** [US cent/kWh]
Scenario 1	Gas 15%, Coal 55%	9.06	9.64	6.29	25.0
Scenario 2	Gas 25%, Coal 45%	9.45	9.00	4.82	23.1
Scenario 3	Gas 35%, Coal 35%	10.03	8.23	4.81	22.7
Scenario 4	Gas 45%, Coal 25%	10.84	7.48	5.18	23.0
Scenario 5	Gas 55%, Coal 15%	11.89	6.57	5.81	23.8

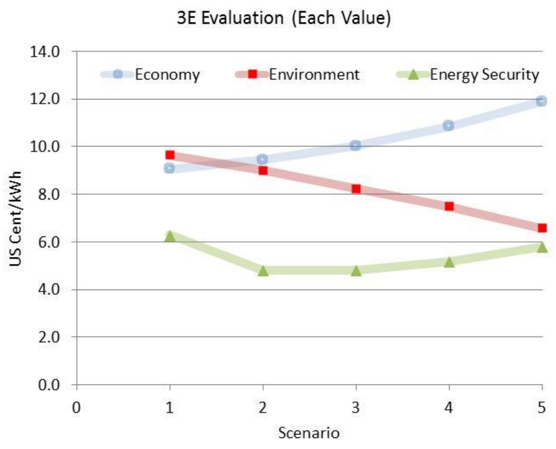


Figure 12-46 3E Evaluation Result (Each Value)

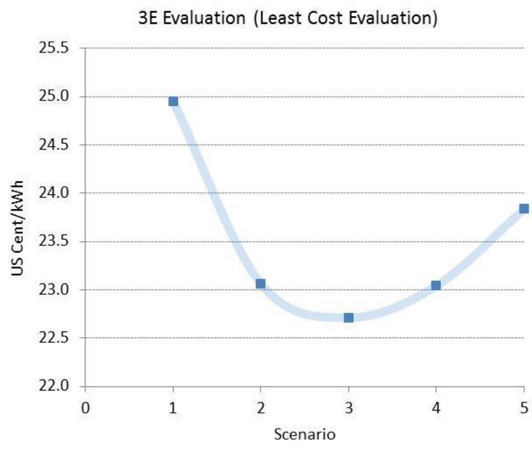


Figure 12-47 3E Evaluation Result (Total)

Chapter 13 Hydropower Supply

13.1 Outline of Hydropower Potential Study

13.1.1 Background

Bangladesh's climate is categorized as a subtropical zone monsoonal climate, and its characteristic is abundant rainfall. In the winter, from October to March, it is warm and dried by the Northeast monsoon. In summer, from March to June, it is hot and humid, and particularly from June to October, squalls and monsoons hit the country. Average annual rainfall is recorded as 1500 to 1800 mm in Western areas, 2000 mm in the area surrounding Dhaka, and more than 5000 mm in the Assam hilly terrain area in the Northeast. In the Chittagong hilly terrain area in the Southeast, annual rainfall is recorded as 2500 to 4000 mm on average. As such, Bangladesh has relatively high rainfall and abundant water resources, particularly in the Northeast and Southeast of the country.

On the other hand, as for the topography of Bangladesh, most of the national land is spread over the delta area, along the Bay of Bengal on the Indian subcontinent. There are lots of swamps and jungles. Most of the areas are lowland lower than 9 m above sea level. Even in the hilliest area of Chittagong, elevation of the area is from 300 m to 600 m. The highest point of Bangladesh is known as Mount Keokradong, at 1230 m above sea level. In this regard, Bangladesh has relatively limited hydropower potential even though it has abundant water resources.

Karnafuli Hydropower Plant, using the water of Kaptai Lake, is the only hydropower plant in Bangladesh, with a total installed capacity of 230 MW. Its No.1 and 2 units (2 units of 40 MW) and No.3 unit (50MW) were installed with assistance from the United States, and operation started in 1962 and 1982 respectively. No. 4 and 5 units were installed with assistance from Japan, and operation started in 1987. Further, No. 6 and 7 units were planned as Japanese Yen Loan Projects in order to strengthen the power supply for peak demand. However, since an Environmental Impact Assessment was not carried out and local consensus was not attained, a Japanese ODA loan was not provided for the project. The problem was caused by conflicts between indigenous people and immigrant Bengali people who were living around Kaptai Lake. Compensation issues during the construction of Kaptai Dam were also one of the causes. Even now, entry to the area is restricted because of order problems.

Despite of such a situation, the Government of Bangladesh expects hydropower development for reduction of CO2 emissions and power system stability as well. The JICA Survey Team carried out the hydropower potential study for Pumped Storage Power Plant (PSPP) and Small Scale Hydropower Plant (SSHP).

13.1.2 Objective of the Study

The objective of the Study is to identify hydropower potential sites for the future development. Pumped Storage Power Plant (PSPP) and Ordinary Hydropower Plant (Ordinary HP) or Small Scale Hydropower Plant (SSHP) are targeted in this Study.

13.1.3 Study Flow

The study flow for identification of potential sites for PSPP and SSHP is shown in Figure 13-1.

13.1.4 Limitation in the Study

On the course of the study, the JICA Survey Team encountered the following difficulties:

- Limitation of maps available, and
- Limitation of access to the potential site areas due to security reasons.

Since topographic maps available for Chittagong hilly areas are only 1/50,000 scale maps with 100m counter lines, those maps could not be used for planning purpose and conceptual design of hydropower projects. Therefore, the JICA Survey Team identified and planned potential sites based on google earth with limited accuracy.

The JICA Survey Team also encountered the difficulty to access to the remote locations in Chittagong hilly areas due to security reasons. During the site reconnaissance, the Survey Team hired security guards. The Survey Team was, however, able to stay in the hilly areas for limited time only during day time, and to visit only the locations accessible by cars. And also, talking directly to local people was also restricted.

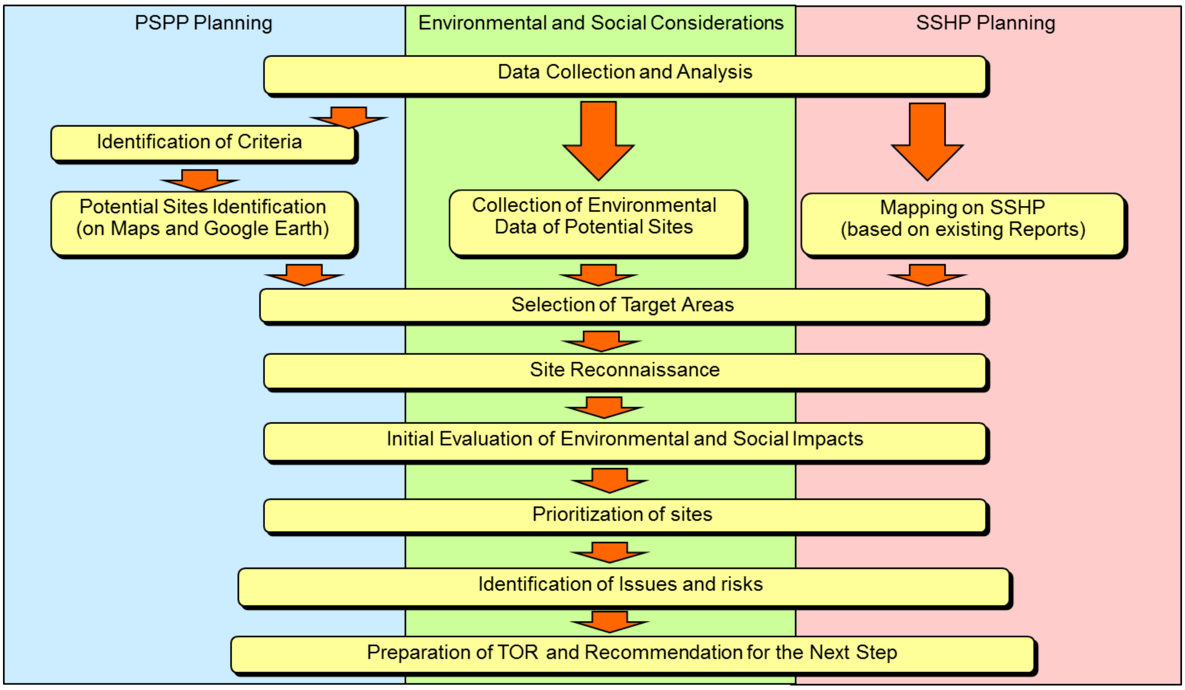


Figure 13-1 Flowchart of Hydropower Potential Study

13.2 Current Situation of Hydropower Development in Bangladesh

13.2.1 Outline of Karnafuli Hydropower Plant

Kaptai Dam is on the Karnafuli River at Kaptai, 65 km (40 mile) upstream of Chittagong in Rangamati District, Bangladesh. It is an earth-fill embankment dam with a reservoir (known as Kaptai Lake) water storage capacity of 6,477 million m3 (5,251,000 acre·ft). The primary purpose of the dam and the reservoir was to generate hydroelectric power. Its construction was completed in 1962. The generators of the 230 MW (310,000 hp) Karnafuli Hydroelectric Power Station were commissioned between 1962 and 1988. It is the only hydropower plant in Bangladesh.

A brief reconnaissance occurred in 1906 when the Karnafuli Hydropower Plant was first contemplated. The second study was carried out in 1923. In 1946, E. A. Moore recommended the proposed project at Barkal about 65 km upstream of the present dam site at Kaptai. In 1950, the Marz Rendal Vatten Consulting Engineers suggested a site at Chilardak, about 45 km upstream of Kaptai. In 1951, the government engineers proposed Chitmoram, 11 km downstream of the present site. Under the guidance of then chief engineer (Irrigation) Khwaja Azimuddin, the construction site was finally chosen at the present site in 1951.

Utah International Inc. was selected as the construction contractor. The construction of the dam was started in 1957. When the first phase of the construction was completed in 1962, the dam, spillway, penstock and two units of 40 MW Kaplan turbines and generators were built in the power station. In August 1982, the third unit of 50 MW was commissioned. In October 1988, the fourth and fifth units of 50 MW turbines and generators were installed, and then the total generation capacity became to 230 MW.

The Kaptai dam is an earth-fill type dam with 45.7m (150 ft) high, 670 m (2,200 ft) long, and it has a spillway with 16-radial gates whose each width is 11.5m on the left side. The construction of the dam submerged 655 km2 (253 sq mile) area that included 220 km2 (85 sq mile) of cultivable land, 40 percent of the cultivable land in the area. It also forced resettlement of 18,000 families and 100,000 tribal people of which 70% were Chakma. The dam flooded the original Rangamati town and other structures.

As per rule curve the water level of the reservoir is supposed to be 33.2m (109 ft) MSL of the highest water level in November and 23.2m (76 ft) MSL of the lowest level in June as shown in Figure 13-2. In reality actual reservoir operation was different from the rule curve due to difference in rainfall year to year.

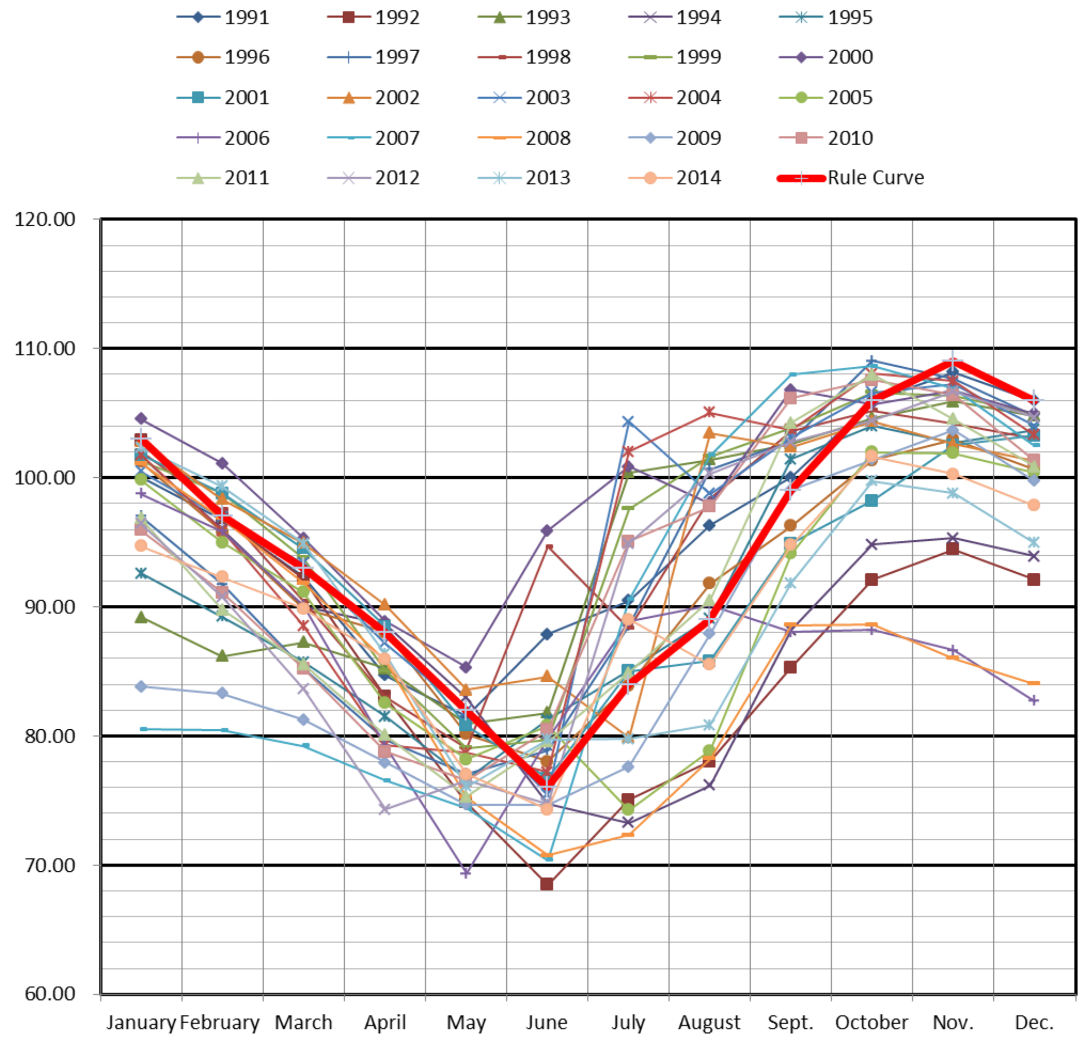


Figure 13-2 Karnafuli Hydro Station Reservoir Operation Rule Curve and its Records

13.2.2 Hydropower Potential and Hydropower Development Plan in Bangladesh

There are only two studies on hydropower potential and/or hydropower development plan in Bangladesh at this moment. The first hydropower potential study in Bangladesh was carried out by National Rural Electric Cooperative Association (NRECA) under the assistance of US-AID in 1981. It covered small scale hydropower potential sites in the whole country except Chittagong Hilly areas. The second study on hydropower potential was carried out by Ministry of Power, Energy and Mineral Resources (MPEMR) in 2014 targeting Ordinary HP potential sites particularly in Chittagong Hilly areas.

Outline of the studies conducted in the past are briefly described below.

(1) Small Hydropower Potential Sites in Bangladesh (except Chittagong Hilly areas)

Under the assistance of US-AID, National Rural Electric Cooperative Association (NRECA) carried out small hydropower potential study in 1981, and 20 sites were listed as shown in Table 13-1 and Figure 13-3.

Most of the potential sites are to utilize dams and/or canals for irrigation, and those capacities are relatively small from several ten to 200kW, which are a range of micro hydropower projects. Only some potential sites with capacity of several MW are also included in the list. In the study, Chittagong hilly areas where there is high possibility of high hydropower potential due to relatively large undulation are not included.

Table 13-1 SSHP Potential Sites List in the Country (excluding Chittagong Hilly Area)

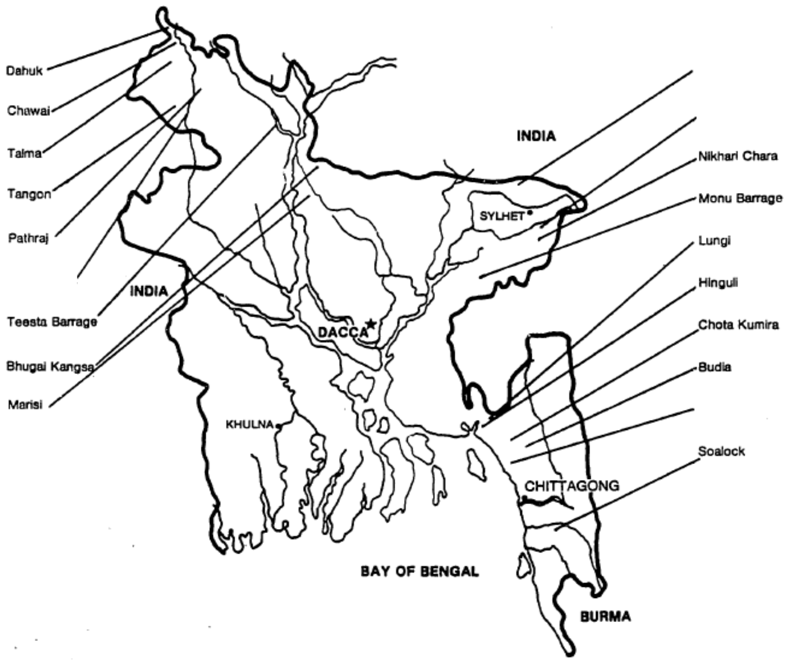
Sites	Discharge (cfs)	Head (feet)	Available Operation Months (months)	Installed Capacity (kW)	Annual Generation (1000kWh)	Type
Chota Kumira	11	40	12	30	250	New Storgae Dam
Hinguli	12	15	12	12	100	New Storgae Dam
Soalock	70	35	12	170	1400	New Storgae Dam
Longi	15	10	12	10	90	New Storgae Dam
Dudia	6	25	12	10	90	New Storgae Dam
Nikhari Chara	17	40	12	50	400	New Dam
Monu Barrage	200	12	7	160	800	Existing Dam
Marisi	120	18	12	80	600	Storage Dam
Bhgai-Kangsa	280	18	12	190	1400	Storage Dam
Dahuk	140	12	12	75	500	Storage Dam
Chawai	200	12	12	100	700	Storage Dam
Talma	140	12	12	75	500	Storage Dam
Patraj	200	12	12	100	100	Storage Dam
Tangon	200	12	12	100	700	Storage Dam
Teesta Canal Mile23	7300	10	12	5000	36000	Canal Head
Rangpur Canal Mile7	2500	10	12	1700	12000	Canal Head
Rangpur Canal Mile19	1800	10	12	1250	9000	Canal Head
Rangpur Canal Mile33	1100	10	12	750	5000	Canal Head
Bogra Canal Mile7	4000	10	12	2700	20000	Canal Head
Teesta Barrage	2000	7	7	1200	5000	Dam

Source) Bangladesh An assessment of small hydropower potential, NRECA, November 1981

(2) Ordinary HP Potential Sites in Chittagong Hilly Area

Ministry of Power, Energy and Mineral Resources (MPEMR) requested Streams Tech, Inc. (STI), which is an American firm, to carry out the hydropower potential study on the three river basins (Sangu River, Matamuhuri River and Bakkhali River) in Chittagong Hilly Area in order to find potential sites for hydropower development next to Kaptai hydropower plant.

As results of the potential study, 18 sites in total were found; 10 sites in the Sangu River, 5 sites in the Matamuhuri River, and three sites in the Bakkhali River as shown in Table 13-2 and Figure 13-4. Installed capacities of those potential sites would be varied from 0.1 MW to 201.7 MW.



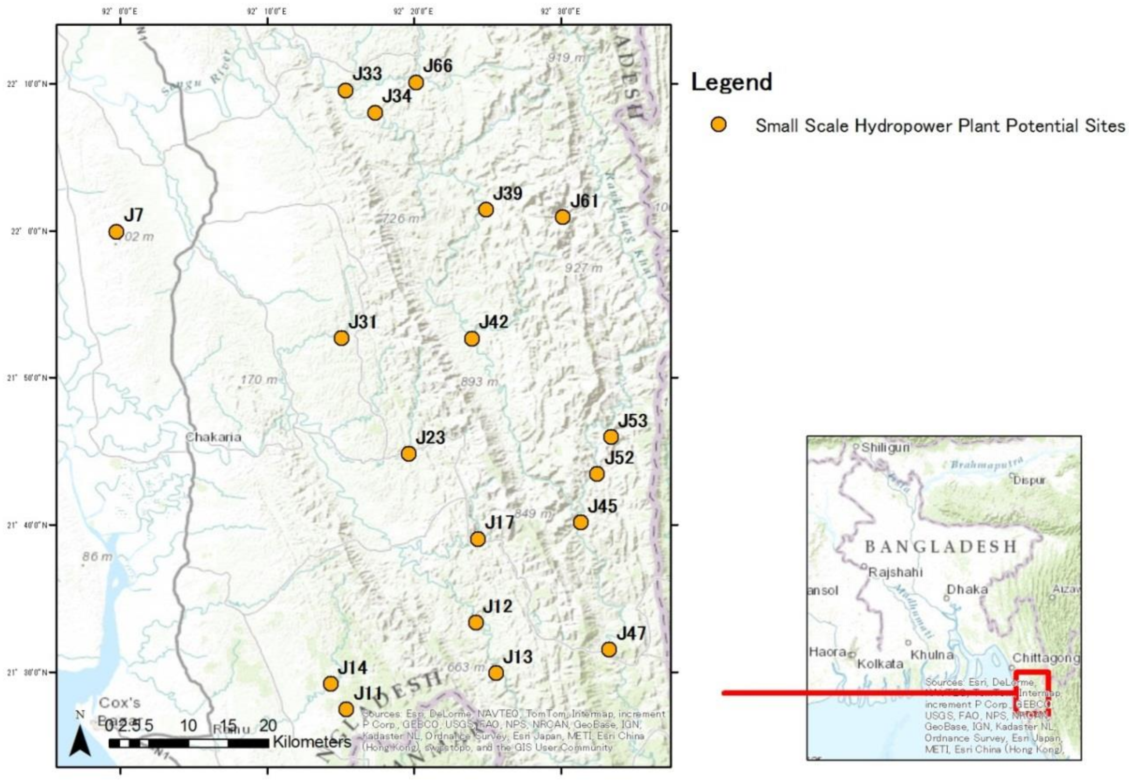
Source) Bangladesh An assessment of small hydropower potential, NRECA, November 1981

Figure 13-3 Location Map of SSHP Potential Sites in the Country

Table 13-2 Ordinary HP Potential Sites List in Chittagong Hilly Area

River	Location	Head	Flow (m^3/s)	Power (MW)	Max. Energy (MWh/year)	Percent of Time
Sangu	J33	12	268	23.5	37,648	18.3
Sangu	J34	20	217	31.8	50,877	18.3
Sangu	J39	70	200	102.7	144,000	16.0
Sangu	J42	60	156	68.6	96,676	16.1
Sangu	J45	20	101	14.8	21,035	16.2
Sangu	J47	40	47	13.9	16,126	13.3
Sangu	J52	20	30	4.4	5,733	15.0
Sangu	J53	30	25	5.5	7,106	14.7
Sangu	J61	40	9	2.6	3,296	14.6
Sangu	J66	20	31	4.6	6,426	16.0
Matamuhuri	J12	20	55	8.0	7,406	10.6
Matamuhuri	J13	15	41	4.5	4,430	11.3
Matamuhuri	J17	50	21	7.5	8,295	12.7
Matamuhuri	J23	50	16	5.9	6,535	12.7
Matamuhuri	J31	10	10	0.7	842	12.9
Bakkhali	J11	10	14	1.0	1,388	16.1
Bakkhali	J14	10	16	1.1	1,547	15.5
Banshkhali	J7	12	1	0.1	95	13.1

Source) Study on Prospective Hydropelectricity Generation in Southeast Bangladesh



Source) Study on Prospective Hydropelectricity Generation in Southeast Bangladesh

Figure 13-4 Location Map of Ordinary HP Potential Sites in Chittagong Hilly Area

(3) Hydropower Projects under Other Donors' Assistance

The JICA Survey Team conducted interview with MPEMR, Power Division, BPDP as well as donor agencies such as WB, ADB, US-Aid, to ask if they have any projects related to hydropower projects in Bangladesh. According to the their answers, there is no projects conducted in the past and planned for the future even technical assistance related to hydropower development other than the two studies mentioned above.

13.3 Environmental law and Regulations

Environmental laws and regulations related to hydropower development are as follows:

13.3.1 Environment Conservation Act

Bangladesh Environment Conservation Act (1995) covers environmental protection, pollution control, conservation area, environmental clearance, industrial discharge standards, environmental standards, solid waste discharge standards, and environmental guidelines. Bangladesh Environment Conservation Rules (1997) stipulates the following items including procedures of issuance of Environment Clearance Certificate (ECC).

- Declaration of ecologically critical area
- Vehicles emitting smoke injurious to health and otherwise harmful
- Application relating to pollution or degradation of environment
- Notice for collection of sample

- Procedure for issuing ECC
- Procedure for hearing of appeal
- Determination of environmental standards
- Information of special incident

13.3.2 Environmental Impact Assessment Regulations and Guidelines

Procedures of Environmental Impact Assessment (EIA) are stipulated in Bangladesh Environment Conservation Rules (1997), and EIA Guidelines for Industries (1997) is also provided by Department of Environment (DoE).

There is no rules and regulations which instruct Strategic Environmental Assessment for this study in such Master Plan stage in Bangladesh.

Procedures of EIA in Feasibility Study stage is provided in Bangladesh Environment Conservation Rules (1997). The rules classify project types in four (Green, Amber-A, Amber-B, Red) and different procedures for each. A power plant project is categorized in Red which is required Initial Environmental Examination (IEE) followed by comprehensive EIA. The locations for the power plant are restricted under the following conditions:

- Industrial units shall not be located in any residential area
- Industrial units shall preferably be located in areas declared as industrial zones or in areas where there is concentration of industries or in vacant areas.
- Industrial units likely to produce sound, smoke, odor beyond permissible limit shall not be acceptable in commercial areas.

The projects catabolized in Red have to obtain both Site Clearance Certificate (SCC) and ECC based on the Bangladesh Environment Conservation Rules (1997). The SCC and ECC are normally applied at the same time. But they can be applied separately if the project such as manufacturing facility adds the pollution control facilities later. In case of the power plant, SCC and ECC should be applied at the same time and those procedures are described as follows:

1) Project proponent prepares IEE and Terms of Reference of EIA (TOR/EIA), submits them to DoE.
2) DoE reviews the IEE and TOR/EIA and issue approval or rejection.
3) When Project Proponent gets approval of IEE and TOR/EIA, Project proponent can conduct EIA study and prepares EIA report.
4) Project proponent submits EIA application to DoE.
5) DoE reviews the application documents
6) When the EIA is approved, the project proponent applies ECC and SCC to DoE.
7) DoE grants ECC and SCC to the project proponent within thirty working days, or the application shall be rejected mentioning appropriate reasons.
8) The project proponent can start construction with ECC and SCC.

EIA Guidelines for Industries (1997) mentions that the public participation is important during EIA preparation and information disclosure and exchanging views with many stakeholders in various ways are required for effective public participations. Some sample methods for public participations introduced in the EIA Guidelines (1997) are:

- Radio and Television
- Newspaper
- Advertisement
- Lobbying activity
- Workshop

- Public explanatory meeting
- Public discussion meeting
- Civil advisory committee

13.3.3 Relevant ministries and agencies to Environmental Conservation

Ministry of Environment and Forest (MoEF) takes a main role for Environmental policies and regulations. Responding the growing Environmental concern MoEF was established in 1989 substitute for Ministry of Forest. MoEF has been a permanent member of the Executive Council of National Economic Commission. The Council is the main decision maker of the economic policy and responsible for approval of all the public investment projects. As a member of the Council MoEF supervises the activities of the following organizations:

- Department of Environment (DoE)
- Department of Forest (DoF)
- Forest Industries Development Corporation (FIDC)

In order to expand the scope of environmental management and strength the performance, the government stipulates the environment pollution control ordinance in 1977. Based on the ordinance Environmental Pollution Control Board was proposed for deciding policies and planning approaches. The Environmental Pollution Control Board was renamed to Department of Environmental Pollution Control (DEPC) in 1982 and six sub-departments are established in Dhaka, Chittagong, Khulna, Barisal, Sylhet, and Rajshahi. DEPC was changed to DoE and settled under the MoEF jurisdiction by Presidential order.

13.3.4 Laws and regulations on Land acquisition and Resettlement

Laws and regulations relevant to land acquisition and resettlement are the Land Acquisition Act (1894), The Acquisition and Requisition of the Immovable Property (Amendment) Act (1994), and The Acquisition and Requisition of Immovable Property Ordinance (1982) revised in 2004. The main procedures are as follows:

1) Project owner applies for expropriation of land and immovable property to Deputy Commissioner
2) Deputy Commissioner gives public notice of the application and starts site survey
3) Deputy Commissioner gives public notice of the decision of the expropriation
4) Deputy Commissioner decides the compensation cost and pays compensation
5) Implement the expropriation

Preparation of the Resettlement Action Plan by the project proponent is not mandated but land owners have a right to take objections.

13.4 Selection of Hydropower Potential Sites for this Study

13.4.1 Identification of Pumped Storage Power Plant (PSPP) Sites

(1) Criteria for Finding PSPP Potential Sites

In consideration of technical, economic, environmental and social aspects, criteria for finding PSPP potential sites were determined as shown in Table 13-3. However, in consideration of the limited data available, the criteria were used just for reference in order to identify potential sites as many as possible.

For comparison of the potential sites, those installed capacities were set as 500MW in consideration of scale of the potential sites.

Table 13-3 Criteria for Finding PSPP Potential Sites

Item		Consideration Point	Criteria	
Technical	Generation plan	・Peak duration time ・Installed capacity	・7hrs ・About 500 MW	○ ○
	Limit of manufacturing of power facility	・Design head ・K Value (Hpmax / Hgmin) ・Max. utilizing water depth of pond	・Less than 750m of maximum head ・Less than the limit (1.25-1.4) ・Less than 30m (40m in case of full facing pond type)	○ ○ ○
	Location / Layout	・Catchment area of Lower reservoir ・Crest length of Lower Dam ・Dam height ・Length of water way ・Length / Head (L/H) ・Overburden of underground power cavern	・More than $50km^2$ ・Less than 500m ・Less than 200m ・Less than 10km ・Less than 10 ・Less than 500m	○ ○ ○ ○ ○ ○
	Geological conditions	・Active fault (Quaternary fault) ・Fault and fractured zone ・Landslide area ・Permeability of peripheral rock of upper reservoir	・Elongation from active faults >10km ・Avoid large-scaled fault and fractured zone ・Avoid large-scaled landslide area ・Avoid lime stone / Quaternary volcanic rock	● ● ● ●
Topographical conditions		・Demand center / pumping energy source ・Existing and planned power network ・Accessibility	・Near demand center / pumping energy source ・Near bulk power network (Substation) ・Good accessibility to the site	○ ○ ●
Environmental	Natural	・Protected Area (e.g. Natural Parks) ・Endangered species	・Avoid important Protected Areas (Natural Parks, Nature Parks, and Ramsar Sites) ・Avoid the critical habitats of important fauna and flora	○ ●
	Social	・Mining right ・Historical and Cultural heritage ・Houses to be resettled	・Avoid the area of mining concession ・Avoid being submerged ・Less than 50	● ● ●

○ : considered in primary project finding ● : necessary to confirm the situation by site survey

(2) Finding of PSPP Potential Sites

In consideration of the criteria for finding of PSPP potential sites mentioned above, the JICA Survey Team carried out the finding PSPP potential sites with the Google Earth. In total, nine potential sites were found as shown in Figure 13-5.

No. 6 site is only potential site, which utilizes Kaptai Lake as a lower reservoir. The remaining eight sites found are located in the Sangu River basin, which require new construction of both upper reservoir and lower reservoir.

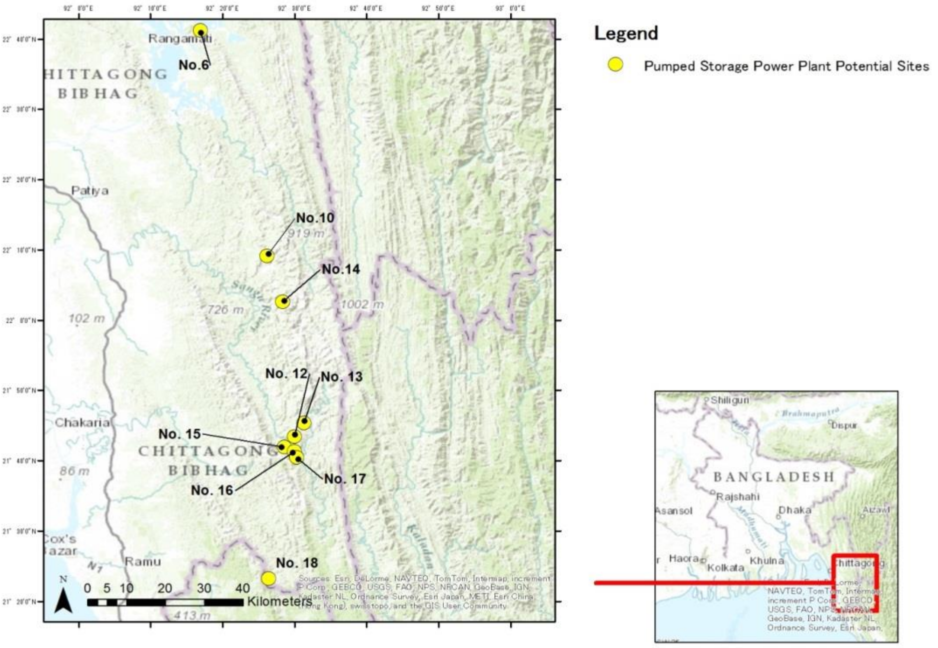
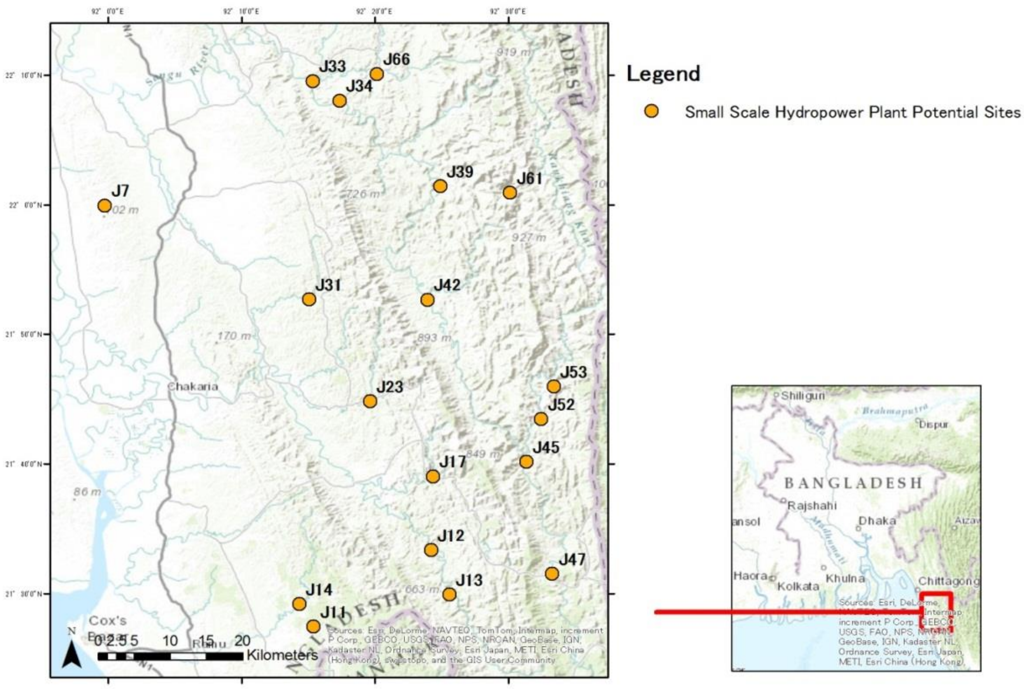


Figure 13-5 PSPP Potential Sites

13.4.2 Selection of Ordinary HP /SSHP Potential Sites for this Study

In consideration of attractive scale of hydropower development, the Ordinary HP potential sites in Chittagong hilly area were targeted in this Study.



Source) Study on Prospective Hydropelectricity Generation in Southeast Bangladesh

Figure 13-6 Ordinary HP Potential Sites in Chittagong Hilly Area

13.5 Selection of Target Areas and Site Reconnaissance

The JICA Survey Team selected Chittagong Hilly Area as a target area for site reconnaissance, since most of the potential sites are located in the area. However, accessible potential sites are limited due to peace and order situation, and limited access roads. Therefore, targeted sites for site reconnaissance were not selected in advance. Only accessible sites among all potential sites were surveyed during the site reconnaissance.

The JICA Survey Team together with an official of BPDB and local consultants carried out the site reconnaissance of the potential sites from June 8 to June 14, 2015. Results of the site reconnaissance are as follows:

13.6 Geology around the Potential Sites

As one of the technical requirements for PSPP development, geology of the project site must be firm and impermeable, since dams and/reservoir are newly created, and a large scale cavern for a powerhouse is excavated in deep underground.

Figure 13-7 shows the geology of Chittagong Hilly Area where hydropower potential sites are located. Geology around the potential sites is Boka Bil Formation (Neogene) or Bhuban Formation (Miocene), which consists of sand stone, mad stone and those alternate layer. Though the rocks are relatively low concreteness, it is assumed possible to construct PSPP on such geology. Active faults near the potential sites are not recognized. Thus, from viewpoints of regional geology around the project sites, PSPP development in the area is possible.

Typical alternate layer of sand stone and mad stone and mad stone

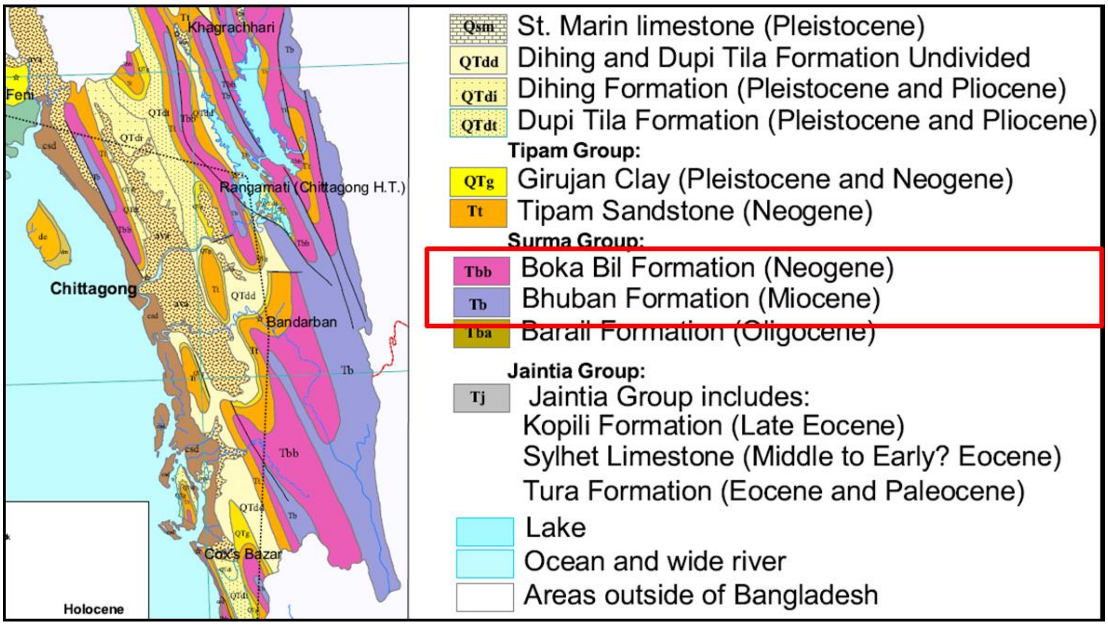


Figure 13-7 Geological Map of Chittagong Hilly Area

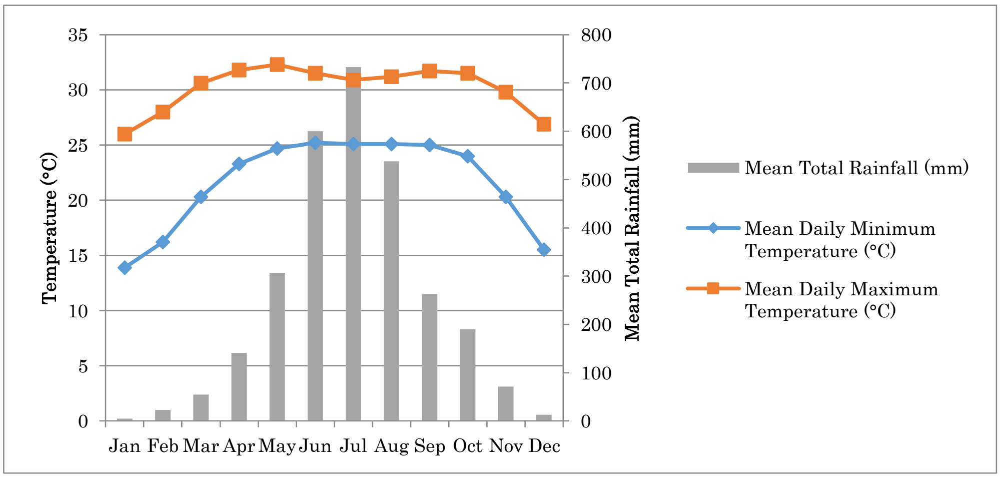
13.7 Environmental and Social Considerations

13.7.1 Baseline of Environmental and Social Information in and around the Potential Sites

(1) Physical Environment

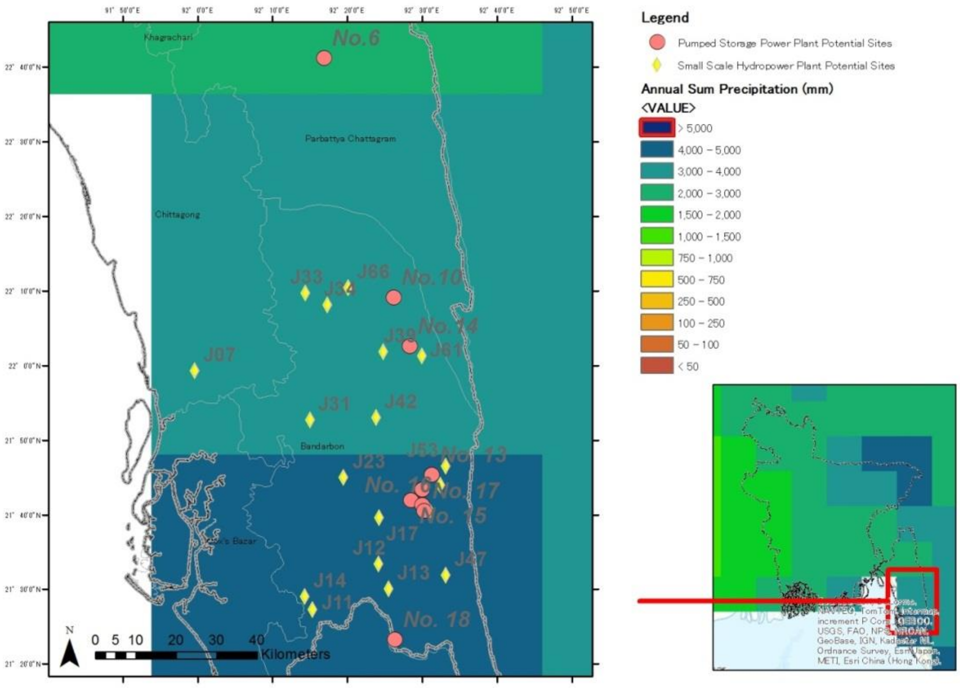
(a) Climate and weather

The climate of Chittagong and Chittagong high land fall in Tropical monsoon climate (Am) by Köppen climate classification. The light dry season is from December to March as shown in Figure 13-8. Amount of precipitation in southern part of Chittagong where many potential project sites are located is greater than northern part as shown in Figure 13-9.



Source: World Meteorological Organization

Figure 13-8 Temperature and Rainfall in Chittagong (average from 1971 to 2000)



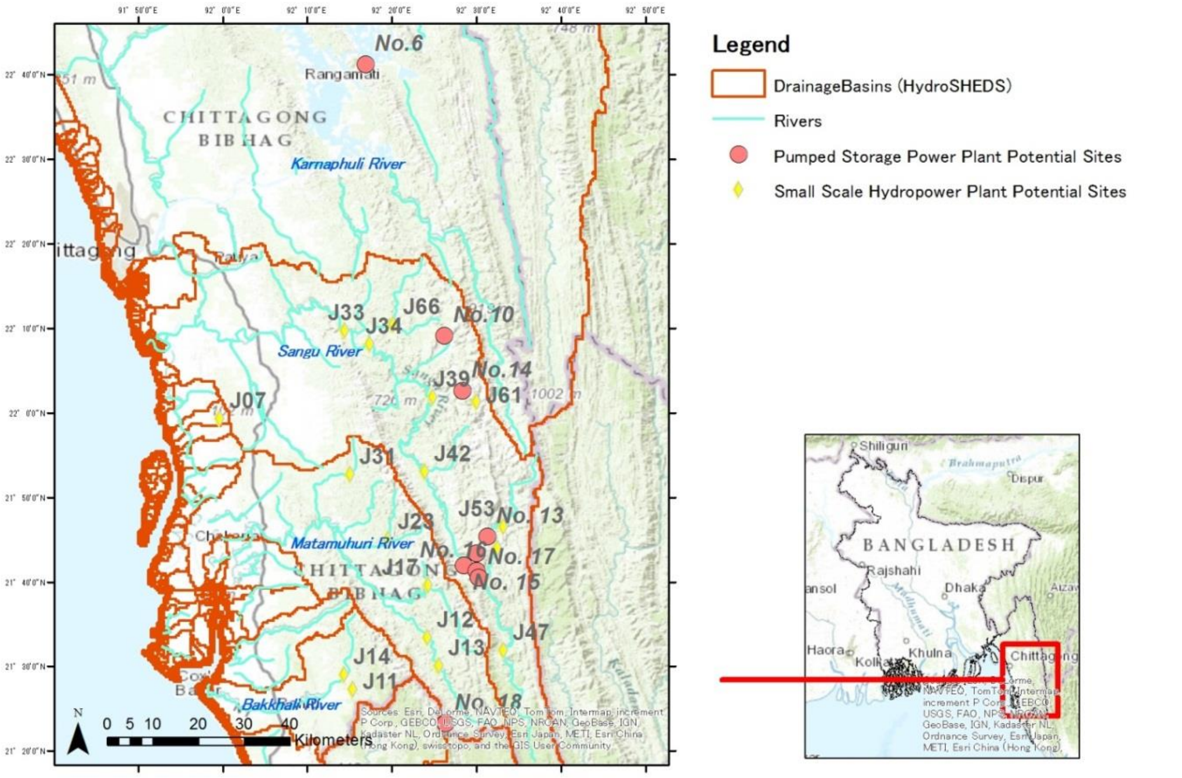
Source: WorldClim bio-climatic variable: BIO12

Figure 13-9 Annual Sum Rainfall around the Survey Area

(b) River system and water quality

River systems in Bangladesh are divided in two, the systems flowing down to sea from north to south including Padma River (Ganges river), Jamuna River (Brahmaputra River) and Meghna River, and systems flowing down from Chittagong high land to Bay of Bengal. Ganges River, Brahmaputra River, and Meghna River are international rivers from contiguous countries. Their total basin is 1.73 million km2 and including Bhutan, Nepal, a part of India and China. Main streams from Chittagong high land to Bay of Bengal are Karnaphuli river, Sangu river, Matamuhuri river, and Bakkhali river. Most of the potential sites are located in three southern systems as shown in Figure 13-10. 15 potential sites are in the Sangu river system and 6 potential sites are in the Matamuhuri river system as shown in See Table 13-4.

The surface river water quality in Bangladesh is not good condition. Meghna River system in dry season is seriously polluted. Arsenic concentration of underground water in Bangladesh is also high especially in downstream area of Ganges/ Brahmaputra/ Meghna river system and causing health problems. On the other hand arsenic concentration is not confirmed in Chittagong high land other than sea side of northern Chittagong.



Source: Lehner, B., Verdin, K., Jarvis, A. (2006): HydroSHEDS Technical Documentation

Figure 13-10 Main Rivers on Chittagong Hill Tracts

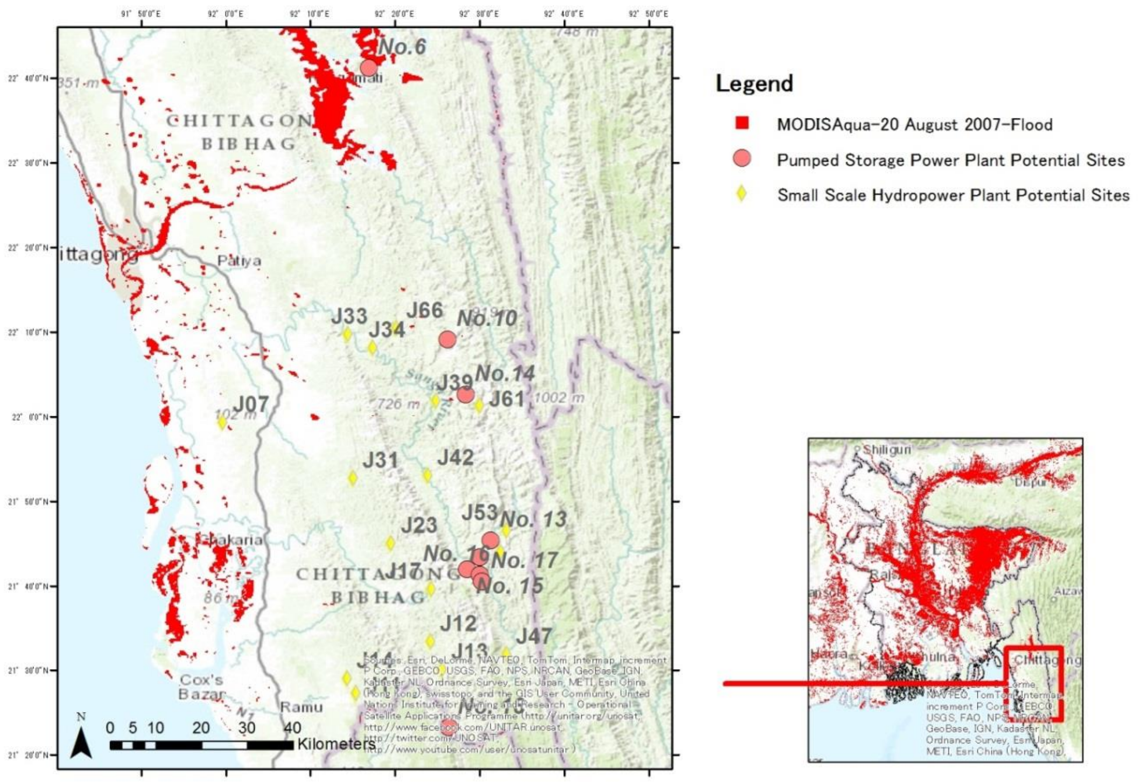
Table 13-4 River System and Potential Sites

River system	PSPP		SSHP	
	Main Stream	Tributary	Main Stream	Tributary
Bakkhali	-	-	J14	J11
Banshkhali	-	-	-	J7
Kaptai lake	-	No.6	-	-
Matamuhuri	-	No.18	J12, J13	J17, J23, J31
Sangu	-	No.10, No.12, No.13, No.14, No.15, No.16, No.17	J33, J34, J39, J42, J45, J47	J52, J53, J61, J66

(c) Flood and Salinity

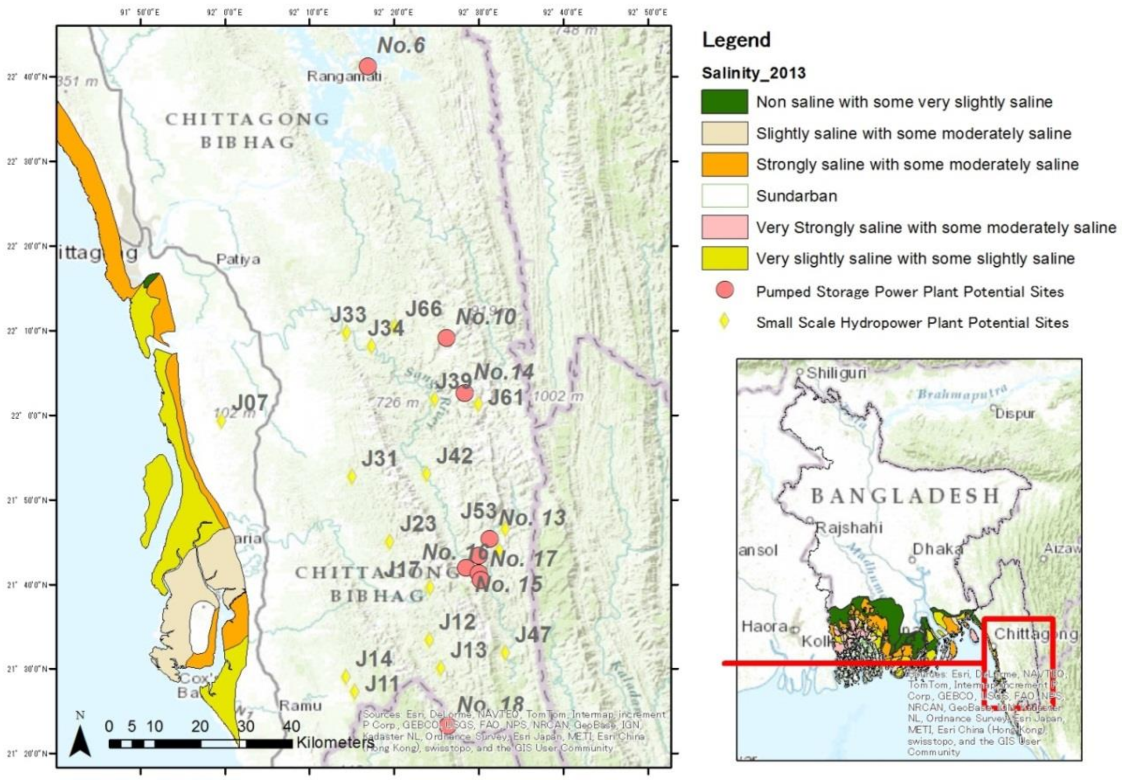
Bangladesh is repeatedly visited by severe floods. One of the biggest floods observed in 20 August 2007 is estimated as 72,972.76 km2 of flooded area based on the analysis of NODIS-Aqua by UNITAR/UNOSAT (See Figure 13-11).

Salinity of underground water is also serious along the coast in Bangladesh. The salinity affected areas are shown in Figure 13-12. None of the hydropower potential sites is located in flood or salinity affected area.



Source: Flood vectors - MODIS-Aqua (20 August 2007), UNITAR/UNOSAT 2014

Figure 13-11 Flood Affected Area in August 2007



Source: Soil Resource Development Institute SRMAF Project

Figure 13-12 Saline Affected Area

(2) Natural Environment

(a) Domestic Protected Area

Domestic protected areas in Bangladesh are National Parks, Wildlife Sanctuary designated by Wildlife Preservation Act (1973), Ecologically Critical Areas by Environment Act (1995), Forest reserve, Protected forest by Forest Act (1927) and Botanical Garden, Eco-parks and Safari Park which are Ex-situ Conservation Areas. Official name, locations will be confirmed later. Some of the Hydropower potential sites might be in the Forest reserve.

Table 13-5 Designated Area by Wildlife (Preservation) Act, 1973

Designation	No.	Name	Location	Area (ha.)	Established	Potential site
National Park	1	Bhawal National Park	Gazipur	5,022.00	11-5-1982	
	2	Madhupur National Park	Tangail/ Mymensingh	8,436.00	24-2-1982	
	3	Ramsagar National Park	Dinajpur	27.75	30-4-2001	
	4	Himchari National Park	Cox's Bazar	1,729.00	15-2-1980	
	5	Lawachara National Park	Moulavibazar	1,250.00	7-7-1996	
	6	Kaptai National Park	Chittagong Hill Tracts	5,464.00	9-9-1999	
	7	Nijhum Dweep National Park	Noakhali	16,352.23	8-4-2001	
	8	Medhakachhapia National Park	Cox's Bazar	395.92	8-8-2008	
	9	Satchari National Park	Habigonj	242.91	15-10-2005	
	10	Khadimnagar National Park	Sylhet	678.80	13-04-2006	
	11	Baroiyadhala National Park	Chittagong	2,933.61	06-04-2010	
	12	Kuakata National Park	Patuakhali	1,613.00	24-10-2010	
	13	Nababgonj National Park	Dinajpur	517.61	24-10-2010	
	14	Singra National Park	Dinajpur	305.69	24-10-2010	
	15	Kadigarh National Park	Mymensingh	344.13	24-10-2010	
	16	Altadighi National Park	Naogaon	264.12	24-12-2011	
	17	Birgonj National Park	Dinajpur	168.56	24-12-2011	
Wildlife Sanctuary	18	Rema-Kalenga Wildlife Sanctuary	Hobigonj	1,795.54	7-7-1996	
	19	Char Kukri-Mukri Wildlife Sanctuary	Bhola	40.00	19-12-1981	
	20	Sundarban (East) Wildlife Sanctuary	Bagerhat	31,226.94	6-4-1996	
	21	Sundarban (West) Wildlife Sanctuary	Satkhira	71,502.10	6-4-1996	
	22	Sundarban (South) Wildlife Sanctuary	Khulna	36,970.45	6-4-1996	
	23	Pablakhali Wildlife Sanctuary	Chittagong Hill Tracts	42,087.00	20-9-1983	
	24	Chunati Wildlife Sanctuary	Chittagong	7,763.97	18-3-1986	J07
	25	Fashiakhali Wildlife	Cox's Bazar	1,302.43	11-4-2007	

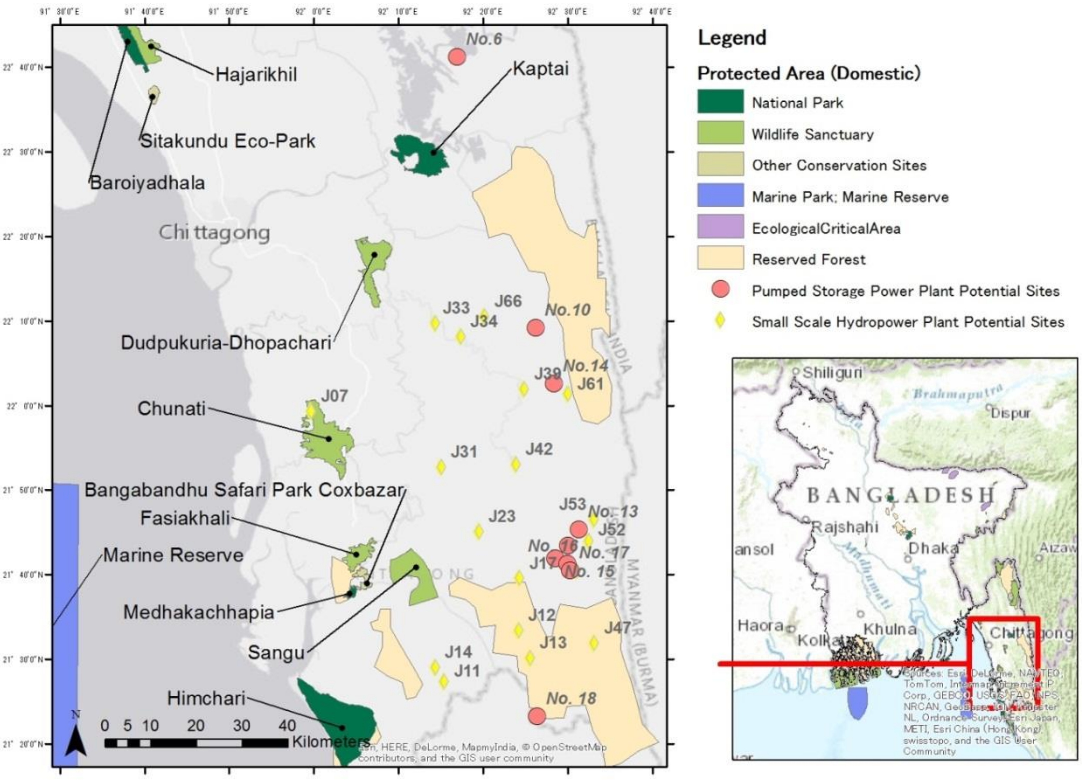
Designation	No.	Name	Location	Area (ha.)	Established	Potential site
		Sanctuary				
	26	Dudpukuria-Dhopachari Wildlife Sanctuary	Chittagong	4,716.57	6-4-2010	
	27	Hajarikhil Wildlife Sanctuary	Chittagong	1,177.53	6-4-2010	
	28	Sangu Wildlife Sanctuary	Bandarban	2,331.98	6-4-2010	
	29	Teknaf Wildlife Sanctuary	Cox's Bazar	11,615.00	24-03-2010	
	30	Tengragiri Wildlife Sanctuary	Barguna	4,048.58	24-10-2010	
	31	Dudhmukhi Wildlife Sanctuary	Bagerhat	170.00	29-01-2012	
	32	Chadpai Wildlife Sanctuary	Bagerhat	560.00	29-01-2012	
	33	Dhangmari Wildlife Sanctuary	Bagerhat	340.00	29-01-2012	
	34	Sonarchar Wildlife Sanctuary	Patuakhali	2,026.48	24-12-2011	
	35	Nazirganj Wildlife (Dolphin) Sanctuary	Pabna	146.00	01-12-2013	
	36	Shilanda-Nagdemra Wildlife (Dolphin) Sanctuary	Pabna	24.17	01-12-2013	
	37	Nagarbari-Mohanganj Dolphin Sanctuary	Pabna	408.11	01-12-2013	

Table 13-6 Designated Area by the Other Acts

Act	Designation	No.	Name	Location	Area (ha.)	Established	Potential sites
Ex-situ Conservation Areas	Botanical Garden	1	National Botanical Garden	Dhaka	84.21	1961	
		2	Baldha Garden	Dhaka*	1.37	1909	
	Eco-parks and Safari Park	3	Madhabkunda Eco-Park	Moulavibazar*	265.68	2001	
		4	Sitakunda Botanical Garden and Eco-park	Chittagong	808.00	1998	
		5	Dulahazara Safari Parks	Cox's Bazar	600.00	1999	
		6	Modhutila Eco-Park	Sherpur	100.00	1999	
		7	Banshkhali Eco-Park	Chittagong*	1,200.00	2003	
		8	Kuakata Eco-Park	Patuakhali	5,661.00	2005	
		9	Tilagar Eco-Park	Sylhet	45.34	2006	
		10	Borshijora Eco-Park	Moulavibazar	326.07	2006	
	Others	1	Swatch of no ground Marine Protected Area	-	-	-	
		2	Marine Reserve	-	-	-	
Environment (Conservation) Act, 1995	Ecologically Critical Areas	1	The Sundarbans	-	-	-	
		2	Cox's Bazar (Teknaf, Sea beach)	*	-	-	
		3	St. Martin Island	*	-	-	
		4	Sonadia Island	*	-	-	
		5	Hakaluki Haor	-	-	-	

Act	Designation	No.	Name	Location	Area (ha.)	Established	Potential sites
		6	Tanguar Haor	-	-	-	
		7	Marjat Baor	*	-	-	
		8	Gulshan-Banani-Baridhara Lake	*	-	-	
		9	Rivers (Buriganga, Bait, Turag, and Sitalakhya)	*	-	-	
Forest Act, 1927	Forest reserve	-	-	*	-	-	No. 18, J12, J13, J47
	Protected forest	-	-	*	-	-	

*: Locations or boundaries are not clear.



Source: WDPA

Figure 13-13 Domestic Protected Areas around the Hydropower Potential Sites

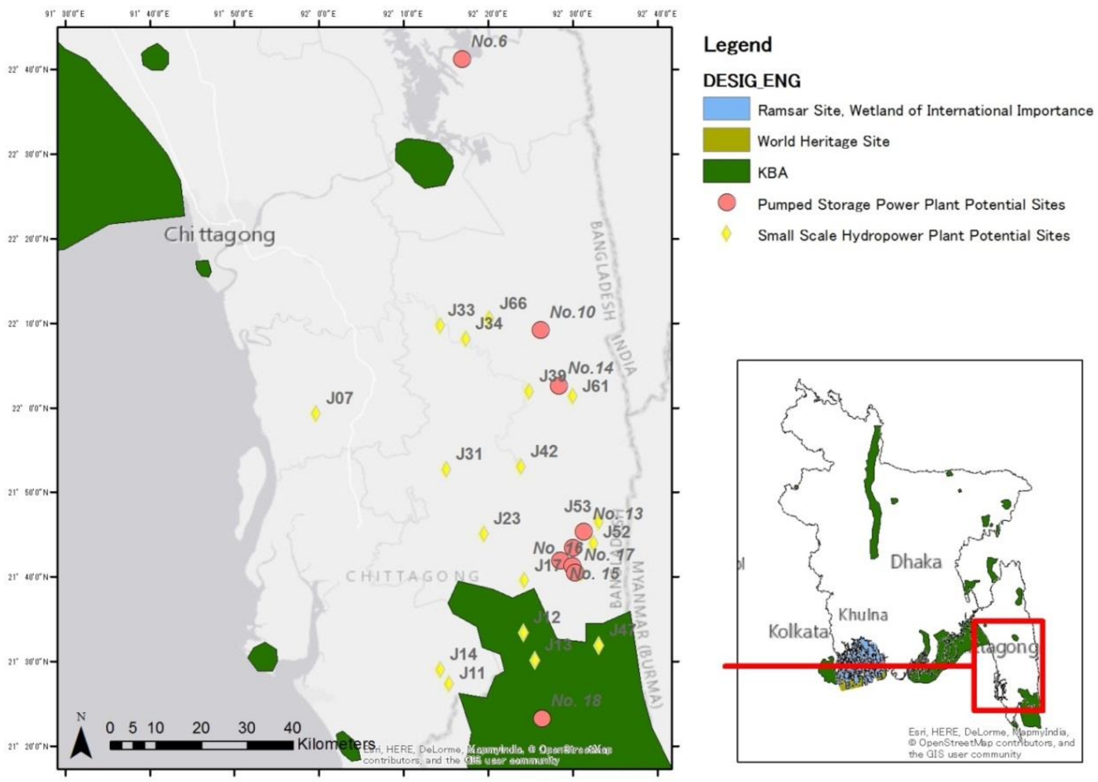
(b) International protected area and Key Biodiversity Area

There are three protected areas registered by International treaty in Bangladesh. Registered wetlands under the Ramsal Convention are Subdarbans Reserved Forest in estuary of Khunla District, and Tanguar Haor located at the border northern part of Sylhet District. World heritage area is the Sundarbans next to southern side of the Sundarbans Ramsal wetland. All of the international protected areas are far from the Hydropower potential sites.

There are 20 Key Biodiversity Areas (KBA) in Bangladesh as shown in Table 13-7. None of them are assigned as Alliance for Zero Extinction Sites (AZEs) where are identified to prevent and safeguard key sites, each one of which is the last remaining refuge of one or more Endangered or Critically Endangered species. Some of the Hydropower potential sites falls in the KBA as shown in Figure 13-14.

Table 13-7 Key Biodiversity Areas in Bangladesh

International name	Area (ha)	Potential sites
Aila Beel	160	
Ganges-Brahmaputra-Meghna delta	75000	
Hail Haor	8906	
Hakaluki Haor	20400	
Hazarikhil Wildlife Sanctuary	2903	
Himchari National Park	1729	
Jamuna-Brahmaputra river	200000	
Lawachara / West Bhanugach Reserved Forest	900	
Madhupur National Park	8436	
Muhuri Dam	500	
Pablakhali Wildlife Sanctuary	42087	
Patenga Beach	500	
Rajkandi Reserved Forest	1000	
Rampahar-Sitapahar Wildlife Sanctuary	3026	
Rema-Kalenga Wildlife Sanctuary	1095	
Sangu Matamuhari	20000	No.18,J12, J13, J47
Sonadia Island	4916	
Sunderbans (East, South, West Wildlife Sanctuaries)	139699	
Tanguar Haor and Panabeel	1566	
Teknaf Game Reserve	11615	



Source: IBAT, WDPA

Figure 13-14 KBA around Hydropower Potential Sites

(c) Distribution of the protected species

In total 198 IUCN red list species are recorded in Bangladesh including 21 plants, 43 mammals, 52 birds, 23 reptiles, 1 amphibians, 53 fishes, and 2 invertebrates. In terms of mammals, the known distribution areas around the Hydropower potential sites are of Indian hog deer (Axis porcinus), Asian Elephant (Elephas maximus), Phayre's leaf monkey (Trachypithecus phayrei), Western hoolock gibbon (Hoolock hoolock), and Dhole (Cuon alpinus). All of them are Endangered category (EN). Relatively limited distribution areas are of Indian hog deer and Asian Elephant as shown in Table 13-8. Some of the Hydropower potential sites are in the these distribution areas. It is reported that some kinds of freshwater dorphines are living in Kaptai area (Ahmed et al. 2001)[31]

Table 13-8 Number of IUCN Red List Species Recorded in Bangladesh

Taxonomic group*	EW	CR	EN	VU	NT	Total
Plants		5	3	8	5	21
Mammals		3	13	18	9	43
Birds		8	6	17	21	52
Reptiles	1	3	8	11		23
Amphibians				1		1
Fishes		2	3	15	34	54
Invertebrates			1	1	2	4
Grand Total	1	21	34	71	71	198

* : Extinct in Wild(EW), Critically Endangered(CR), Endangered(EN), Vulnerable(VU), Near Threatened(NT)

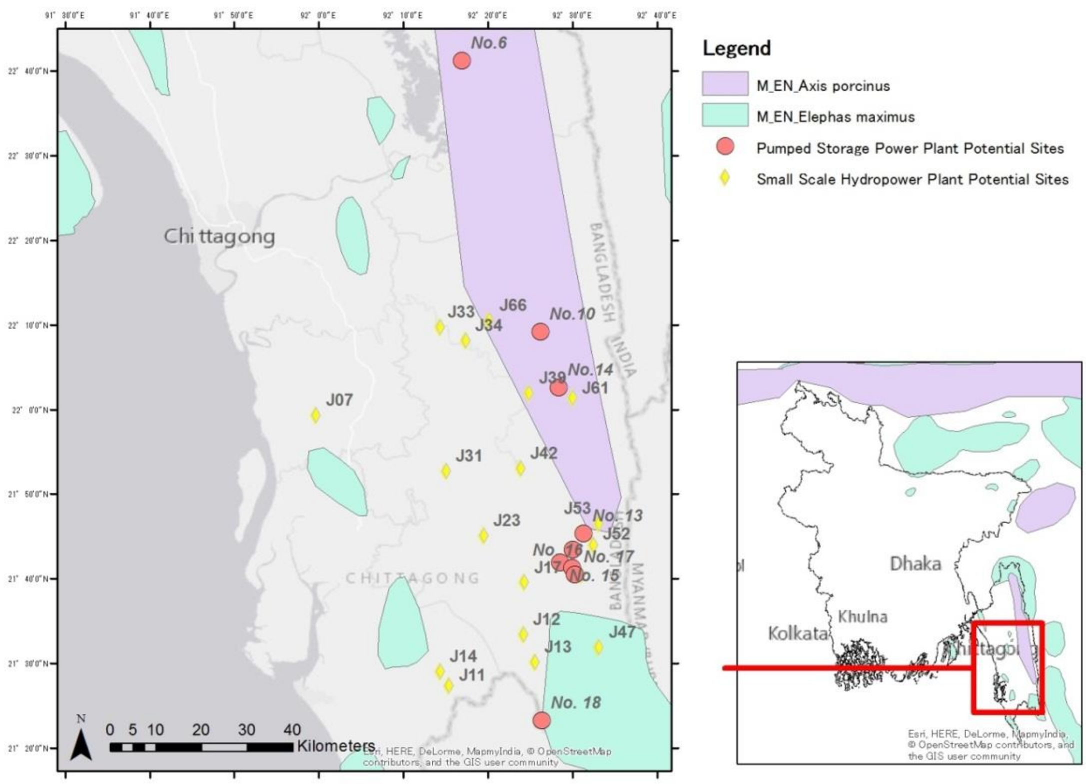
Table 13-9 Known Distribution Area of Endangered Mammals and Potential Sites

Potential sites	Indian hog deer (Axis porcinus)	Asian Elephant (*Elephas maximus*)	Phayre's leaf monkey (*Trachypithecus phayrei*)	Western hoolock gibbon (*Hoolock hoolock*)	Dhole (*Cuon alpinus*)
No.06	*		*	*	
No.10	*		*	*	
No.12			*	*	
No.13			*	*	
No.14	*		*	*	
No.15			*	*	
No.16			*	*	
No.17			*	*	
No.18		*	*	*	
J07			*	*	
J11			*	*	
J12			*	*	
J13			*	*	
J14			*	*	
J17			*	*	
J23			*	*	

[31] 2001, Ahmed, Benazir, Ali, Muhammad Edrise, Braulik, Gill & Smith, Brian D. " Status of the Ganges river dolphin or shushuk *Platanista gangetica* in Kaptai Lake and the southern rivers of Bangladesh" in *Oryx*, Vol. 35, No. 1, January. P. 61-72.

Potential sites	Indian hog deer (Axis porcinus)	Asian Elephant (*Elephas maximus*)	Phayre's leaf monkey (*Trachypithecus phayrei*)	Western hoolock gibbon (*Hoolock hoolock*)	Dhole (*Cuon alpinus*)
J31			*	*	
J33			*	*	
J34			*	*	
J39	*		*	*	
J42			*	*	
J45			*	*	
J47		*	*	*	
J52			*	*	
J53	*		*	*	
J61	*		*	*	
J66	*		*	*	

Source: IUCN

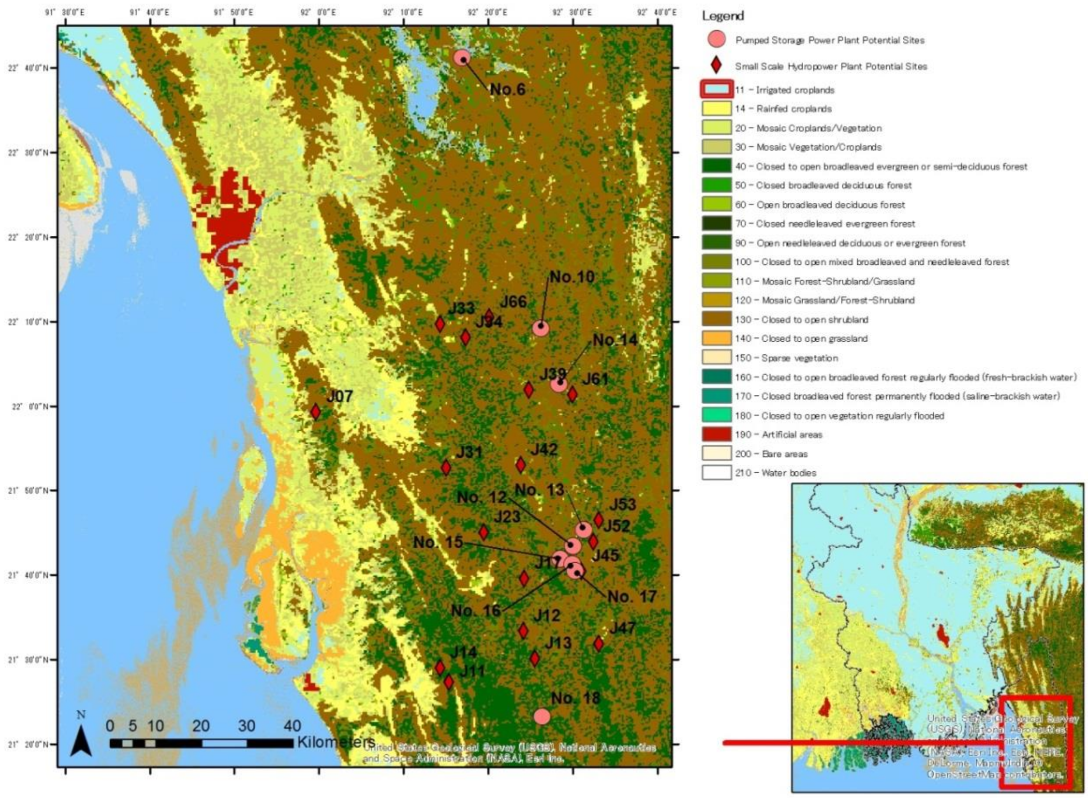


Source: IUCN

Figure 13-15 Known Distribution Area of Indian Hog Deer and Asian Elephant

(d) Vegetation

According to the GlobCover 2009 based on the satellite image, Irrigated croplands (11) are widely spread in Ganges Delta. The Chittagong Hill Tract is coverd by Closed to open broadleaved evergreen or semi-deciduous forest (40), Closed to open shrubland (130), and Mosaic Forest-Shrubland/Grassland (110). Rainfed croplancs (14) spread in the coast area of Chittagong district. Hydropower potential sites are located on the hills dominated by forest and shrubs as shown in Figure 13-16.



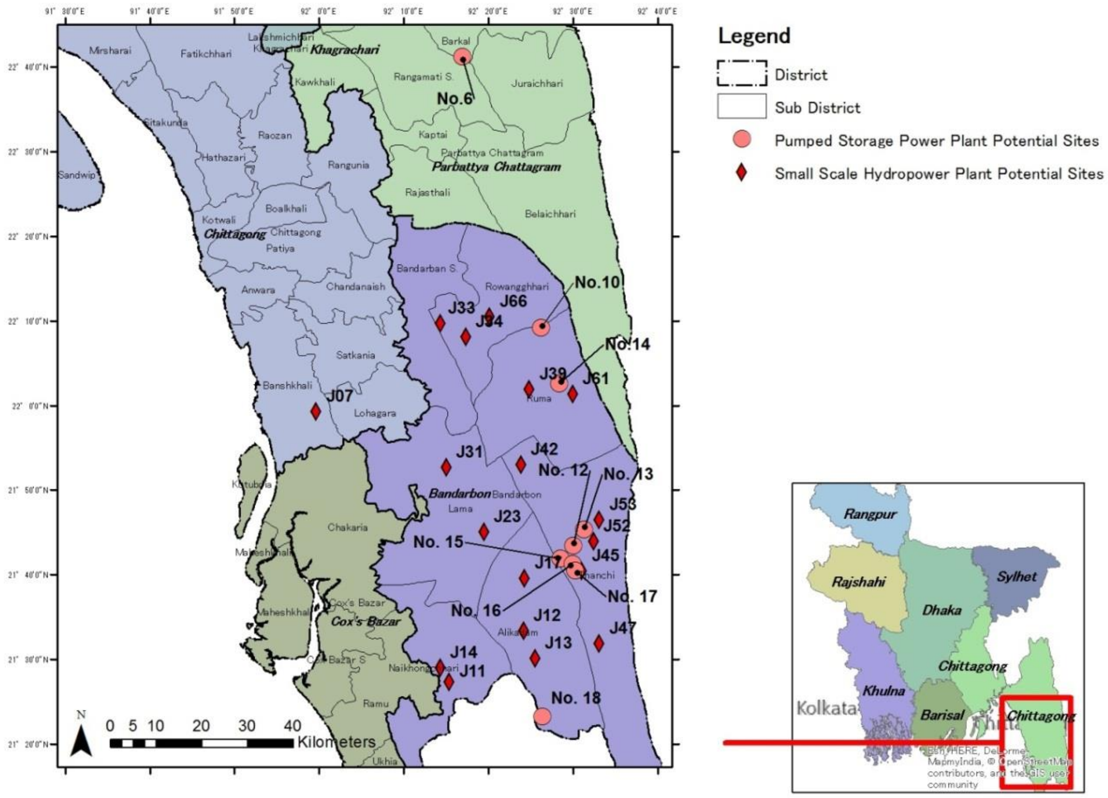
Source: GlobCover 2009 (http://ionia1.esrin.esa.int/)

Figure 13-16 Vegetation around the Hydropower Potential Sites by GlobCover (2009)

(3) Social Environment

(a) Administrative sections

The highest administrative sections in Bangladesh are seven Divisions followed by District, Sub-District (Upazila), and Village (Union/Mouza). The hydropower potential sites are located in Chittagong Division including Rangamati District, Chittagong District, Bandarban District, and Cox's Bazar District.



Source: ArcGIS Online, ESRI

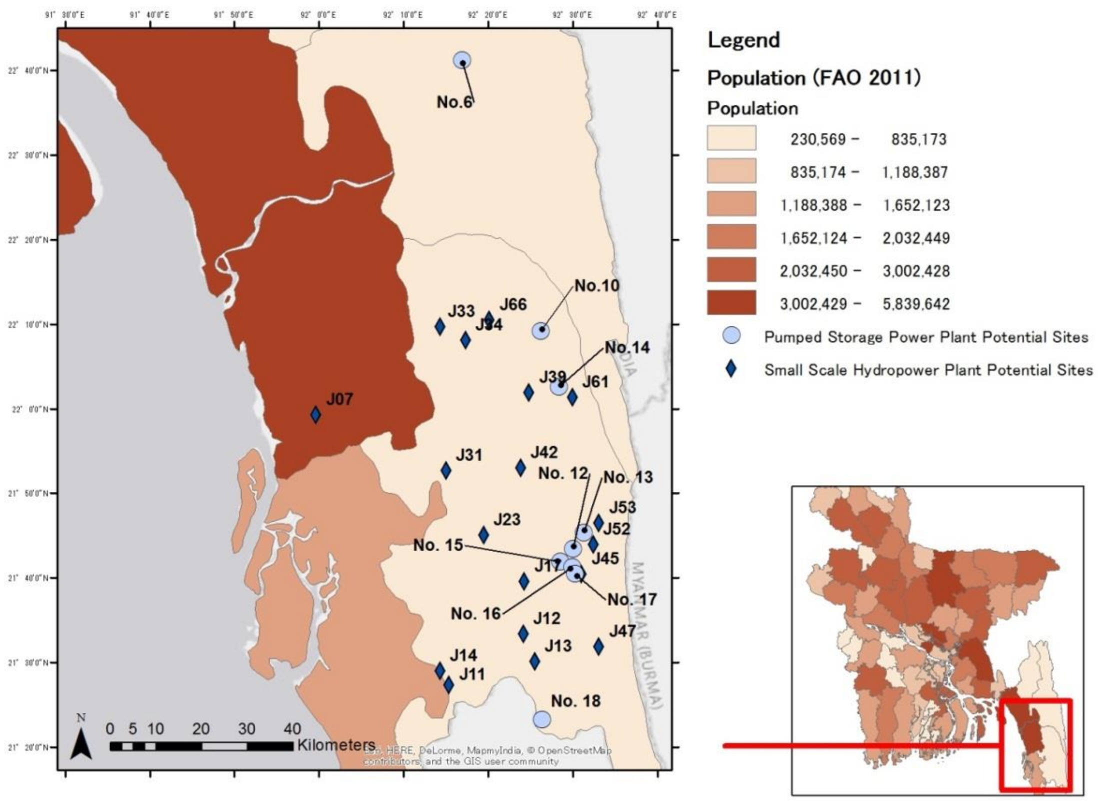
Figure 13-17 Administrative Boundaries around the Hydropower Potential Sites

Table 13-10 Administrative Jurisdiction of the Potential Sites

District	Sub-district (Upazila)	Village (Union/Mouza)	Potential Sites	
			PSPP	SSHP
Bandarban	Alikadam	Alikadam	-	J17, J23
		Chokhyong	No.18	J12, J13
	Bandarban	Bandarban	-	J33
	Lama	Rupshipara	-	J31
	Rawangchhari	Rawangchhari	-	J34, J66
	Ruma	Paindu	No.10	
		Ruma	No.14	J39, J61
	Thanchi	Remakri	No.15, No.16, No.17	J45, J47
		Thanchi	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	-	J7
Cox's Bazar	Ramu	Kaoarkhop	-	J11, J14
Rangamati	Barkal	Shuvolong	No.6	

(b) Population

According to the census 2011, the population of Bangladesh is over 150 million (152,518,015: the eights biggest country in the world). The population density in Bangladesh is 1,238 person/km2 which are more than triple the density in Japan (343 person/km2, 2005) cited by CIA World Fact Book 2012. Hydropower potential sites are located relatively fewer population districts. Apart from J7, all of the potential sites are located in low population area.



Source: FAO 2011

Figure 13-18 Population by Divisions around the Hydropower Potential Sites

Table 13-11 Village (Union/Mouza) Population of Potential Sites

Village (Union/Mouza)	No of.H/Hs	No of Population	Potential Sites	
			PSPP	SSHP
Alikadam	5,391	28,495	-	J17, J23
Chokhyong	4,031	20,822	No.18	J12, J13
Bandarban	2,023	9,219	-	J33
Rupshipara	2,457	11,565	-	J31
Rawangchhari	1,988	8,804	-	J34, J66
Paindu	1,267	5,803	No.10	
Ruma	2,667	12,417	No.14	J39, J61
Remakri	1,281	6,119	No.15, No.16, No.17	J45, J47
Thanchi	1,547	7,599	No.12, No.13	J42, J52, J53
Silkup	4075	20,043	-	J7
Kaoarkhop	4,373	24,004	-	J11, J14
Shuvolong	2,501	11,728	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

(c) Traffic and electricity

The road networks in Bangladesh cover whole the country. Main roads near the Hydropower potential sites are road stretching along the coast as shown in Figure 13-10. Although some roads are shown on the hill near the potential hydropower site, the conditions of the roads are not confirmed.
Electrification rates around the project sites are under 50%. Following table shows the electricity rates by Villages.

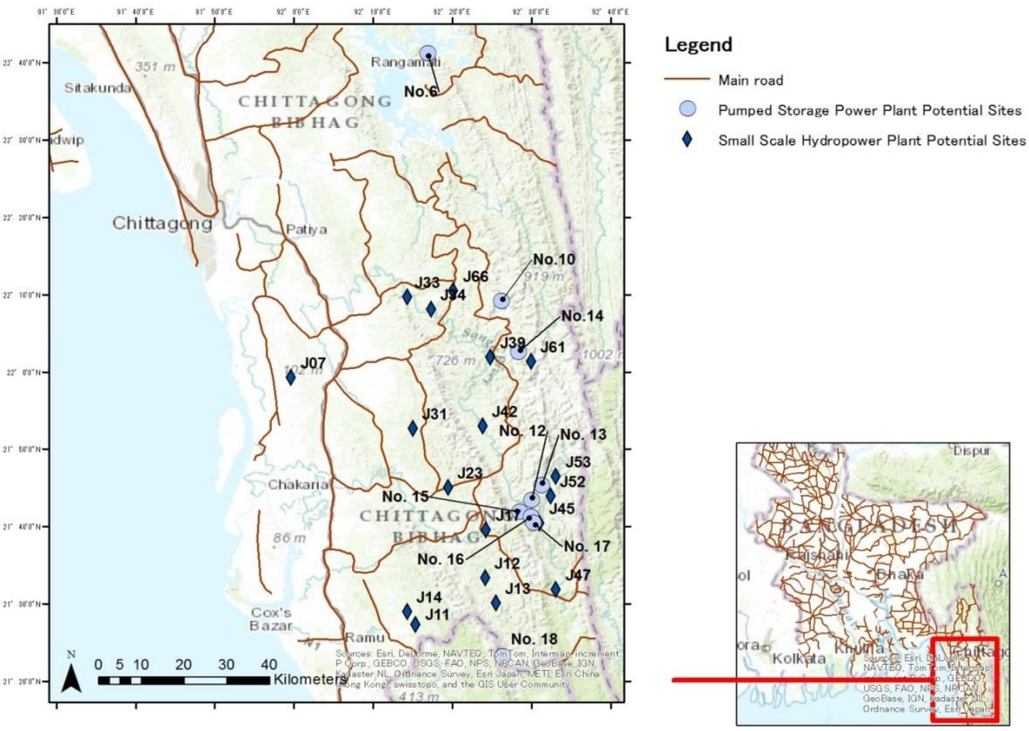


Figure 13-19 Main Roads around the Hydropower Potential Sites

Table 13-12 Percentage of Electrification around the Potential Sites

Administrative section			No of H/Hs	Electricity	Potential sites	
District	Upazila	Union/Mouza			PSPP	SSHP
Bandarban	Alikadam	Alikadam	5,391	18.70%	-	J17, J23
		Chokhyong	4,031	11.07%	No.18	J12, J13
	Bandarban	Bandarban	2,023	34.30%	-	J33
	Lama	Rupshipara	2,457	11.00%	-	J31
	Rawangchhari	Rawangchhari	1,988	27.70%	-	J34, J66
	Ruma	Paindu	1,267	28.60%	No.10	
		Ruma	2,667	42.80%	No.14	J39, J61
	Thanchi	Remakri	1,281	7.08%	No.15, No.16, No.17	J45, J47
		Thanchi	1,547	19.20%	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	4,075	34.60%	-	J7
Cox's Bazar	Ramu	Kaoarkhop	4,373	17.70%	-	J11, J14
Rangamati	Barkal	Shuvolong	2,501	27.10%	No.6	

(d) Land use

The villages which potential sites locate are widely developed for farm land for permanent or temporary as shown in Table 13-13. 59% of the farm land is used for Temporary cultivation, and 22% is used for Permanent cultivation.

Table 13-13 Land Use of the Related Sub-district

District	Upazila	Land Use Area (Acre) as per Agriculture Census 2008					Potential sites	
		Operated Area (Total)	Permanent	Temporary	Perma.fallow	Others	PSPP	SSHP
Bandarban	Ruma	21,755	4,860	13,693	64	3,138	No.10, No.14	J39, J61
	Ali Kadam	14,932	3,052	9,908	159	1,813	-	J17, J23
	Lama	39,510	14,652	14,182	1,357	9,319	-	J31
	Rawangchhari	19,613	5,358	8,829	30	5,396	-	J34, J66
	Thanchi	9,806	2,037	7,220	15	534	No.12, No.13, No.15, No.16, No.17	J42, J52, J53, J45, J47
Rangamati	Barkal	32,496	10,256	16,568	811	5,672	No.6	
Cox'Bazar	Ramu	34,172	1,873	23,949	189	8,161	-	J11, J14
Chittagong	Banshkhali	40,603	1,161	24,835	165	1,773	-	J7

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

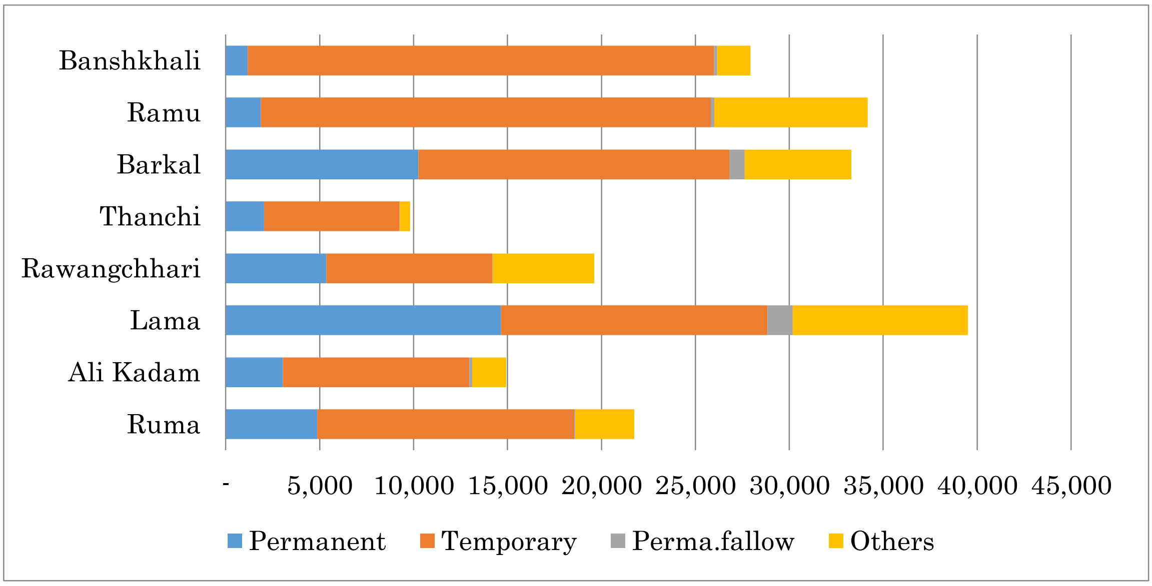


Figure 13-20 Land Use around the Potential Sites

(e) Ethnic minorities and religions

According to the population census (2011) there are 27 indigenous tribes in Bangladesh. They are mainly living in Chittagong Hill Tracts (CHT), Sylhet Division, Rajshahi Division, and Mymensingh District. Majority of Shuvolong Union where No.6 locates are Chakma. Marma is relatively high rate in Bandarban District. Maro is dominated in Alikadam Union where the potential sites of J17 and J23 (See Table 13-14 and Figure 13-21) locates.

Table 13-14 Ethnicity around the Potential Site

Administrative section			Ethnicity						Potential Sites	
District	Upazila	Union/Mouza	Marma	Chakma	Tripura	Maro	Others	Total	PSPP	SSHP
Bandarban	Alikadam	Alikadam	1,286	-	2,374	9,702	1,654	15,016	-	J17, J23
		Chokhyong	2,760	-	705	1,897	949	6,311	No.18	J12, J13
	Bandarban	Bandarban	3,606	-	220	-	2,212	6,038	-	J33
	Lama	Rupshipara	-	-	175	1,469	25	1,669	-	J31
	Rawangchhari	Rawangchhari	4,361	-	395	-	3,517	8,273	-	J34, J66
	Ruma	Paindu	3,402	-	-	4	2,301	5,707	No.10	
		Ruma	5,066	-	714	719	3,609	10,108	No.14	J39, J61
	Thanchi	Remakri	2,835	-	1,822	599	670	5,926	No.15, No.16, No.17	J45, J47
		Thanchi	1,938	-	1,191	2,914	599	6,642	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	-	-	-	-	-	-	-	J7
Cox's Bazar	Ramu	Kaoarkhop	-	7	-	-	-	7	-	J11, J14
Rangamati	Barkal	Shuvolong	182	8,670	-	-	95	8,947	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

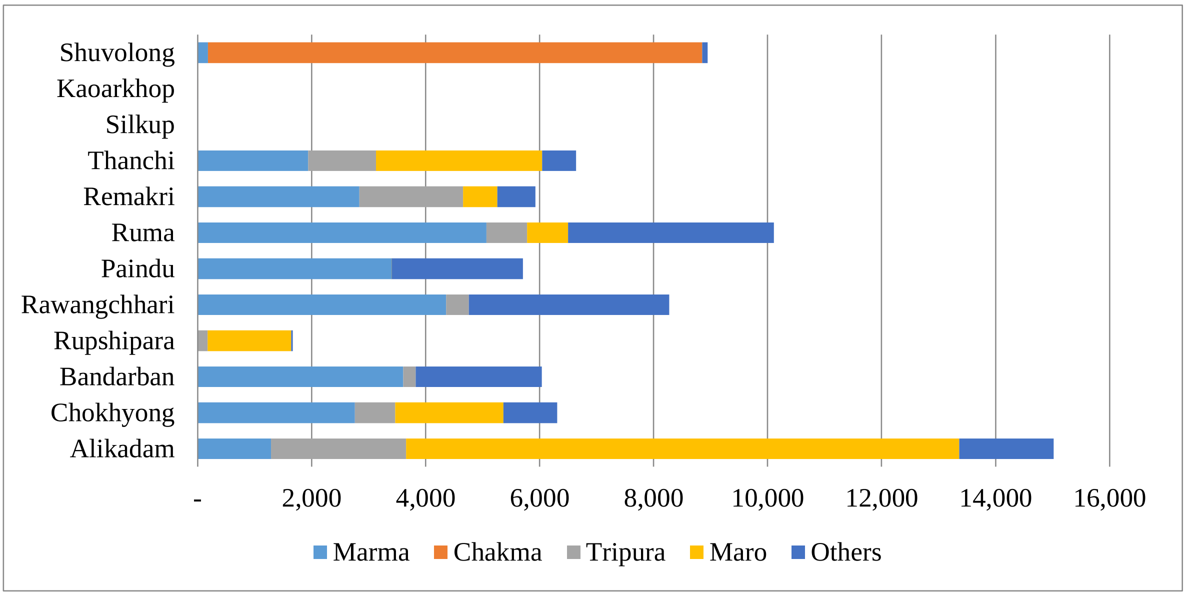


Figure 13-21 Ethnicity around the Potential Sites

According to the population census (2011) more than four religions are confirmed on the hill area. Buddhists are relatively high in Bandarban District. Some villages such as Kaoarkhop, Chokhyong are dominated by Islam as shown in Table 13-15 and Figure 13-22.

Table 13-15 Religions around the Potential Site

Administrative section			Population	Religion					Potential Sites	
District	Upazila	Union/Mouza		Islam	Hindu	Christian	Buddhist	Other's	PSPP	SSHP
Bandarban	Alikadam	Alikadam	28,495	12,973	939	2,812	9,912	1,859	-	J17, J23
		Chokhyong	20,822	13,707	716	845	5,321	233	No.18	J12, J13
	Bandarban	Bandarban	9,219	2,921	130	824	5,271	73	-	J33
	Lama	Rupshipara	11,565	6,864	15	259	4,361	66	-	J31
	Rawangchhari	Rawangchhari	8,804	460	118	2,202	6,016	8	-	J34, J66
	Ruma	Paindu	5,803	74	-	1,983	3,746	-	No.10	
		Ruma	12,417	1,520	491	3,813	5,779	814	No.14	J39, J61
	Thanchi	Remakri	6,119	22	1	2,260	3,123	713	No.15, No.16, No.17	J45, J47
		Thanchi	7,599	746	163	2,558	3,537	595	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	20,043	17,938	795	0	1,310	0	-	J7
Cox's Bazar	Ramu	Kaoarkhop	24,004	23,023	256	-	725	-	-	J11, J14
Rangamati	Barkal	Shuvolong	11,728	2,492	201	1	9,033	1	No.6	

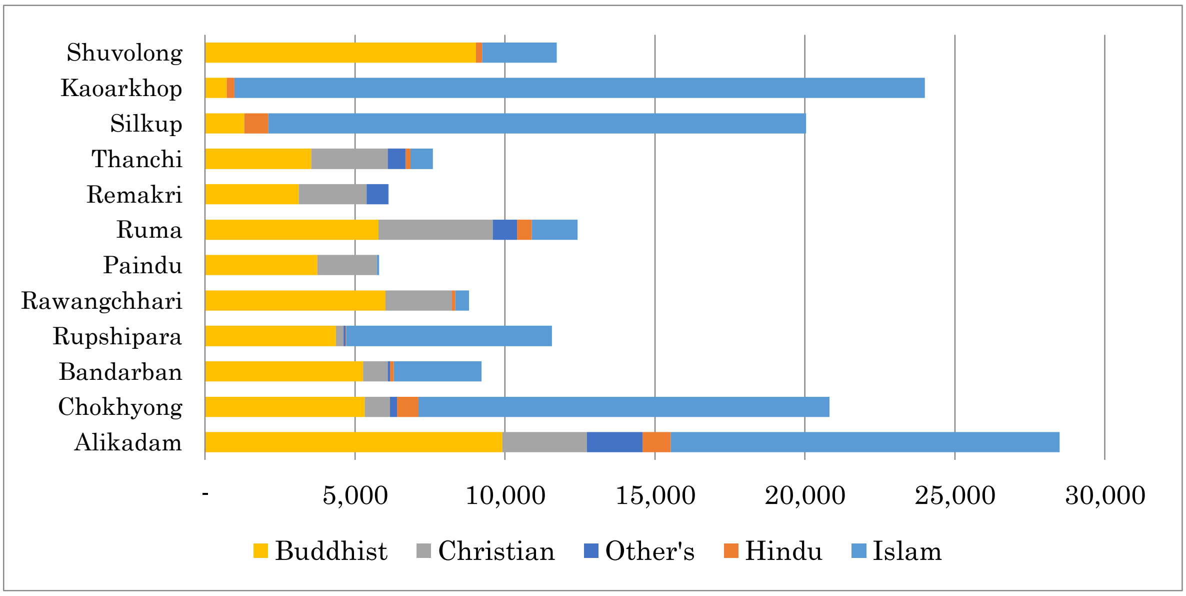
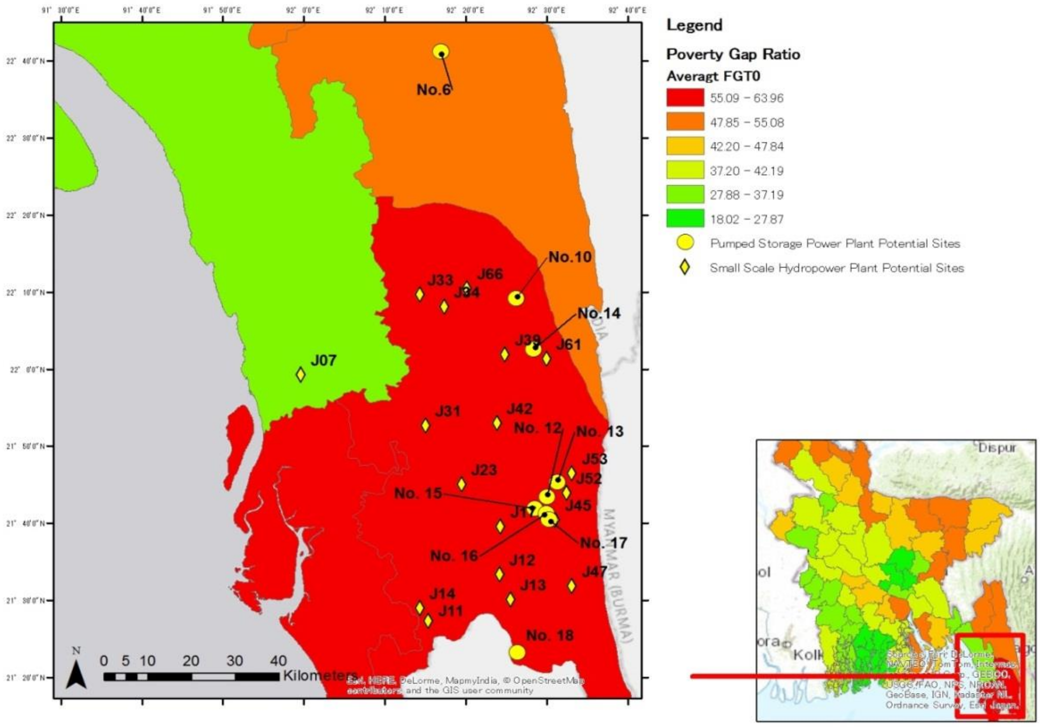


Figure 13-22 Religions around the Potential Sites

(f) Poverty and Literacy rate

Poverty gap index (the average poverty gap in the population as a proportion of the poverty line) by District shows that the poverty in Eastern area and Northern area is relatively lower than the other areas as shown in Figure 13-23. The Hydropower potential sites are the most poverty area among these areas.



Source: Feature Service, 2014

Figure 13-23 Poverty Gap Index around the Hydropower Potential Sites

Literacy rate around potential sites are lower than 50%. Literacy rate of Remakri Union/Mouza where No.15m No.16 and No.17 located is 0.00%.

Table 13-16 Literacy Rate around the Potential Sites

Administrative section			Population	Literacy	Potential sites	
District	Upazila	Union/Mouza			PSPP	SSHP
Bandarban	Alikadam	Alikadam	28,495	30.50%	-	J17, J23
		Chokhyong	20,822	32.40%	No.18	J12, J13
	Bandarban	Bandarban	9,219	38.30%	-	J33
	Lama	Rupshipara	11,565	25.80%	-	J31
	Rawangchhari	Rawangchhari	8,804	31.00%	-	J34, J66
	Ruma	Paindu	5,803	21.00%	No.10	
		Ruma	12,417	28.90%	No.14	J39, J61
	Thanchi	Remakri	6,119	0.00%	No.15, No.16, No.17	J45, J47
		Thanchi	7,599	26.09%	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	20,043	34.6%	-	J7
Cox's	Ramu	Kaoarkhop	24,004	33.70%	-	J11, J14

Bazar						
Rangamati	Barkal	Shuvolong	11,728	48.60%	No.6	

Source: Population and Housing Census 2011, Community Report, BBS & District Statistics 2011

(g) History, social and economic conditions of Chittagong Hill Tracts

1) History and peace negotiation in Chittagong Hill Tracts

People in Chittagong Hill Tracts (CHT) has been faced various difficulties for a long time (see Table 13-17). Construction of Kaptai dam (1957 – 1962) has forced hundred thousand people to leave their houses and land and sixty thousand people of them have moved to India and Burma under the East Pakistan government(Faisal & Pervin, 2002[32]). After independence of Bangladesh in 1971, many conflicts are triggered by Bengalese immigration. After the peace between United People's Party of the Chittagong Hill Tracts (Parbatya Chattagram Jana Sanghati Samiti: PCJSS) and Bangladesh government in 1997, some commitments are implemented. But many commitments were not implemented at 2004. Then both indigenous people and immigrated Bengalese were not satisfied the government actions.

Table 13-17 History of Chittagong Hill Tracts

1957-1962: Construction of the Kaptai Hydropower Plant by East Pakistan government. Hundred thousand people lost their houses and land and sixty thousand people of them have moved to India and Burma as refugees. 1971: East Pakistan army drew off from CHT. Bangladesh attained independence. 1972: Manabendra Narayan Larma founded the United People's Party of the Chittagong Hill Tracts (Parbatya Chattagram Jana Sanghati Samiti: PCJSS). 1976-1984: Bangladesh government carried out transmigration program brought 400,000 Bengali settlers. 1979-1996: Many conflicts between indigenous people and Bangladesh government. 1997: Chittagong Hill Tracts Accord was signed between Government of Bangladesh and PCJSS. The Accord includes (1) Taking back the tribal refugees from India’s Tripura State, (2) Reformation of the local government structure by equitable participation of indigenous people, (3)Chittagong Hill Tracs Regional Council (CHTRC) may co-ordinate and supervise in the matters of general administration, law and order and development of the three Hill Districts, (4) Hill District Council is responsible for Land and land management, Police (local), Tribal law and social justice etc. (5) Expansion of the power to levy taxes by Hill District Council and rising development budget by central government, (6) Giving land ownership of tribal people through the established land commission 1998: Forest and land conservation committee was established 1999: Land committee was established 2000: Task force for returning Indigenous Refugees was established

2) Socio-Economic condition of Chittagong Hill Tracts

UNDP Chittagong Hill Tracts Development Facility surveyed population, security, conflict, land, house, income and agriculture of CHT and published “SOCIO-ECONOMIC BASELINE SURVEY OF CHITTAGONG HILL TRACTS” (2009). The study reported small village size, dependence on Agriculture, and poverty households of CHT. Main findings of the report are as follows:

a) Population

[32] 2002, Faisal, I. M. & Parveen, Saila. “People versus Power: The Geopolitics of Kaptai Dam in Bangladesh”, in Water Resources Development, Vol. 18, No. 1, P. 197-208, Carfax Publishing.

- The para in CHT, synonymous to the village in the plain land, on average consists of about 46 households and a population of around 240 persons
- A 62% of the Bangalee populations are living in rural CHT for less than 30 years (Around two-thirds of the current Bangalee population in CHT are transmigrated people).
- Only 7.8 % of all CHT people completed primary education and 2.4% completed secondary education.

b) Dispute and security

- About 22% indigenous households have lost their lands.
- At least one household member in 13% of CHT rural households had to out-migrate from its para before the signing of the CHT Accord in 1997.
- The common people's day-to-day life in CHT is closely associated with the traditional power structure and lower tier of the local government, and to some extent with the security forces.
- Overall participation in local level organization is low.
- In terms of composite score on women and development issues, the IPs, on average, are in a better-off position with 12 percentage-points higher scores than that of the Bangalees.
- Majority of the population in CHT have extremely inadequate knowledge about the content of the CHT Accord 1997.
- Before the CHT Accord, a slightly less than one-fifth of the households had faced armed violence, and 5% reported that at least some from their households were wounded or killed. About 17% households with slightly less than 25% of the indigenous peoples and 8% of the Bangalees reportedly faced extortion during the last three years.
- The confidence building index (CBI) comprising 20 pertinent indicators and estimated using a 5-point Likert Scale (0 being 'no confidence' and 4 being 'highly confident') shows a moderate confidence level across the communities (CBI = 2.1).

c) Land and houses

- Land ownership of a household in context of CHT is to be understood along with three major types of ownership: (i) individual registered ownership, (ii) traditional ownership (recorded and/or not recorded with headman) under usufruct rights, and (iii) usufruct rights to ownership of common property (different from that in plain land).
- Almost all households possess own houses in rural CHT.
- The majority (63%) of the houses of IPs are kutcha followed by machan. Almost all the houses of Bangalees (96%) are kutcha.

d) Household income and expenditure

- The reported contribution of female members in generating household annual net income is low.
- The household annual expenditure in rural CHT is lower than that of rural Bangladesh (Tk. 62,000(USD 780) vs. 73,000(USD 919)).

- The share of annual household spending for the maintenance of female members is disproportionately low (around 30%) and is indicative of high extent of intra-household discrimination against women and female child.
- About 87% households reportedly have some savings
- About 54% of all CHT households have some access to credit
- Overall 43% households (50% indigenous and 34% Bangalee) listen to radio

e) Agriculture

- Farming/cultivation (through ploughing) is the occupation of 18% of the total population in CHT.
- Out of estimated 364,000 acres (1,473km2) of available cultivatable land, about 73,000 acres (295km2) are under plough cultivation and about 99,000 (401km2) are available for jum and about 66,000 acres (267km2) of land used for homesteads.
- On average, 52% of the total household members in CHT (2.75 persons per household (household size being 5.2) being either employed or employable.
- The cultivation technologies practiced in CHT for crop culture are plough and jum depending upon the suitability of the land. Nearly two-thirds of rural households are farming households.
- An average rural CHT household has brought about 138 decimals (5,583 m2) of land under field cropping and 161 decimals (6,514 m2) under jum in the 2007 cropping year.
- The annual household net income of an average rural household is around Tk. 66,000 (USD 831)[33] (Bangladesh rural being Tk. 84,000 (USD 1,057)).

f) Food and Health

- Food habit of the CHT people is almost similar to that of the plain land people except that they consume a very few items like nappi (a special type of fish paste), bamboo shoots, and dry vegetables.
- The per capita daily energy intake of an average household is 1,798 k.cal, which is less than the level for the hardcore poor (below 1,805 kcal).
- ‘Food Poverty’ is widespread in CHT. Most indigenous peoples in CHT are not secured in relation to availability of food during most time in a year
- About 62% households in the region irrespective of ethnicities, according to direct calorie intake (DCI) method, are living below the absolute poverty line (below 2,122k.cal), while 36% are hardcore poor (below 1805 k.cal).
- About three-fourth of the households (74%) are living below the lower poverty line (<Tk.866≒10 USD / person/month) and 86% below the upper poverty line (<Tk.1,025≒13 USD / person/month), according to CBN method.
- About 82% of children of 5-16 years are enrolled in primary or secondary schools
- Peoples’ knowledge about health problems, health facilities and health service providers is crucial

[33] 1 USD = 76.15 BDT in March 2015

- The contraceptive prevalence rate is 54% (national 56%), and the unmet need for family planning is 12% (national 17.6%).
- The major source(s) of drinking and cooking water in CHT are not safe.

3) Support programs

Some areas are supported by government and NGOs. Ruma Union/Mouza which is located No.14, J39 and J61 is supported by ASA, BRAC and government. Thanchi Union/Mouza (No.12, No.13, J42, J52, and J53) is supported by BRAC, CARITAS, and UNDP.

Table 13-18 Supporting Organizations

Administrative section			No of Population	Support by Gov/NGO	Potential sites	
District	Upazila	Union/Mouza			PSPP	SSHP
Bandarban	Alikadam	Alikadam	28,495		-	J17, J23
		Chokhyong	20,822		No.18	J12, J13
	Bandarban	Bandarban	9,219		-	J33
	Lama	Rupshipara	11,565		-	J31
	Rawangchhari	Rawangchhari	8,804	BRAC, Proshika, BNKS	-	J34, J66
	Ruma	Paindu	5,803		No.10	
		Ruma	12,417	ASA, BRAC, GB	No.14	J39, J61
	Thanchi	Remakri	6,119		No.15, No.16, No.17	J45, J47
		Thanchi	7,599	BRAC, CARITAS, UNDP	No.12, No.13	J42, J52, J53
Chittagong	Banshkhali	Silkup	20,043		-	J7
Cox's Bazar	Ramu	Kaoarkhop	24,004		-	J11, J14
Rangamati	Barkal	Shuvolong	11,728		No.6	

(h) Agriculture around the Kaptai reservoir

According to JICA (2004) many farmers around the reservoir were confirmed and they depend on cultivation under the high water level during June to October, when water level lowering. The cultivation was affected by water level such as less lowering and/or early increasing. The affected farmers seemed to manage their livelihood by debt by relatives or shylock, saving food, filling up by wild food, selling livestock or properties, or working as temporally labor.

13.7.2 Environmental and Social Impacts anticipated by Project

(1) PSPP potential sites

(a) PSPP No.6

PSPP No.6 is located in Shuvolong village, Barkal sub-district, Rangamati district. Reservoir area is 21.4 ha. Some houses are confirmed at the end of water way. Farm land and Forests are seen in the reservoir area. No big house but small huts can be seen on the image. Relatively good forests are remained at the waterway route. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma and Chakma might be affected by the project.

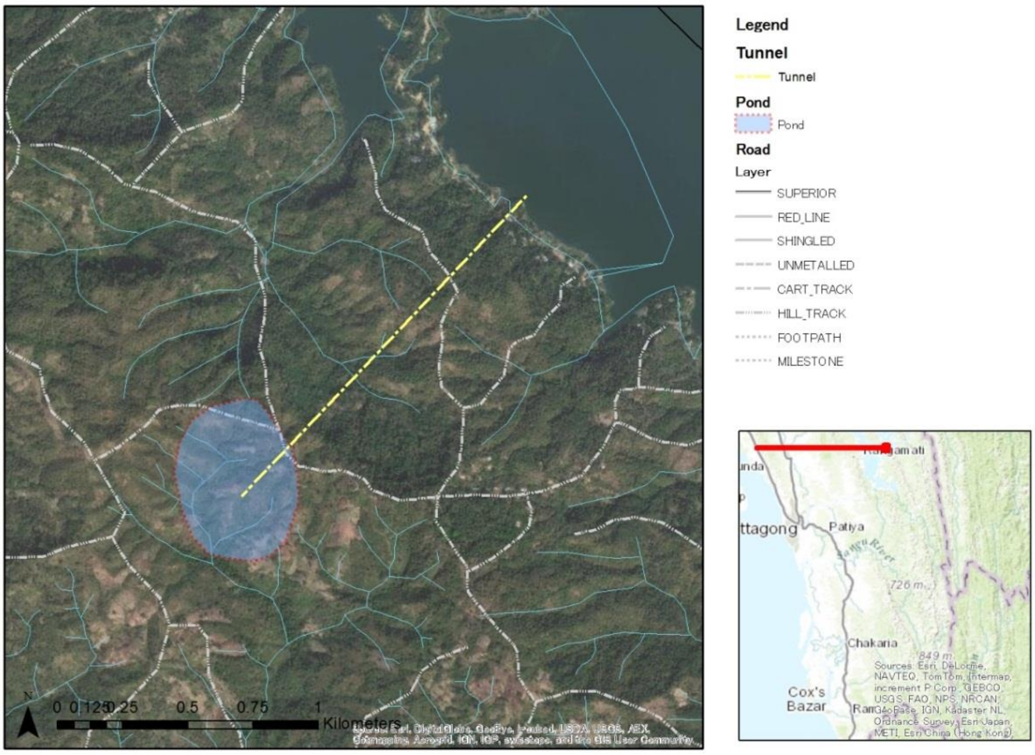
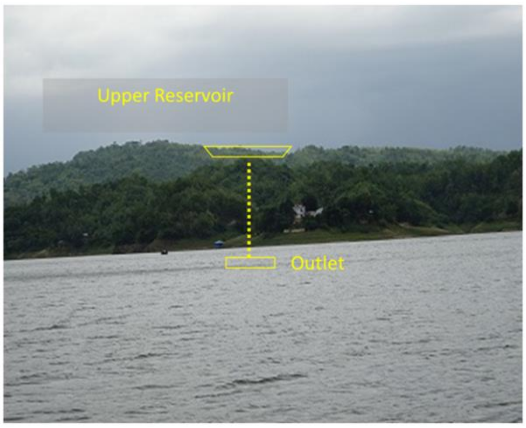


Figure 13-24 PSPP No.6

Table 13-19 Feature of PSPP No.6

Items	Value
Effective Head (m)	176
Designed Discharge (m^3/s)	330
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	230
LWL of Lower Reservoir (m)	33
Effective Reservoir Volume (m^3)	8,400,000
Length of Waterway (m)	1,640
L/H	8.8



View of PSPP No. 6

(b) PSPP No.10

PSPP No.10 is located in Paindu village, Ruma sub-district, Bandarban district. Upper pond area is around 33.2 ha and Lower pond is 155.8 ha. No big house but small huts can be seen on the image. Forest coverage would be around 70%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma and Maro might be affected by the project.

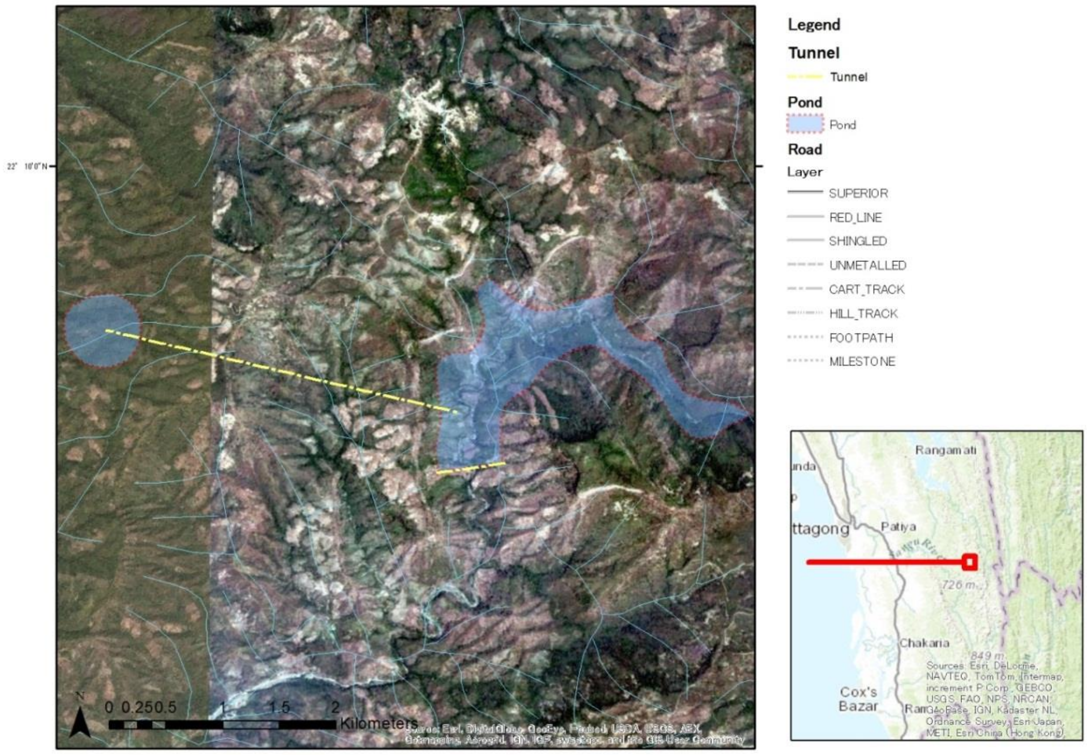


Figure 13-25 PSPP No.10

Table 13-20 Feature of PSPP No. 10

Items	Value
Effective Head (m)	185
Designed Discharge (m^3/s)	313
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	360
LWL of Lower Reservoir (m)	143
Effective Reservoir Volume (m^3)	9,400,000
Length of Waterway (m)	2,990
L/H	15.2

(c) PSPP No.12

PSPP No.12 is located in Thanchi village, Thanchi sub-district, Bandarban district. Area of upper pond is 29.2 ha and lower pond is 27.7 ha. No big house is confirmed. Small huts can be seen on the satellite image. Relatively good conserved forests are remained around the lower pond. Forest coverage would be around 60%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.

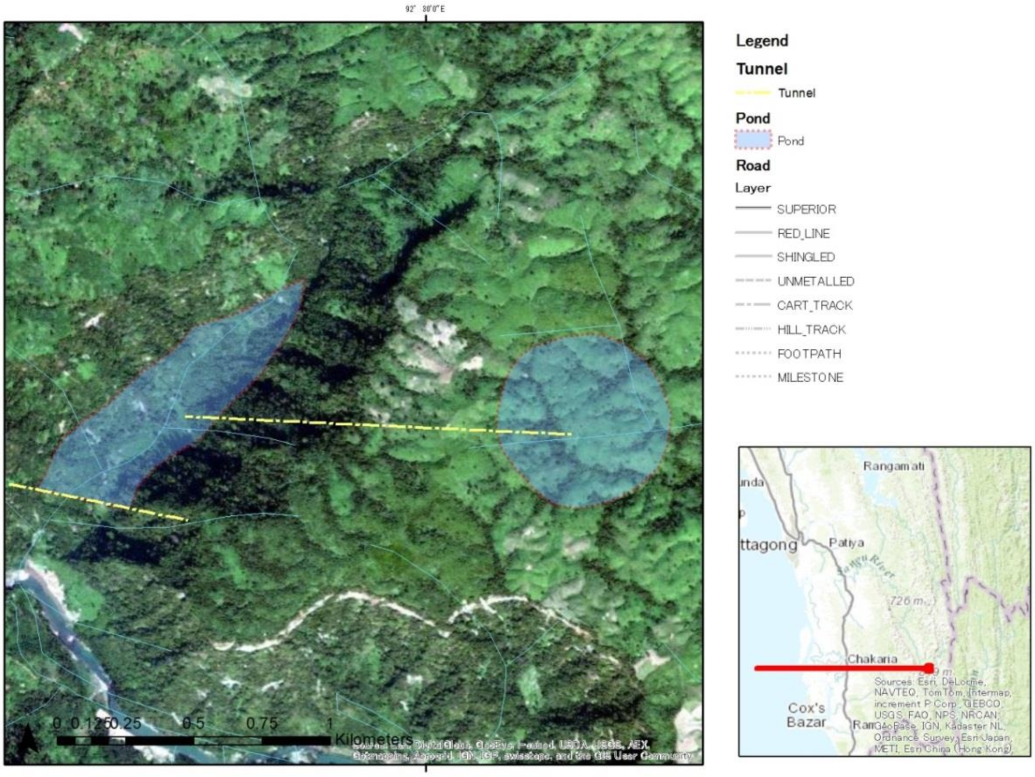


Figure 13-26 PSPP No.12

Table 13-21 Feature of PSPP No.12

Items	Value
Effective Head (m)	186
Designed Discharge (m^3/s)	312
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	340
LWL of Lower Reservoir (m)	122
Effective Reservoir Volume (m^3)	7,500,000
Length of Waterway (m)	1,330
L/H	6.7

(d) PSPP No.13

PSPP No.13 is located in Thanchi village, Thanchi sub-district, Bandarban district. Upper pond area is 15.8 ha and Lower pond area is 57.2 ha. No house but small huts are seen on the image. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.

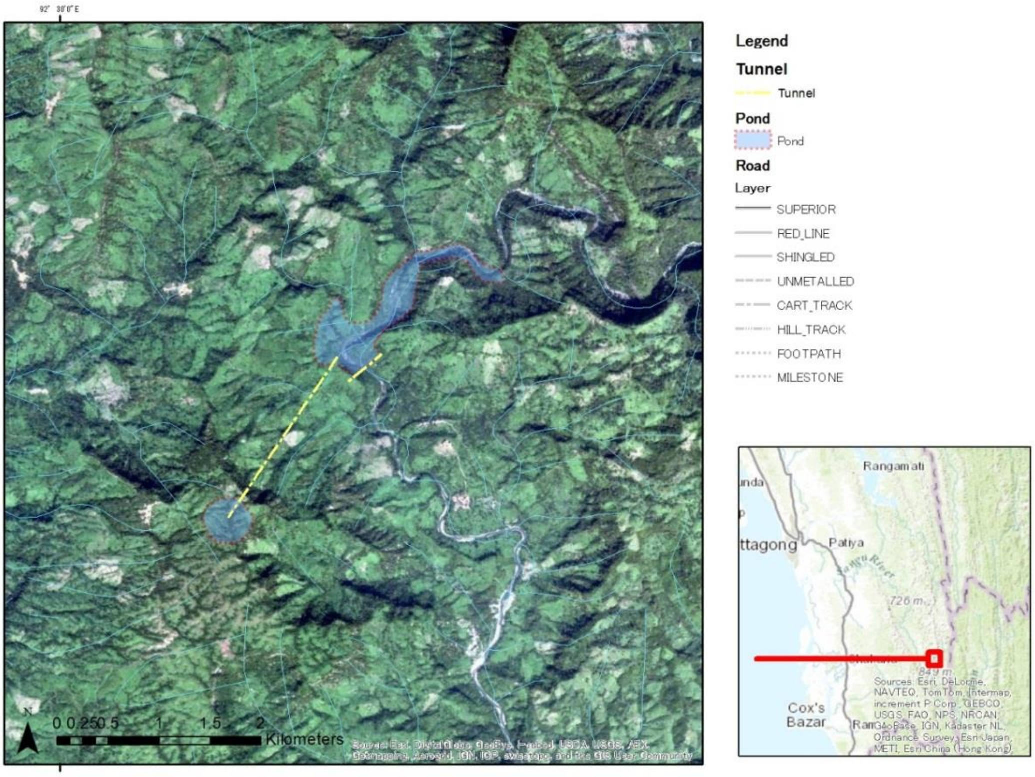


Figure 13-27 PSPP No.13

Table 13-22 Feature of PSPP No.13

Items	Value
Effective Head (m)	329
Designed Discharge (m^3/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	480
LWL of Lower Reservoir (m)	130
Effective Reservoir Volume (m^3)	4,500,000
Length of Waterway (m)	1,890
L/H	5.4

(e) PSPP No.14

PSPP No.14 is located in Ruma village, Ruma sub-district, Bandarban district. Upper pond area is 74.9 ha and lower pond area is 11.4 ha. No house and hut can be seen on the image. Forest coverage is around 70%. The project sites cover the distribution areas of Endangered mammals such as Indian hog deer (*Axis porcinus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.

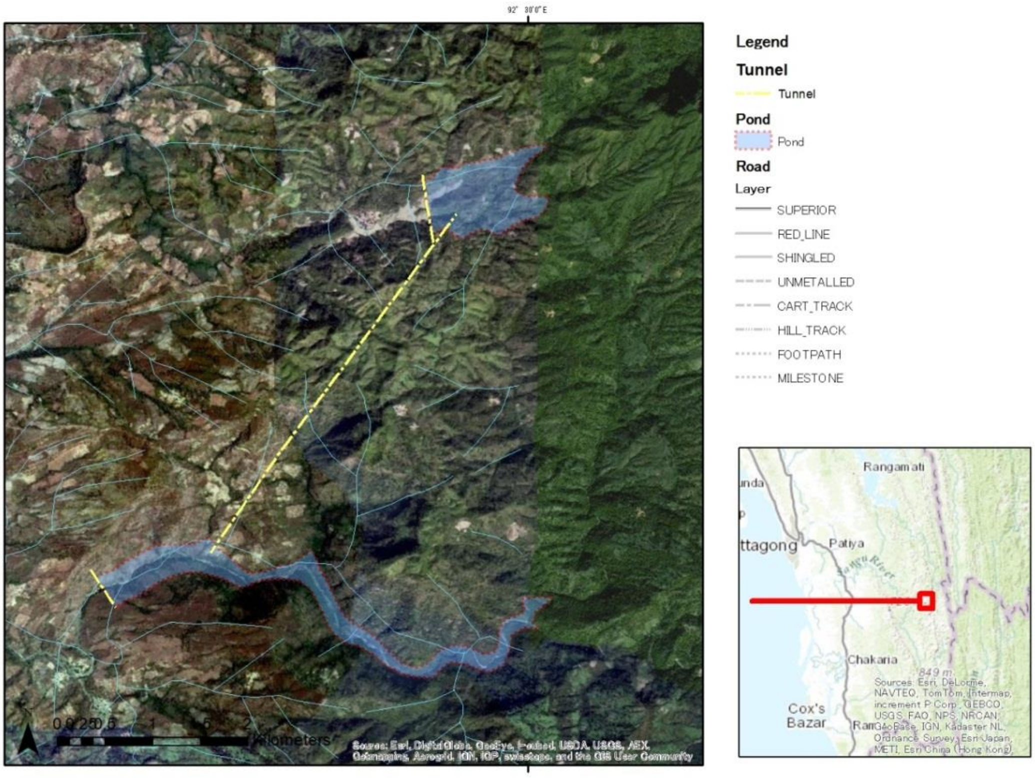


Figure 13-28 PSPP No.14

Table 13-23 Feature of PSPP No.14

Items	Value
Effective Head (m)	329
Designed Discharge (m^3/s)	176
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	530
LWL of Lower Reservoir (m)	160
Effective Reservoir Volume (m^3)	4,500,000
Length of Waterway (m)	4,280
L/H	12.2

(f) PSPP No.15

PSPP No.15 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond is 13.6 ha and Lower pond is 105.5 ha. Five houses can be seen on the image. Forest coverage is around 50%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (T*rachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.

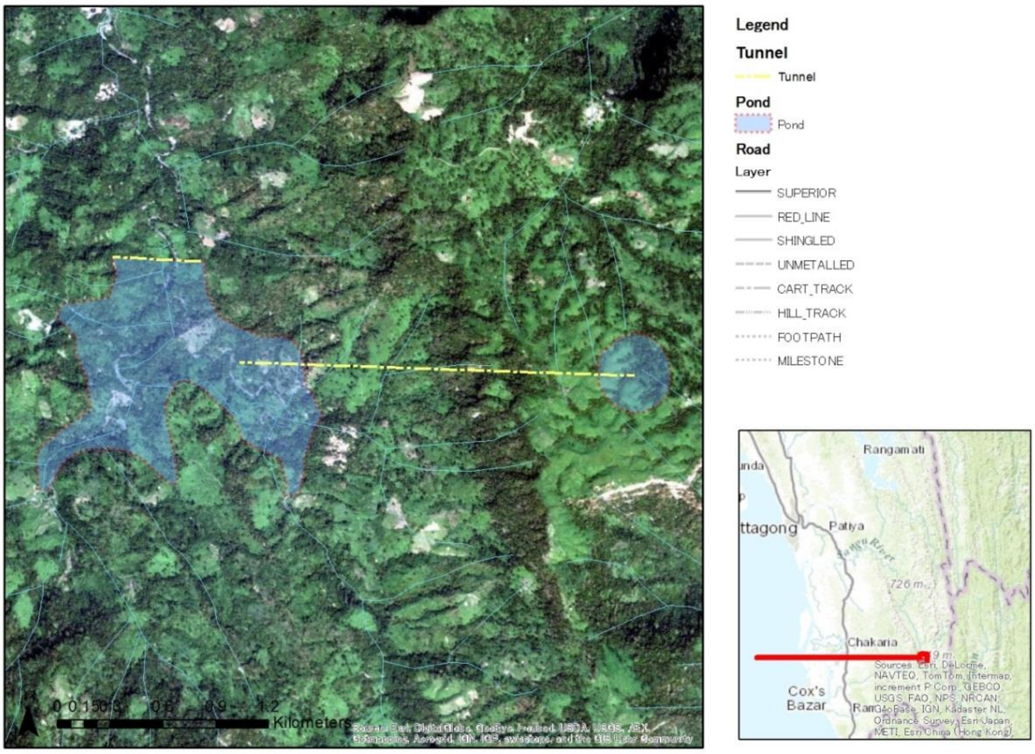


Figure 13-29 PSPP No.15

Table 13-24 Feature of PSPP No.15

Items	Value
Effective Head (m)	369
Designed Discharge (m^3/s)	157
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	540
LWL of Lower Reservoir (m)	127
Effective Reservoir Volume (m^3)	4,000,000
Length of Waterway (m)	2,100
L/H	5.3

(g) PSPP No.16

PSPP No.16 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond area is 26.5 ha and Lower pond area is 51.1 ha. No house but some huts can be seen on the image. Forest coverage is around 40%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.

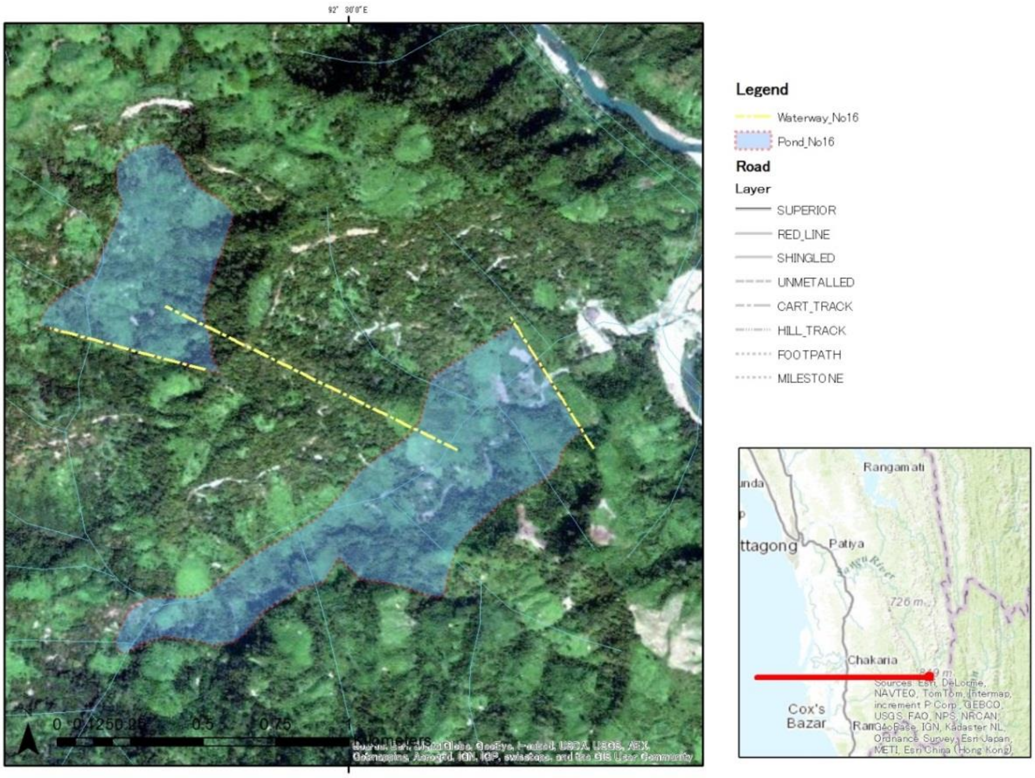


Figure 13-30 PSPP No.16

Table 13-25 Feature of PSPP No.16

Items	Value
Effective Head (m)	248
Designed Discharge (m^3/s)	234
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	395
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m^3)	5,900,000
Length of Waterway (m)	1,060
L/H	4.0

(h) PSPP No.17

PSPP No.17 is located in Remakri village, Thanchi sub-district, Bandarban district. Upper pond is 15.1 ha and Lower pond is 16.4 ha. No house and hut can be seen on the image. Forest coverage is around 30%. The project sites cover the distribution areas of Endangered mammals such as Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.

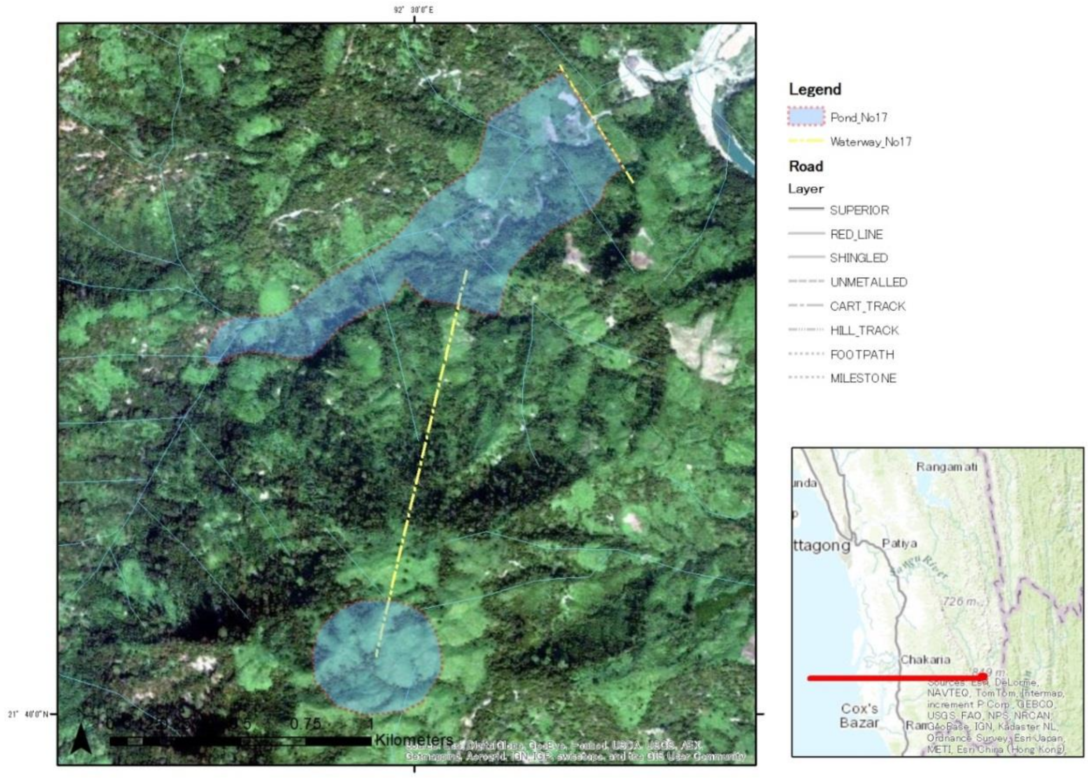


Figure 13-31 PSPP No.17

Table 13-26 Feature of PSPP No.17

Items	Value
Effective Head (m)	361
Designed Discharge (m^3/s)	161
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	520
LWL of Lower Reservoir (m)	116
Effective Reservoir Volume (m^3)	8,400,000
Length of Waterway (m)	1,520
L/H	4.0

(i) PSPP No.18

PSPP No.18 is located in Chokhyong village, Alikadam sub-district, Bandarban district. Upper pond is 18.3 ha and Lower pond is 153.6 ha. No house but small hut can be seen on the image. Forest coverage is around 80%. The part of the reservoir covers Forest reserve and all of the area is in the Sangu Matamuhari Key Biodiversity Area. The project sites cover the distribution areas of Endangered mammals such as Asian Elephant (*Elephas maximus*), Phayre's leaf monkey (*Trachypithecus phayrei*), and Western hoolock gibbon (*Hoolock hoolock*). Ethnic minority of Marma, Tripura, and Maro might be affected by the project.

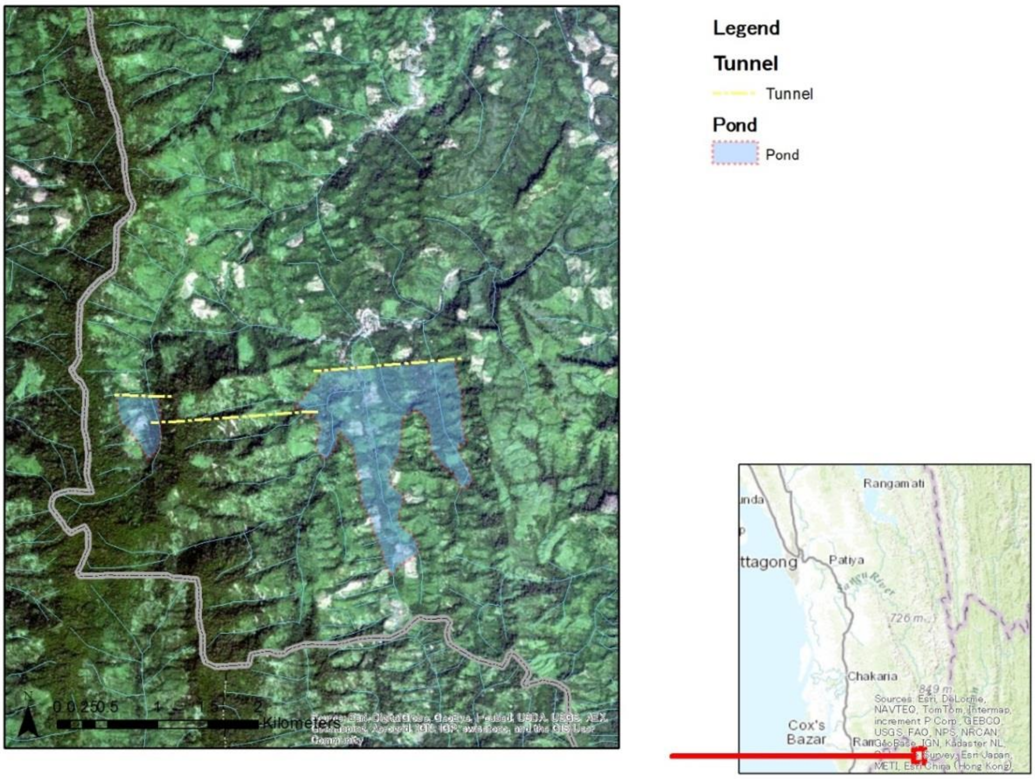


Figure 13-32 PSPP No.18

Table 13-27 Feature of PSPP No. 18

Items	Value
Effective Head (m)	249
Designed Discharge (m^3/s)	233
Installed Capacity (MW)	500
HWL of Upper Reservoir (m)	405
LWL of Lower Reservoir (m)	140
Effective Reservoir Volume (m^3)	5,900,000
Length of Waterway (m)	1,580
L/H	6.0

(2) Ordinary HP/SSHP Potential Sites

Environmental and social impact of eighteen potential SSHPs is briefly examined. Four of the project sites are located in the protected area. Most of the project sites are located in the distribution area of two or three endangered mammal species. One to five ethnic minority groups might be affected by each ordinary HP/SSHP project.

Table 13-28 Summary of Environmental Impact of SSHPs

SSHP	River	Governorate			Protected Area	No. of affected Endangered Mammals	No. of Ethnic minority groups
		District	Upazila	Union/Mouza			
J07	Banshkhali	Chittagong	Banshkhali	Silkup	Chunati Wildlife Sanctuary	2	0
J11	Bakkhali	Cox's Bazar	Ramu	Kaoarkhop		2	1
J12	Matamuhuri	Bandarban	Alikadam	Chokhyong	Forest reserve, KBA	2	3
J13	Matamuhuri	Bandarban	Alikadam	Chokhyong	Forest reserve, KBA	2	3
J14	Bakkhali	Cox's Bazar	Ramu	Kaoarkhop		2	1
J17	Matamuhuri	Bandarban	Alikadam	Alikadam		2	3
J23	Matamuhuri	Bandarban	Alikadam	Alikadam		2	3
J31	Matamuhuri	Bandarban	Lama	Rupshipara		2	2
J33	Sangu	Bandarban	Bandarban	Bandarban		2	2
J34	Sangu	Bandarban	Rawangchhari	Rawangchhari		2	2
J39	Sangu	Bandarban	Ruma	Ruma		3	3
J42	Sangu	Bandarban	Thanchi	Thanchi		2	3
J45	Sangu	Bandarban	Thanchi	Remakri		2	3
J47	Sangu	Bandarban	Thanchi	Remakri	Forest reserve, KBA	3	3
J52	Sangu	Bandarban	Thanchi	Thanchi		2	3
J53	Sangu	Bandarban	Thanchi	Thanchi		3	3
J61	Sangu	Bandarban	Ruma	Ruma		3	3
J66	Sangu	Bandarban	Rawangchhari	Rawangchhari		3	2

During the site reconnaissance, the JICA Survey Team was able to visit the locations near the five potential sites among 18 sites.

The projects of J33, J39, 42 are planned to hold back water on the Sangu main river by dams. Since many local people are living along the Sangu river, even a small dam may causes large scale of resettlement.


Houses along the Sangu river


Houses along the Sangu river

The project of J61 and J66 are located on the tributary of Sangu River. However, J61 project has too small water flow in dry season in comparison with the planned discharge. As for J66 project is located at the center of the town of Rowanchhari so that it causes large number of resettlement.


Upstream of J66 site


Downstream of J61 site

13.8 Summary of Hydropower Potential Study

13.8.1 PSPP Potential Sites

In general, preferable PSPP sites have smaller waterway length per gross head (L/H), less environmental and social impacts, shorter access road required and sufficient catchment area for lower reservoir as water source. And also, possibility of expansion of the scale is one of the advantages from viewpoints of economic efficiency in development.

Table 13-29 shows the comparison of PSPP potential sites based on the results of the literature survey and site reconnaissance. The JICA survey team selected PSPP No.17 as the best preferable potential site for the first PSPP project in Bangladesh, PSPP No.13 as the second potential site.

For realization of the projects, some difficulty exists during planning and designing stages. Maps available at this moment are only 1/50,000 maps with 100m contour lines. Those maps cannot be used even for conceptual design. And site reconnaissance and site survey is limited due to security reason in the Chittagong hilly area. In addition, during preparation stage for construction, implementing agency may encounter difficulty in acquisition and compensation of land due to local sentiment against hydropower development.

In this regard, the JICA Survey Team has a concern that immediate project implementation of the PSPP projects in Chittagong hilly area may be difficult.

13.8.2 Ordinary HP/SSHP Potential Sites

The JICA Survey Team was able to visit limited number of ordinary HPs during the site reconnaissance. However, the JICA Survey Team assumes that most of the potential sites along the Sangu main river may cause large scale of resettlement due to relatively gentle slope of the river. Though there are some prospective sites in terms of technical and economic viability, those sites may not suitable sites for development in consideration of environmental and social impact aspects.

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

In this regard, those potential sites seem that they are not attractive for development of hydropower projects particularly for Japan’s Yen Loan Projects.

Table 13-29 Comparison of PSPP Potential Sites

Site No.		No.6	No. 10	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18
Upper Reservoir	Type	Artificial Pond	Artificial Pond	Artificial Pond	Artificial Pond	Ordinary	Artificial Pond	Ordinary	Artificial Pond	Ordenary
	Dam Height							80		80
	HWL	230	360	340	480	530	540	395	520	405
	NWL	220	350	330	470	520	530	390	510	395
	LWL	190	320	300	440	500	500	365	480	375
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Lower Reservoir	Type									
	Dam Height	–	70	80	70	70	60	70	70	70
	HWL	33	173	152	160	190	157	146	146	170
	NWL	33	153	132	120	170	137	126	126	130
	LWL	33	143	122	130	160	127	116	116	140
	Net Volume	8,400,000	9,400,000	7,500,000	4,500,000	4,500,000	4,000,000	5,900,000	4,100,000	5,900,000
Waterway	Length (L)	1640	2990	1330	1890	4280	2100	1060	1520	1580
	Diameter	8.4	8.2	8.1	6.1	6.1	5.8	7.0	5.8	7.0
	Length X Diameter	13,724	24,378	10,816	11,561	26,180	12,122	7,466	8,876	11,107
Gross Head	(H)	187.0	197.0	198.0	350.0	350.0	393.0	264.0	384.0	265.0
L/H		**8.8**	**15.2**	**6.7**	**5.4**	**12.2**	**5.3**	**4.0**	**4.0**	**6.0**
Net Head		175.8	185.2	186.1	329.0	329.0	369.4	248.2	361.0	249.1
Discharge		330	313	312	176	176	157	234	161	233
Installed Capacity	(Efficiency=88%)	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
Social Aspects	Resettlement	Several HH Local Sentimental	None	None	None	None	Several Ten HH	None	None	None
Natural Environmental Aspects	Pretected Area	–	–	–	–	–	–	–	–	Shangu-Matamuhuri Wildlife
Access to the Site		52km	24km	18km	30km	29km	15km	21km	21km	
Others		–	–	Too small CA	Expansion Possibility	–	–	No Expansion	Expansion Possibility	Small CA
Comprehensive Evaluation		E	E	D	B	E	D	C	A	E

*CA: Catchment Area

[ ] Evaluation Items

13.9 Recommendations for the Next Steps

13.9.1 Possibility of Project Implementation as an Yen Loan Project

The JICA Survey Team assumes that development of some potential sites of PSPP and ordinary HP listed above may be physically possible. However, it is also anticipated that some limitation may make the project implementation difficult during the next stages. Though maps are important for planning and designing stages, the currently available maps are only 1/50,000 maps with 100m contour lines. Those maps cannot be used even for conceptual design. And not only site reconnaissance but also site investigation will be limited due to security reason in the Chittagong hilly area for the moment.

In addition, in consideration of local sentiment against hydropower development in Chittagong hilly area, there is a risk that it may be difficult to obtain local consent about development of PSPPs and ordinary HPs in the area for the moment. Implementing agency may encounter the difficulty on acquisition of land for the projects.

In this regard, the JICA Survey Team has a concern that immediate implementation of hydropower projects in Chittagong hilly area may be difficult. Thus, Hydropower projects are not necessary to be listed in the reviewed PSMP2010.

13.9.2 Reference TOR for the future Projects

If the difficulty such as peace and order issues and local sentiment against hydropower development is improved, the PSPP potential sites of PSPP No. 17 and No. 13 would become possible to be implemented at the scale of 500MW to 1,000MW.

As a next step of the project implementation, a feasibility study will be conducted. For reference, the general items of Terms of Reference (TOR) for the feasibility study for PSPP projects are shown in Table 13-30 and Table 13-31.

Table 13-30 TOR for Feasibility Study on PSPP Project (1)

Task 1. Background and Necessity of Pumped Storage Power Plants
- 1-1 Overview of the power development policy in Bangladesh
  - ・To confirm development policy of power facilities
  - ・To confirm position of PSPP in the above policy
- 1-2 Overview of power demand and supply balance, power development plan
  - ・To grasp power demand growth and situation of development of power facilities
  - ・To grasp power demand forecast and development plan of power facilities
- 1-3 Confirmation of the progress of power sector reform
  - ・To confirm action plan of establishment of Balancing Market
- 1-4 Overview of power market

Task 2. Necessity of PSPP projects
- 2-1 Evaluation of necessity and justification of introduction of PSPP projects
  - ・To examine requirements of kW and kWh (peak duration hours) from the power system
  - ・To simulate demand supply balance considering wind power development (capacity and operational status)
- 2-2 Examination of applicability of Adjustable Speed (AS)-PSPP
- 2-3 Validity of JICA’s assistance
- 2-4 Optimization of development schedule and transmission connection plan
  - ・To optimize development schedule
  - ・To build transmission connection plan

Table 13-31 TOR for Feasibility Study on PSPP Project (2)

Task 3. Basic design
- 3-1 Hydrological, topographical and geological survey
  - To make plan and execute investigations based on the conceptual design
  - To carry out topographic survey, borehole drilling, reconnaissance, seismic prospecting, sonic prospecting, laboratory tests
  - To install gauging station and measure hydrological and meteorological data
- 3-2 Comparative study on alternatives
  - To select location of the upper and lower ponds
  - To select types of dams and ponds
  - To determine location of powerhouse site and waterway route
  - To review the optimal development scale
- 3-3 Basic design of civil structure and steel structure
  - To execute basic design of civil structure and steel structures
  - To execute basic design of waterway and underground powerhouse
- 3-4 Basic design of electro-mechanical equipment
  - To design pump-turbines and motor-generators, including AS system
  - To review facilities of switch yard based on transmitting plan such as composition of GSI, layout, yard area
  - To review design of main circuit of low voltage, cable, GIS and earthing
- 3-5 Basic design of transmission lines
  - To conduct system analysis
  - To design of transmission method and monitoring control method
- 3-6 Evaluation on the possible application of new technologies

Task 4. Overall Project Implementation Plan
- 4-1 Construction planning
- 4-2 Consulting services
- 4-3 Procurement method and package
- 4-4 Implementation plan
- 4-5 Cost estimation

Task 5. Environmental and Social Considerations
- 5-1 Related law, system and organization
- 5-2 Scoping
- 5-3 Environmental and Social Survey
- 5-4 Support for holding public consultation
- 5-5 Preparation of EIA report
- 5-6 Preparation of Abbreviated Resettlement Plan
- 5-7 Preparation of environment management plan and monitoring plan
- 5-8 Technical support and advice to Implementing Agency

Task 6. Project Implementation Structure and Operation and Maintenance Structure
- 6-1 Project Implementation Structure
- 6-2 Operation and Maintenance Structure
- 6-3 Considerations regarding Project Implementation and Operation & Maintenance

Task 7. Evaluation of the Project
- 7-1 Economic and Financial Analysis
- 7-2 Risk Analysis
- 7-3 Index of Operation Efficiency
- 7-4 Necessity of Technical Support

Task 8. Technical Transfer

Chapter 14 Renewable Energy Supply

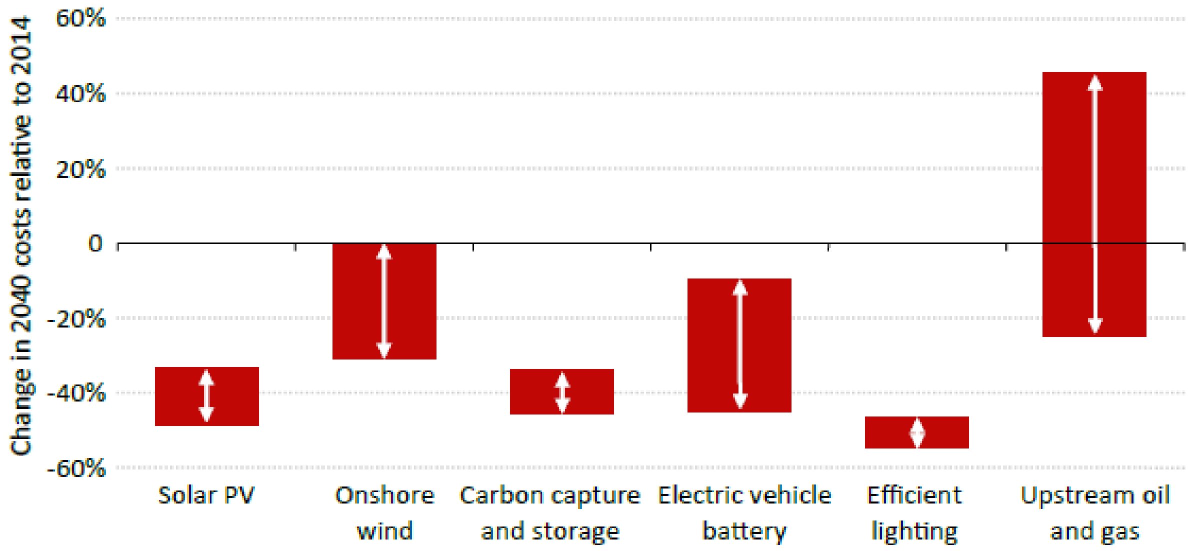
14.1 Environments around Renewable Energy[34]

World Trend

As described in "Bangladesh Policies on Energy and Power" Chapter, the international community has committed to achieve "Affordable and clean energy - ensure access to affordable, reliable, sustainable and modern energy for all" by 2030. In addition, population and economic growth will lead to the 30% more energy consumption in the world (out of this, India will take one fourth of this additional energy consumption. This energy consumption estimate already includes population decrease in high-income countries and energy consumption decrease by energy efficiency improvement).

These circumstances have promoted the importance of renewable energy technologies ever before, as the solution to materialize economic growth, energy access improvement and the reduction of greenhouse gas emission altogether. IEA estimates that the share of "modern renewable energy" (excluding traditional solid biomass) in the world total energy demand will increase from 14% in 2014 to 19% in 2040 (in 2040, world renewable energy will take up one third out of total electricity generation, one six of thermal source, and 8% out of total fuel for the transport sector).

The cost reduction of renewable energy technologies, and the cost increase of the conventional oil and gas development and production also contributes to the dissemination of renewable energy. While the renewable energy cost reduction and technology dissemination remain uncertain, the remaining oil and gas development diggings will face more technical challenges and therefore P&D cost for gas and oil will increase with certainty.



Source: IEA World Energy Outlook 2015, Figure 1.3

Figure 14-1 Evolution of energy technology costs per unit in the New Policies Scenario, 2014-2040

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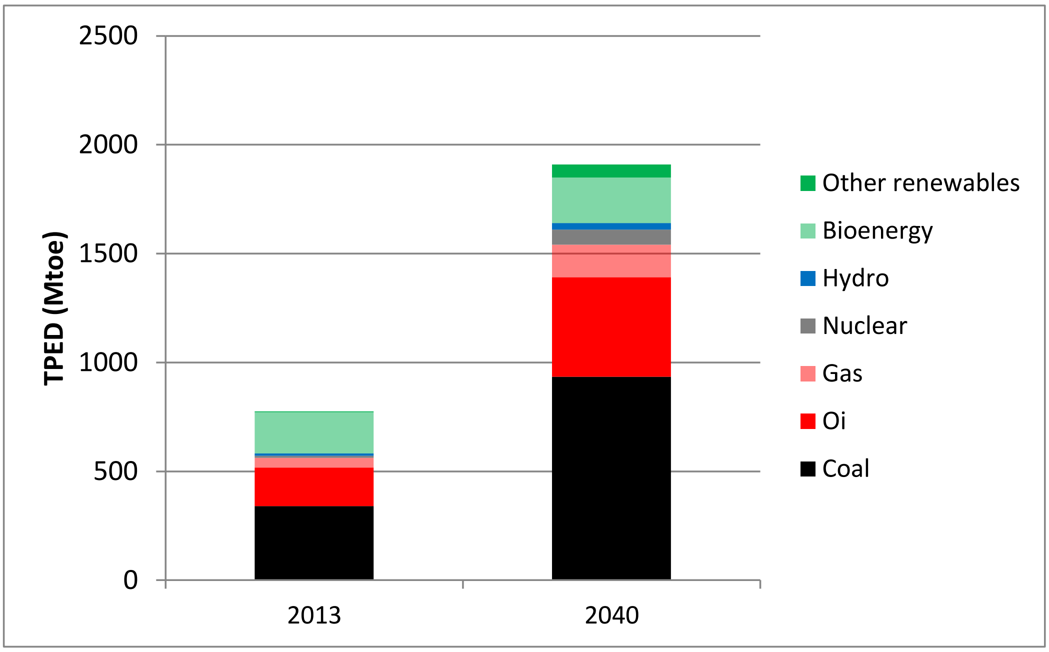
[34] IEA, World Energy Outlook, 2015、 and IEA Mid-Term Market Report Renewable Energy 2015. In this Report, the word "renewable energy", if without specific note, includes hydro power (regardless of the size), wind, geothermal, solar PV, solar thermal, and tidal power, and solid biomass such as firewood or cow dung.

Renewable Energy in India

India's energy demand has sharply increase and has become double since 2000. Especially the household energy demand has shifted from traditional solid biomass to natural gas or LPG, and the dependency on fossil fuel has deepened.

As of 2013, more than 40% of India's total primary energy demand (TPED) comes from coal, while it was 30% in 2000. Thus the dependency on coal has expanded. It is projected that the 50% of the India's TPES will come from coal in 2040.



Source: JICA PSMP2016 Survey team, based on the IEA World Energy Outlook 2015, Annexes India: New Policy Scenario

Figure 14-2 India's TPED Breakdown, 2013 (actual) and 2040 (projection)

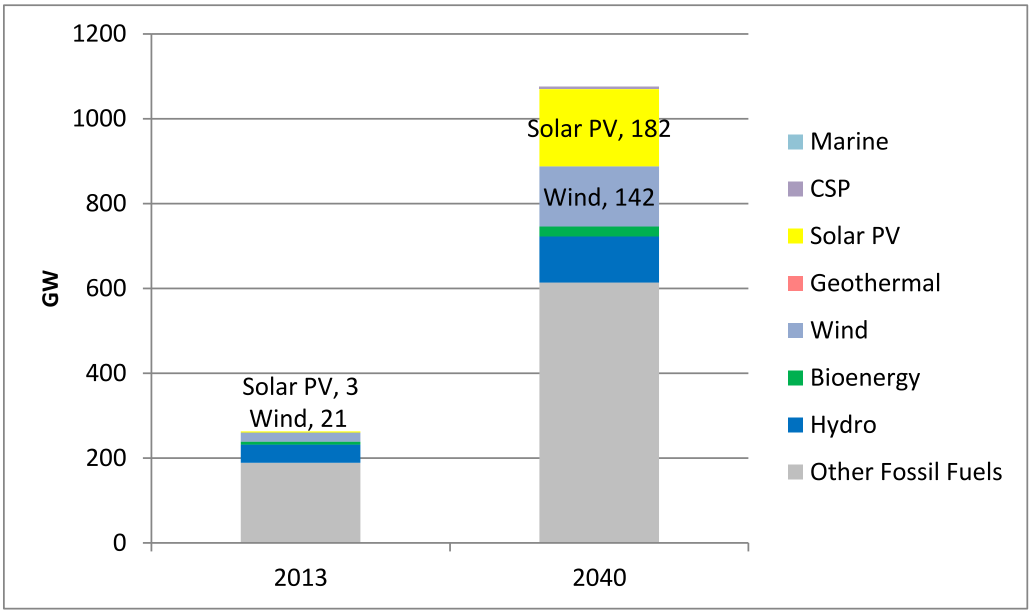
At the same time, India intends to strengthen its stable energy supply and energy security by actively enlarging renewable energy. In power generation, India plans to develop renewable energy power generations about half of the newly added capacity (MW) by 2040 (see Figure 14-2).

Especially the solar PV generation is considered as the center of the renewable energy deployment in India, where India assumes 3% of its lands are wasteland in each state and can be utilized for utility-scale solar, totaling 750GW. India has launched its national plan, Jawaharlal Nehru National Solar Mission Phase 1 since 2010, and plans to deploy 100GW by 2022 (however, IEA assumes that 44GW is the realistic target by 2022, considering many impediments such as finance, solar power purchase by electric companies, land acquisition and transmission line capacity limit[35]).

India's solar PV flagship project is located in Gujarat. Gujarat state administration stipulated the solar PV deployment policy in 2009. This policy includes "exemptions for electricity duties, streamlined the land acquisition process, guaranteed evacuation of power by the Gujarat Energy Transmission Corporation, ensured that no cross-subsidy charges were levied for access within the state and guaranteed tariffs for 25 years. The 500 MW Charanka solar park in Patan – one of the largest in the world –is a notable outcome[36]".

[35] Source needs to be identified, most likely IEA
[36] IEA (2015) ibid. p.535, Box 13.4

The Charanka solar park is participated by many solar PV generation companies, and ADB supported the initial feasibility study in 2004.



Source: IEA World Energy Outlook 2015, Annexes India: New Policy Scenario を元に JICA 調査団まとめ

Figure 14-3 India's Power Generation Development (GW)

14.2 Government Policy for Renewable Energy

Government Policy and Definition

For Bangladesh, renewable energy deployment has been important to diversify energy source, and to complement on-grid rural electrification. In addition, as a low-lying land country and surrounded by the three great rivers, Bangladesh is one of the most vulnerable countries to the sea level raise. Hence renewable energy deployment is critical as climate change mitigation for Bangladesh.

MPEMR established Renewable Energy Policy in 2008, and defined its goal as renewable energy share 5% of the total installed capacity (MW) by 2015, and 10% by 2020. According to SREDA website, the Bangladesh's total installed capacity is projected to be 13,000MW in 2015 and the renewable energy capacity 650MW by then.

Bangladesh's renewable energy target is defined as follows:

By 2015, 5% out of total generation capacity:

$$\frac{Installed\ renewable\ energy\ capacity\ (MW)\ at\ 2015}{Installed\ all\ generation\ capacity\ (MW)\ at\ 2015} \geq 5\%$$

By 2020, 10% out of total generation capacity:

$$\frac{Installed\ renewable\ energy\ capacity\ (MW)\ at\ 2020}{Installed\ all\ generation\ capacity\ (MW)\ at\ 2020} \geq 10\%$$

PSMP2016 projects the total installed generation capacity to be about 13,000MW in 2020, and the total government plan for additional renewable energy generation deployment to be 2,753MW (cumulative capacity: 3,185MW). This means that if the government actually implements the renewable energy generation as it plans, the policy target (10% renewable in 2020) would be achieved.

Renewable Energy Promotion Policy and Regulation

In Bangladesh, renewable energy deployment has been heavily concentrated on micro-scale off-grid SHS, except for the Kaptai Hydropower plant. However, Bangladesh is planning to deploy utility-scale (mega) solar power and wind power, accompanied with promotion policy and regulation. The current status and policy is well documented in SREDA's "Scaling Up Renewable Energy in Low Income Countries (SREP), Investment Plan for Bangladesh (October 2015)", supported by World Bank.

According to this SREDA document, utility-scale solar and wind projects will have following model and power purchase pricing mechanism:

Table 14-1 RE Project Models and Power Purchase Pricing Mechanism Plan

No.	Development Pattern (Project + Land Ownership)	Power Purchase Pricing Mechanism
1	Government Investment on Public Land	N/A
2	Private Investment (IPP) on Public Land	Auction
3	Private Investment (IPP) on Private Land	Fixed tariff for 20 years to cover levelized cost (through negotiation)

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

It should be noted that the FIT (feed-in-tariff), currently drafted by BERC, would be considered for those utility-scale renewable generations, but mainly for small generation or micro-grid generation. This is based on the recognition that, even though Bangladesh has decent track record for renewable deployment, it is heavily SHS-focused and not grid-connected utility-scale generations, and it would be difficult for Bangladesh to set a "proper" pricing for power purchasing from utility-scale renewable generations in the early stage.

Moreover, it is also recognized that the absence of transparent competitive bidding process has hindered the private investment for utility-scale renewable generation. Therefore, IPP's participation and pricing through transparent process is the most prioritized action for utility-scale renewable generation deployment.

On the other hand, Bangladesh has also regulation on land usage for utility-scale solar PV. As discussed in detail later in this Chapter, utility-scale solar PV requires a vast area land. The government stipulates the policy prohibiting private projects from using agriculture or cultivable land for a utility-scale solar PV project. According to the SREDA document mentioned above, utility-scale solar PV potential becomes only 1400MW with this land-usage regulation, while 19,000MW would be possible without such regulation. However, it is appropriate for the government to take up this regulation, considering the food security for the increasing population, as well as the potential of agri-business in the future economic growth discussed in the 0.

Other incentives to be provided for renewable energy projects are listed below. Most of them are financial/accounting incentives:

- Fiscal Incentives for project investors and operators.
- Import Duty Exemption (Full/ Partial) for certain technology and equipment.
- Duty exemption for 16 items of solar panel [SRO No. 100- Law/2000/1832/Duty, Date-18/04/ 2000].
- Plants & equipments [full value] & spare parts [10% of original plant cost] without payment of customs duties, VAT & any other surcharges.

- Exemption from corporate income tax for 10 years.
- Tax exemption & repatriation facilities on royalties & technical assistance fees.
- Repatriation of equity along with dividends.
- Avoidance of double-taxation on the basis of bilateral agreements.
- Implementation Agreement [IA] & PPA ensure fair and reasonable risk allocation and payment by the purchaser is guaranteed by the GoB.
- Special Act for processing project proposals.

14.3 Organization for Renewable Energy Deployment

Governmental organizations for renewable energy promotion are, mainly SREDA, IDCOL, BREB and BPDB, which are implementing solar PV projects. The details of these organizations are described in “Energy and Power Sector Overview” Chapter.

“Partner Organizations” or POs, are non-governmental organizations working under IDCOL program. They are actually setting up renewable energy generation facilities in rural villages. Major POs are: Grameen Shakti、Rural Services Foundation (RSF), and BRAC. These three NGOs have developed more than 70% of SHS and biogas projects. These POs have been active in micro credit activities, and accumulated know-hows for door-to-door loan collection and installment management. The know-hows help for the world-fastest SHS roll-out and also technical guidance for rural areas. Rural household can afford Taka 13,000~35,000 SHS for three years repayment (36 installment) (more precisely, in general 5% of the installment cost is met by grant from development partners, and end-user bares 40% as the down payment, and repay the rest as installment).

In addition to the POs, many local private companies have gone for the SHS market, such as Rahimafrooz, Siemens Bangladesh, ARMCO, Micro-Electronics and FirstBangladesh Solar.

14.4 Renewable Energy Potential in Bangladesh

14.4.1 Overview

In the SREDA’s document mentioned above, Bangladesh’s renewable energy potential is also documented. It is estimated that the renewable energy potential in Bangladesh has approximately 3,700MW at maximum (in energy-wise 7,000GWh per year) to be added.

Table 14-2 Renewable Energy Potential in Bangladesh

Technology	Resource	Capacity (MW)	Annual Generation (GWh)
Solar Park	Solar	1400*	2,000
Solar Rooftop	Solar	635	860
Solar Home Systems (SHS)	Solar	100	115
Soar Irrigation	Solar	545	735
Wind Park	Wind	637**	1250
Biomass	Rice Husk	275	1800
Biogas	Animal Waste	10	40
Municipal Waste	Municipal Waste	1	6
Mini Hydro	Hydropower	60	200
Mini Grid, Micro Grid	Hybrid	3***	4
Total		3,666	7,010

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

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

14.4.2 Solar

Bangladesh has in average 4-11 hours sunshine throughout year except rainy season from June to August. It indicates that Bangladesh has a good potential for solar PV.

Table 14-3 Average Sunshine Hour

Division	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
Barisal	6.7	7.9	8	7.5	7.3	3.6	4.8	3.4	4.2	6.9	7.7	5.6	6.2
Chittagong	6.2	7.8	8.2	7.6	6.9	3.9	5.5	3.8	4.9	6.8	8.5	5.9	6.4
Dhaka	4.9	7.5	7	6.8	5.5	3.5	4.1	2.5	5.1	6.1	6	4.4	5.3
Khulna	6.8	8.2	8.2	7.7	7.1	4	5.1	3.3	4.3	7.3	7.6	5.1	6.3
Rajchahi	5.6	7.3	8.6	7.6	7	5.1	5	3.8	5.8	7.5	7.1	4.8	6.3
Sylhet	5.9	7.9	6.8	7.4	5.1	3.8	3.8	4.5	5.7	8.2	7.8	7.1	6.2

Source: Bangladesh Meteorological Department Climate Division

However, Bangladesh has also a great battlement to deploy large-scale solar PV, which is land availability. Solar PV technology has low energy-intensity and requires large area land. For SHS, the land availability did not matter. On the other hand, 30MW solar generation for example requires approximately 60ha. land. This means that the 30MW solar generation would require 200 farmers' farmland (an average Bangladesh small-scale farmer's farmland is 0.3ha[37]) .Bangladesh government has already stipulated a policy prohibiting farmland use for private solar projects, which limits the solar park potential to 1,400MW.

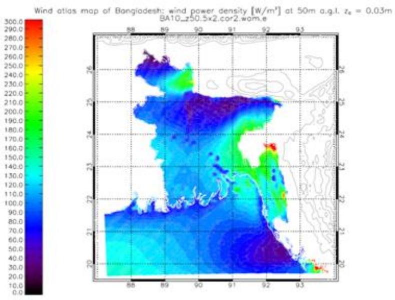
The SREDA document also estimates the solar rooftop potential (on-grid) and solar irrigation potential (off-grid), 634MW and 545MW respectively. Details of SHS can be referred in "Rural Electrification" Section of this Report.

[37] FOA の 2005 年の調査による。
http://www.fao.org/fileadmin/templates/ess/documents/meetings_and_workshops/APCAS23/documents_OCT10/APCAS-10-28_-Small_farmers.pdf

14.4.3 Wind

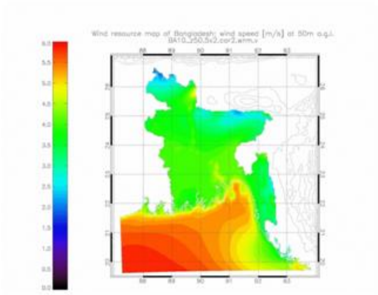
Even though Bangladesh quite often encounters cyclones, the development of wind power generation is yet limited (there are only two points, Muhuri Dam 900 kW and Kutubdia 1000 kW). The above mentioned SREDA document estimates the Bangladesh's wind potential as 624MW, with the consideration for flood-safe land availability.

Wind power potential was studied in the past; however, detail was not enough for investment opportunity identification. Currently USAID-supported Wind Resource Assessment is being conducted and will be completed in 2018.



Source: SREDA homepage

Figure 14-4 Wind Power Density

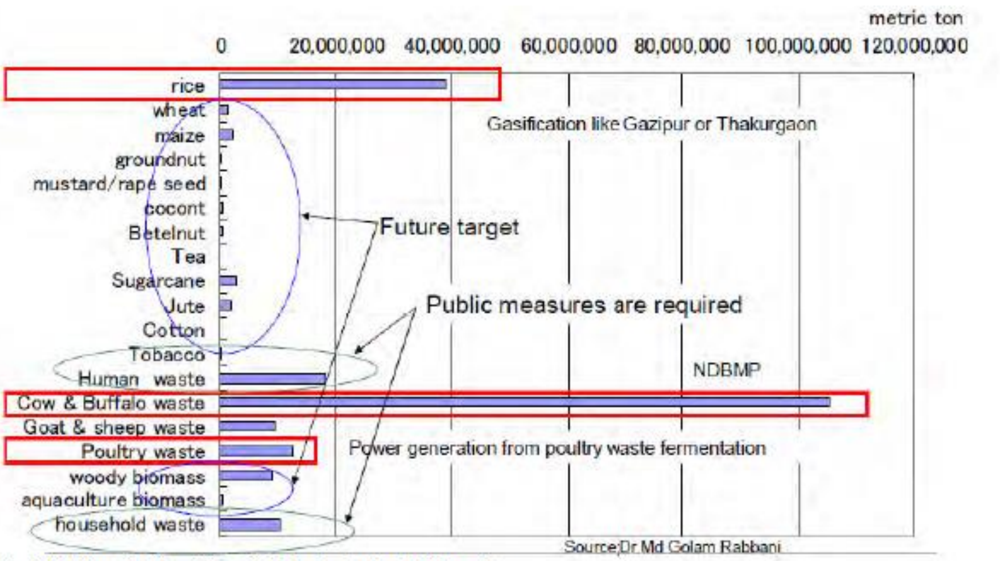


Source: SREDA homepage

Figure 14-5 Wind Speed

14.4.4 Biomass (for power generation)

Bangladesh biomass resource has characteristics of having rich animal waste from livestock industry, but little forest resource (e.g. firewood) available due to protection against deforestation. Among these, it has been pointed out that rice husk has good potential as biomass generation resource in terms of the production amount and resource availability throughout year (JICA past studies also pointed out the risk husk potential). IDCOL has two rice husk power plants in Gazipur and Thakurgaon.



Source: Dr Md Golam Rabbani, Bangladesh Agricultural University

Note: The original metric volume data of biomass are as of following time; 1) rice in 2009,2) cow and buffalo in 2005,3) human census in 2001, 4) forests and wood processing in 2003, 5) aquaculture in 2008 ,and 6) municipal and solid waste in 2008.

Source: JICA Preparatory survey on renewable energy development project, Final Report (November, 2012)

Figure 14-6 Biomass Energy Potential in Bangladesh and IDCOL's Program and Projects

The SREDA-World Bank document estimates the biomass power generation potential as 274MW. In addition, out of biogas potential to be discussed in detail later, biogas power generation potential is quite limited only to 9.4MW (i.e. 1,131MWh/day) . JICA Biogas survey, to be discussed in the next section, has even less estimate 73MWh/day.

14.4.5 Biogas

In this subsection, the potential and importance of biogas as a cooking fuel is discussed based on JICA supported study “Biogas Generation and Demand Survey in Bangladesh (March, 2015)”. Especially in the context of SDG Goal 7 “Affordable and clean energy”, biogas in Bangladesh has great potential to serve as a cooking fuel in rural areas, though it has a limited impact to meet the entire gas demand.

<<Definition and History>>
Biogas can be obtained through anaerobic fermentation of high-water containing organic waste, such as animal waste, food waste and sewage sludge. Biogas contains approximately 60% of methane, where natural gas contains almost 100% of methane. The appropriate range of air temperature for the anaerobic fermentation is between 25 degree to 45 degree Celsius, and Bangladesh fits to the atmospheric condition. In fact, Bangladesh started its biogas study in the late 1970s.

<<Positioning and Current Status>>
In the early stage of biogas deployment, the purpose of the biogas plant (digester) construction was to improve the living environment of livestock businesses and their surroundings, and biogas energy supply was just a “sub product”. From this point, the biogas project in Bangladesh should not be evaluated merely by the economic comparison with other energy alternatives. Currently, Bangladesh produces biogas 190,000 m3/day. The substantial roll-out of biogas digester has started since the late 1990s, and so far approximately 80,000 biogas digesters have been developed and more than 60,000 have been under operation (reasons why nearly 20,000 digesters suspend operation are such as difficulty to collect animal wastes, loss of animals due to illness, or manufactures unable to maintain damaged/broken digesters).

<<Biogas Plant Type and Sales Channel>>
Biogas digester types vary from a small and suitable for one household to a large and suitable for livestock business. A typical small size is to produce biogas 1.2m3/day from 3-4 cattle heads, and can be used for one cooking burner. The most popular biogas digester is 3.2m3/day type, capable to supply cooking fuel for 6-8 people. A Large size digester plant is as large as 1,000m3/day, developed within a daily farm. The plant is supplying cooking energy, as well as fuel for generating power (if the entire gas is used for power generation, the plant can generate 260kW). The produced gas and electrical power are being supplied to the owner’s house, as well as surrounding households. The proportion of gas and electrical power are determined by the local needs, and not fixed.

The 48 POs are selling biogas digesters nationwide. The produced biogas is currently being supplied only to the digester-adjacent households, and not connected to the grid mainly due to the impurities of the biogas. However, cylinder bottling is technically possible, and economically viable if the biogas digester has a production capacity more than 500m3/day. Cylindered biogas could be reached to remote areas.

<<Price and Plant Life>>
The price of the biogas plant construction ranges from 13,000 Taka, including a 1.2m3/day digester and civil work. For a rural household, this price is even expensive and the initial investment is one of the bottlenecks for biogas digester roll-out to be addressed. The most popular digester, 3.2m3/day production capacity, prices 36,000 Taka. Most of plant construction is subsidized by the government about 30% of its cost (13,500 Taka is subsidized the government for 3.2m3/day digester construction).

Many of the biogas digester currently marketed in Bangladesh have in fact poor quality and get cracks only after a few years of operation. However, the above-mentioned JICA Biogas survey shows that the biogas users (current and potential) expect 20-30 years of plant life.

<<Impact of Biogas Deployment>>
The above-mentioned JICA Biogas study suggests that Bangladesh has biogas potential at firm 1.2 million m3/day, six times more than the current 190,000 m3/day from some above 60,000 plants. This 1.2 million m3/day gas has as much energy as 25 mmcfd natural gas. This is derived from the below:

- According to the JICA Biogas survey, 65% of biogas is methane, and calorific value per m3 of biogas is estimated to be 5500 k cal., equivalent to 23.02740 MJ/m.
- Bangladesh natural gas has calorific value 39.59 MJ/m3, which means the biogas has 58.1% calorific value of the natural gas.
- According to the JICA Biogas survey, about 110,000 poultry and daily farms are positive to construct biogas digester if a decent subsidy is provided for plan construction, while 80,000 poultry farms and 70,000 daily farms exist in Bangladesh.
- From the 110,000 poultry and daily farms, approximately 1.2 million m3/day biogas could be produced.
- 1.2 million m3 biogas /day = 1.2 *0.581 million m3 natural gas / day = 1.2 * 0.581 * 35.3147 million cubic feet natural gas /day [38]= 24.61 mmcfd

This approximately 25 mmcfd "natural gas equivalent" seems small to the country's total demand to the natural gas, 2,500 mmcfd. However, the biogas directly from a digester contains impurities and grid connection is not appropriate without investment to purification facilities. Thus the biogas is suitable for off-grid cooking fuel for households. The Bangladesh's household demand for natural gas (mainly as cooking fuel) is estimated to be 290 mmcfd. In this sense, the biogas has potential to meet roughly 10% of the households' natural gas demand.

Moreover, it should be noted that only 8% of entire population in Bangladesh has access to the grid gas. The grid gas users are quite Dhaka-centric (out of 2.4 million contracts of grid gas in Bangladesh, 1.7 million or 70% of the national grid gas connections are in Dhaka area), and very few population have access to grid gas outside of Dhaka area. According to the BBS statistics in 2014, more than 94% of the rural population in Bangladesh uses traditional solid biomass for cooking[39]. If the solid biomass users can gain access to the biogas, its social impact is enormous.

One example of the social impact is the liberation from the respiratory diseases caused by the incomplete combustion of solid biomass. According to the World Health Organization (WHO), solid biomass incomplete combustion by using inefficient traditional cook stove produces toxic substances, so called "black carbons", such as mono dioxide and particle matters, and these substances cause respiratory diseases. WHO warns that 3 billion still need to depend on solid biomass, and 1.5 million die from the respiratory diseases caused by the indoor air pollution (and many of the victims are women and children, because they cook inside of the house or more exposed to the toxic substances for their low height) [40]. WHO claims that the indoor air pollution is the second major cause of illness in low income countries, next to the poor access to the safe water and incomplete sanitary environment. Bangladesh Department of Environment estimates 30 million for the replacement need of indoor cooker in the rural areas in the next 5 years[41].

[38] The unit converter is referred in IEA website: https://www.iea.org/statistics/resources/unitconverter/
[39] Bangladesh Bureau of Statistics, "Statistical Pocket Book Bangladesh", 2014
[40] WHO, "Fuel for Life, Household Energy and Health", 2006
[41] Meeting with Department of Environment and Survey Team, April 2016.

In addition, using biogas improves combustion efficiency, reduces time to collect solid biomass and enable people to allocate more time for more value-added activities (such as supervising child study or side work). The JICA Biogas survey suggests that the biogas potential need is quite high in rural areas (this implies rural people perceive solid biomass very inconvenient) and if biogas is affordable, the potential demand for biogas could be 2.5 million m3/day, roughly equivalent to 500mmcfd natural gas. This is one quarter of the current household natural gas demand.

Furthermore, the JICA survey suggests the maximum potential of Bangladesh biogas production capacity could be 9 million m3/day, if utilizing municipal wastes as well. Out of this maximum potential, JICA Biogas survey proposes 3 million m3/day (equivalent to 63mmcsd natural gas, or 602ktoe/year) is technically feasible. The 3million m3/day biogas could meet the 10% of natural gas projected demand of the household sector in the 2030s (the 10 years average household sector's natural gas demand of 2030s is projected to be about 6,200ktoe/year). The earlier mentioned SREDA-World Bank document also estimates Bangladesh's biogas potential 3.4 million m3/day (or 950,000 biogas plant x 3.2m3/day).

<<Economic Comparison with LPG>>
Even though the biogas has much more potential than just "cooking fuel", economic analysis shows the affordability of biogas to the users and to the national coffer, especially compared with LPG.

- Suppose 110,000 poultry and daily farms construct biogas plants and produce 1.2million m3/day biogas. This means each plant capacity is about 11m3/day.
- Based on the current biogas plan construction cost 36,000 Taka for 3.2m3/day digester, 11m3/day digester construction cost could be 120,000 Taka. 110,000 plants construction would cost 110,000 * 120,000 = 13.2 billion Taka (JICA Biogas survey shows that many biogas experts perceive biogas plant cost 10,000 ~ 15,000 per 1m3/day to be appropriate).
- IDCOL's financial model for biogas program would be as follows, provided with development partner's grant:

  a) Subsidy: 40%
  b) Loan: 40%
  c) Down payment: 20%
  Total : 100%

- Here, a household bares the 60% of the total cost (loan and down payment), plus interest rate 5-8% (depending on PO's program). Hence the "macro" charge to the user would be at most 13.2 billion * 60% * 1.08 = 8.6 billion Taka. The charge to the national coffer is the subsidy part, financed mainly by the development partners, and would be 13.2 billion * 40% = 5.3 billion (interest rate from the develoment partners is negligible).

If the 1.2 million m3/day biogas equivalent (in terms of calorific value) LPG is purchased, the LPG cost would be 47.5 million Taka/day, from the below conversion chart.

LPG Price per Heat Value

Item	Value	Source
LPG Unit Cost for Sale	1050 Tk/cylinder (12kg)	JICA Survey Team. This is not an official price, but observed marketed price
LPG Unit Cost for kg	87.5 Tk/kg	From calculation
LPG Heat Value per kg	50.8 MJ/kg	JICA Consultant information to JICA, 2014
LPG Price per Heat Value	1.72 Tk/MJ	From calculation

Biogas Heat Value

Item	Value	Source
Biogas in Bangladesh Heat Value	5500 kcal/m3	JICA Survey team
Biogas in Bangladesh Heat Value in MJ	23.02740 MJ/m3	From calculation (1 kcal = 0.0041868 MJ)

The equivalent calorific value of LPG would cost: 1.72 Tk/MJ * 27,633 MJ/day = 47,528,554 Taka/day = 47.5 million Taka/day

8.6 billion Taka / 47.5 million Taka/day = 181 days.

Therefore, biogas plant construction would cost as same as the "half-year" LPG purchase cost.

If the biogas digester would be a higher spec model (i.e. glass fiber model), unlike the traditional ceramic model, the construction cost would be 50,000 Taka for the most popular 2.4m3/day capacity[42]. With this figure, the above analysis would be modified as follows:

- The 11m3/day production capacity digester would be 220,000 Taka, based on the 2.4m3/day digester price. The 110,000 plant construction cost would be 10,000 * 220,000 = 24.2 billion Taka.

- Here, a household bares the 24.2 billion * 60% * 1.08 = 15.7 billion Taka. The charge to the national coffer is the subsidy part, financed mainly by the development partners, and would be 24.2 billion * 40% = 9.7 billion.
- 15.7 billion Taka / 47.5 million Taka (for LPG) = 330.5 days

Therefore, higher model biogas plant construction would cost as same as the "one-year" LPG purchase cost.

It should be noted that the charge to the national coffer, 5.3 billion Taka (conventional ceramic digester) to 9.7 billion Taka (glass fiber digester), is much less than the subsidy to BPC which once reached 86 billion Taka in FY2012. Biogas plant does not only bring energy access, but also better hygiene and healthier environment to rural people. Biogas also is carbon neutral fuel, which is LPG is not.

<<Barriers to Biogas Deployment>>
Biogas deployment could bring much impacts, however, there are some barriers to address. The development partners are currently identifying the major barriers and countermeasures for biogas deployment, and the followings are the potential reasons[43]: 1) POs have less experience in handling

[42] According to the World Bank Dhaka Office.
[43] Based on the information provided by the World Bank Dhaka Office.

biogas digester than SHS, 2) Bangladesh society have negative perception to biogas digester from the past experiences (cracks after a few years usage, etc.), 3) few manufactures can properly maintain biogas plants. The IDCOL financial model may not have much room to improve.

By recognizing the poor quality issue of the conventional ceramic biogas digester, SREDA is currently negotiating with National Board of Revenue to exempt the duties on imported glass fiber digester materials, to promote glass fiber digester as the new generation one to roll out.

14.5 Gap Analysis between Planning and Potential

In this section, the difference between the existing plans provided by SREDA in April 2016, and the potential discussed in the previous section. The details of deployment plan (renewable generation) can be referred in the Appendix.

14.5.1 Photovoltaics (SHS, solar irrigation, mega solar)

IDCOL has 6 million PV installation plan. It is supposed the plan by IDCOL will be completed. Installation capacity of photovoltaics will be about 230MW, if 6 million PVs are installed.

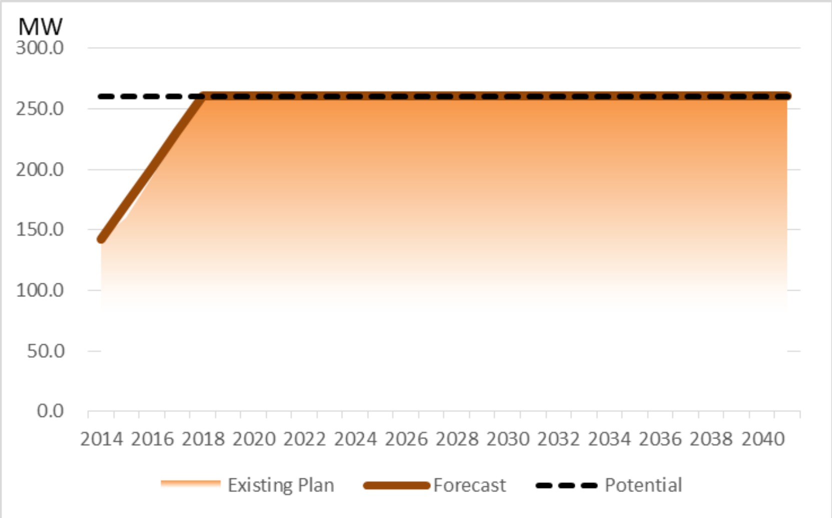


Figure 14-7 Expected installation capacity (Solar Home System)

Although solar irrigation pump has big potential, installation is small. It is supposed that power will be supplied to irrigation pump from the grid in the electrified area, and installation capacity will not reach the potential. Installation speed is assumed to the half of existing plan's speed.

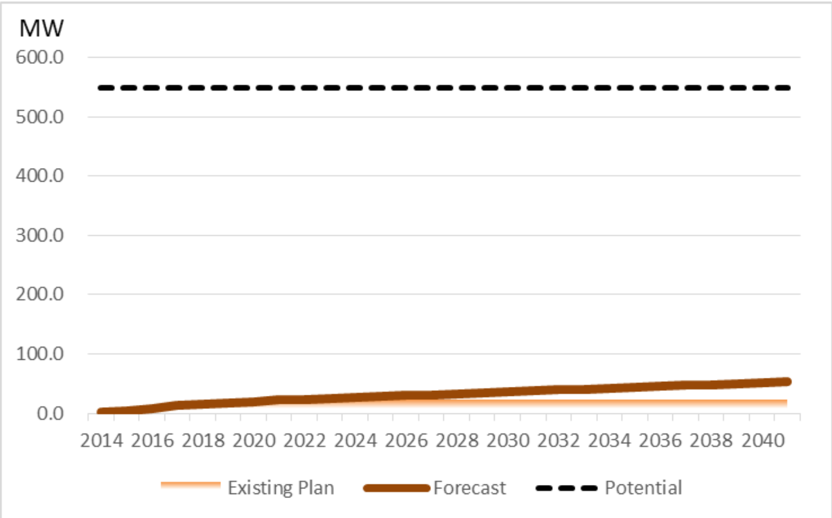


Figure 14-8 Expected installation capacity (Solar Irrigation)

Installation plan capacity of solar park, including mini-grid, exceeds the potential of no usage of agricultural land case. Therefore some agricultural land has to change to solar park land, or plan has to decrease. Expected installation capacity is estimated by the assumption of only existing plan capacity. Each plan requires the detail survey for realization. Future installation capacity will be changed by this survey.

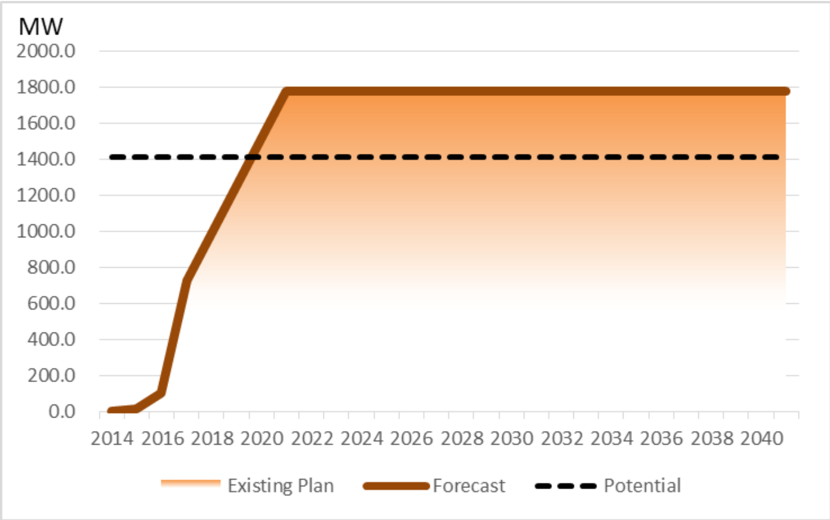


Figure 14-9 Expected installation capacity (Solar Park, Solar Mini Grid)

Installation capacity of solar rooftop is small now. Although it is supposed that big installation is not realized, if FIT will be adopted, installation capacity will be changed.

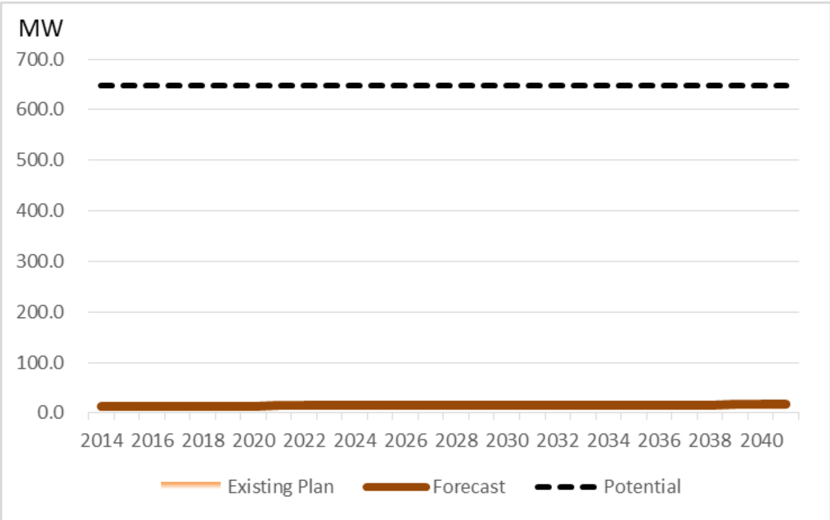


Figure 14-10 Expected installation capacity (Solar Rooftop)

14.5.2 Wind power

There are not enough plans of wind power to the potential. But it is supposed that wind power will be installed to the potential.

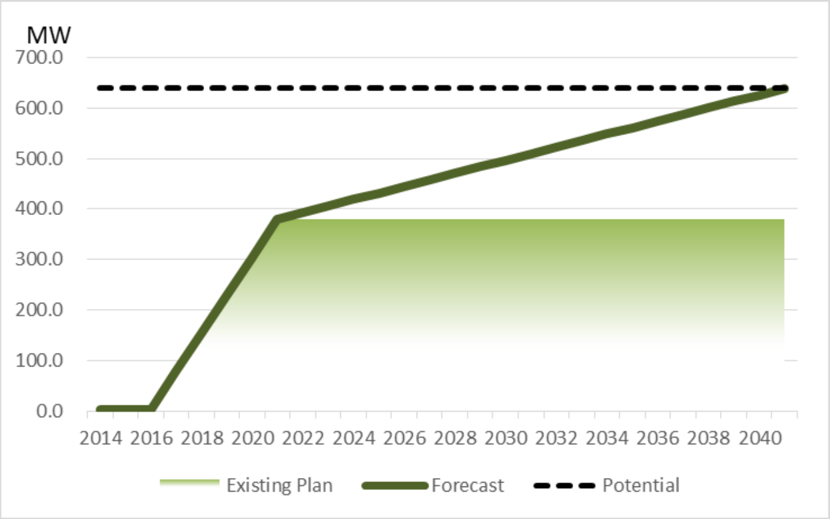


Figure 14-11 Expected installation capacity (Wind)

14.5.3 Biomass and Biogas

Installation capacity of Biomass and Biogas is small now.

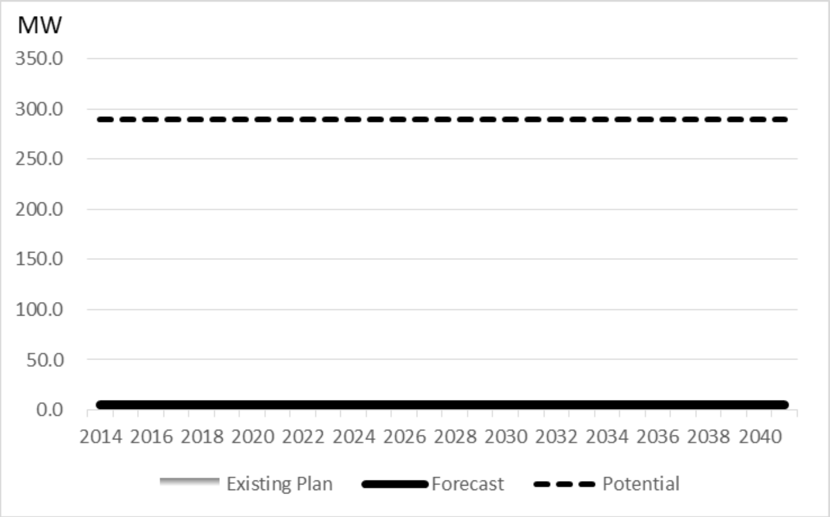


Figure 14-12 Expected installation capacity (Biomass and Biogas)

14.5.4 The others

Installation speed is assumed to be same as existing plan.

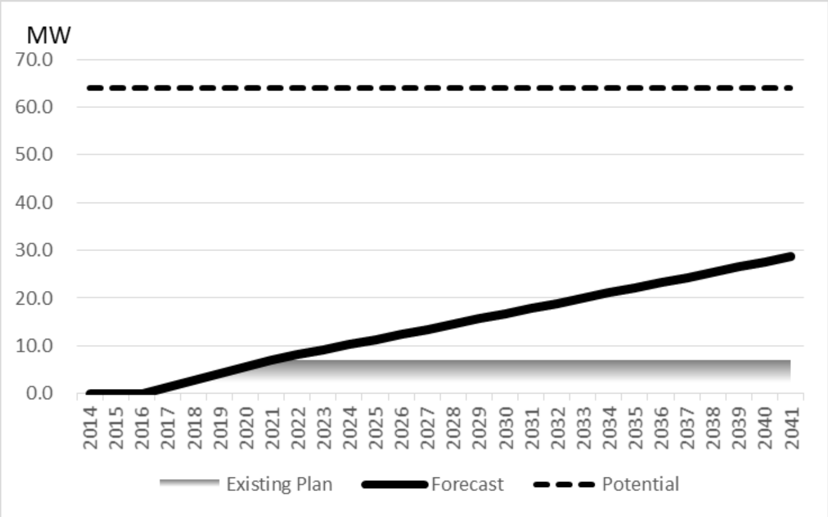


Figure 14-13 Expected installation capacity (Others)

14.5.5 Total Renewable energy development situation and future plan

Upper mentioned renewable energy plan and potential are summarized to the below figures. Capacity of photovoltaic will occupy 75% of all. Step by step photovoltaic installation is important to achieve this target. On the other hand, because installation capacity will be changed by detail survey for realization, it is important to conduct survey in an early stage.

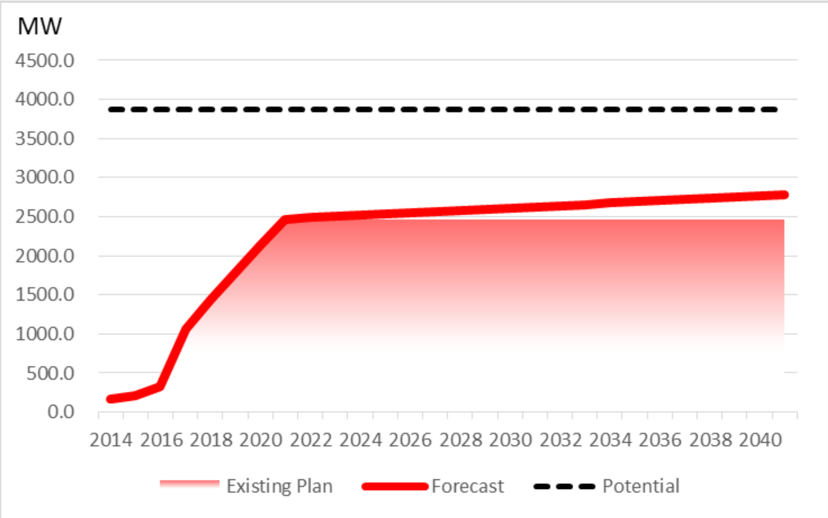


Figure 14-14 Expected installation capacity in Bangladesh

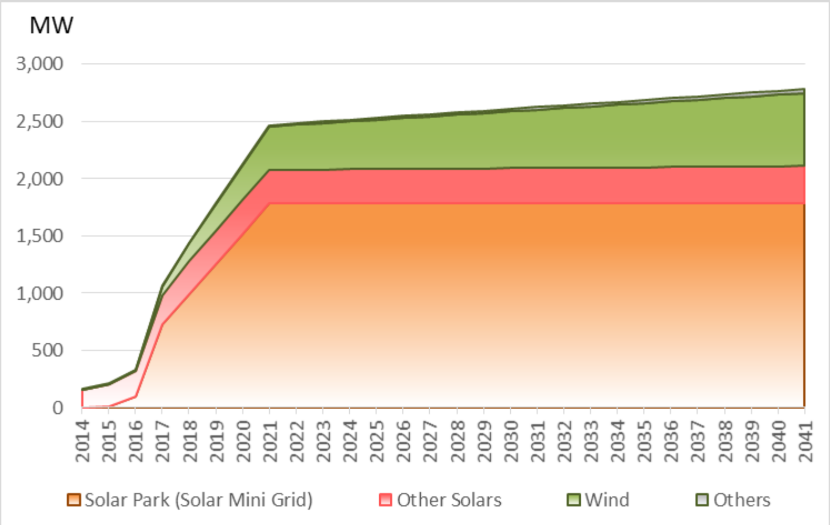


Figure 14-15 Breakdown of expected installation capacity in Bangladesh

On the other hand, the relationships between existing plan, target of SREDA and potential are shown in the below figure. Because target of wind exceeds its potential, target should be revised to the downward target. Because plans of solar park exceed the potential of no usage of agricultural land case, preparation of agricultural land conversion or downward revision of target are required.

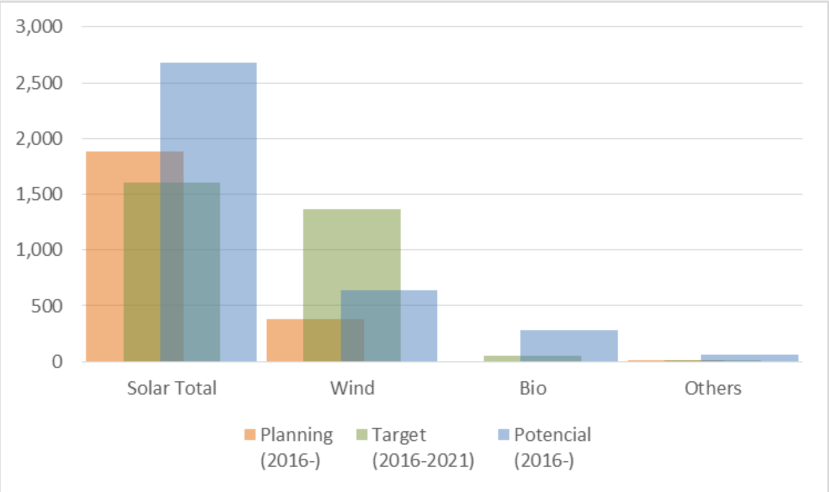


Figure 14-16 Relationships between existing plan, target of SREDA and potential

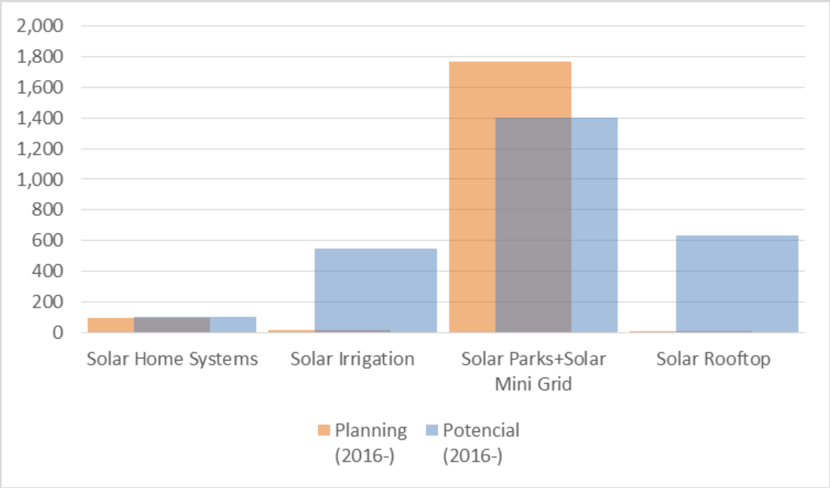


Figure 14-17 Relationships between existing plan and potential (Solar)

14.5.6 Biogas

Since 1996 to 2004, the Government took initiative to roll out 22,000 biogas digesters, in which NOGs such as Grameen Shakti and BRAC, and Local Government Engineering Department (LGED) played a central rolls for implementation. From 2005, Netherland (SNV) supported biogas digester.

As of today, there are in total 80,000 biogas digesters installed but only 62,400 digesters under operation and producing 190,000 m3/day biogas. The reasons of roughly 20,000 digesters not operating are multifold; insufficient (collected) row materials (animal waste), loss of cattle due to illness, or insufficient maintenance for broken digester.

As discussed in the previous section, JICA Biogas study and SREDA-World Bank document estimate the Bangladesh's biogas potential 3 to 3.4 million m3/day by 2041. JICA Survey Team suppose this potential is attainable based on the following assumptions:

- Mid-term target is the additional 0.6 million m3/day in the mid 2020s (accumulated total 0.8 million m3/day).
- By 2025, if the 55,000 farms, the half of the previously discussed 110,000 farms with willingness to introduce biogas digester, introduce digesters, the additional biogas production can reach 0.6 m3/day.
- The 550,000 digesters between 2021 to 2025 can be constructed, if 1-2 day digesters are set up in each Upazila (there are in total 64 Upazilas in Bangladesh). If a glass-fiber digester is domestically manufactured, this takes only 1-2 day to setup.

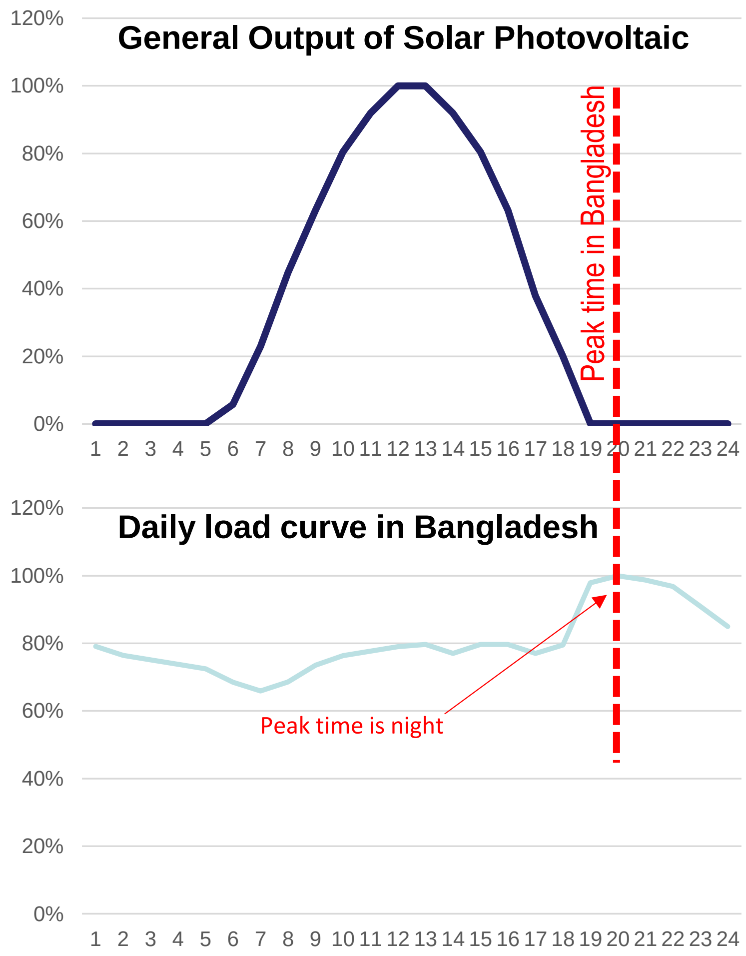
14.6 Integration of the Renewable Energy into Power Development Planning

In Japan, the supply capacities of renewable energy such as solar or wind are calculated by actual values from the site. The JICA Survey Team proposes that the following coefficients can adopted until enough actual values are gathered from renewables in Bangladesh.

Solar: 0 - 21% x Total installed capacity
(Coefficient is changed each month)

Wind: 0 - 7% x Total installed capacity
(Coefficient is changed each month)

But the Power Development Plan is a plan for peak time and the peak time of electricity demand in Bangladesh is night, so the Solar Photovoltaic does not work at peak time. Therefore, electric power (kW) from solar is not considered in the power development plan and electric energy (kWh) is considered. If daily load curve is changed from night peak to day peak in future, electric power (kW) from solar will be considered in the power development plan.



Source: JICA Survey Team

Figure 14-18 Peak of Solar Supply and Electricity Consumption

14.7 Substantial Renewable Energy into Grid Connections

Variable Renewable Energy Grid Connections

In Bangladesh, it is estimated that the potential of grid-connected Variable Renewable Energy (VRE) such as solar and wind, of which power output can vary in the short period, can be 4,200GWh/year (SREDA-World Bank, 2015). In comparison with the total power generation of 82,000GWh in 2020 and 307,000GWh in 2040, the impact of grid-connected VRE is limited and does not require a drastic transformation of the conventional power system development planning.

In fact, IEA discuss that if the VRE is within the 5-10% of the annual total grid-connected power generation (GWh), because such output variation and unpredictability can occur by load change or unplanned power plant outage, and is manageable by the conventional power network planning and operation[44].

However, Bangladesh is still under development phase of power generation and network. Therefore grid-connected utility-scale VREs should be properly integrated in to the power system development plan to ensure appropriate reserve margin and network capacity. Also, currently Bangladesh does not have technical regulation or standard for grid-connected utility-scale VREs. Hence these regulations and standards need to be developed and implemented.

Large Hydro via Cross-Border Power Import

Outside of its boundary, Bangladesh has a huge potential to exploit renewable energy: a regional hydropower potential in the South Asia. It is estimated that Bangladesh can import 5,000 to 6,500 MW hydropower mainly from Nepal and north-west India around 2030. Further details are discussed the "Cross-Border Import" Chapter.

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Appendix Details of Renewable Energy Deployment Plan (Power Generation) by 2021

※It is assumed that renewable energy generation development, of which installation year is not identified, will be installed till 2021.

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2015	11,513						11,513						
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2016	17,500							17,500					
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2017	18,000								18,000				
IDCOL (GrameenShakti)	Solar(Solar Home Systems)		SHS @2018	17,500									17,500			
IDCOL	Solar(Solar Home Systems)		SHS @existing	113,662					113,662							
IDCOL	Solar(Solar Home Systems)		SHS @2015	6,709						6,709						
IDCOL	Solar(Solar Home Systems)		SHS @2016	15,500							15,500					
IDCOL	Solar(Solar Home Systems)		SHS @2017	15,000								15,000				
IDCOL	Solar(Solar Home Systems)		SHS @2017	16,036									16,036			
IDCOL	Solar(Solar Mini Grid)	Complete	100 kWp PGEL solar mini grid project	100	100											
IDCOL	Solar(Solar Mini Grid)	Complete	100 kWp GHEL Solar Mini Grid project	100						100						
IDCOL	Solar(Solar Mini Grid)	Complete	141 kWp Shouro Bangla Ltd mini grid	141						141						

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Mini Grid)	Complete	141 kWp Hydron Bangladesh Pvt. Ltd. Solar Mini Grid	141						141						
IDCOL	Solar(Solar Mini Grid)	Under Construction	148.5 kWp AVA Development Society Solar Mini Grid	149						149						
IDCOL	Solar(Solar Mini Grid)	Under Construction	158.3 kWp GRAM er Alo Ltd. solar mini grid	158						158						
IDCOL	Solar(Solar Mini Grid)	Under Construction	177 kWp Solar Electro Bangladesh Ltd Solar Mini Grid	177						177						
IDCOL	Solar(Solar Mini Grid)	Committed	167 kWp Baraka Renewable Energy Limited Solar Mini Grid	167						167						
IDCOL	Solar(Solar Mini Grid)	Committed	130 kWp Solargao Limited Solar Mini Grid	130						130						
IDCOL	Solar(Solar Mini Grid)	Proposed	Tauras Energy Limited solar mini grid	150						21	21	21	21	21	21	21
IDCOL	Solar(Solar Mini Grid)	Proposed	161.75 kWp G-Tech Solutions Ltd Solar Mini Grid	162						23	23	23	23	23	23	23
IDCOL	Solar(Solar Mini Grid)	Proposed	187.5 kWp Parasol Energy Ltd Solar Mini Grid	188						27	27	27	27	27	27	27
IDCOL	Solar(Solar Mini Grid)	Proposed	200 kWp Superstar Renewable Energy Limited Solar Mini Grid	200						29	29	29	29	29	29	29
IDCOL	Solar(Solar Mini Grid)	Proposed	200 kWp Intraco Limited Solar Mini Grid	200						29	29	29	29	29	29	29

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Mini Grid)		SMG @existing	0					0							
IDCOL	Solar(Solar Mini Grid)		SMG @2015	994						994						
IDCOL	Solar(Solar Mini Grid)		SMG @2016	2,257							2,257					
IDCOL	Solar(Solar Mini Grid)		SMG @2017	1,603								1,603				
IDCOL	Solar(Solar Irrigation)	Complete	GRAM 01 (05)	36				36								
IDCOL	Solar(Solar Irrigation)	Under Construction	GRAM 02 (18)	36						36						
IDCOL	Solar(Solar Irrigation)	Complete	SDRS (3)	36					36							
IDCOL	Solar(Solar Irrigation)	Complete	ARS (7)	36				36								
IDCOL	Solar(Solar Irrigation)	Under Construction	Solargao 01 (34)	36						36						
IDCOL	Solar(Solar Irrigation)	Under Construction	Solargao 02 (10)	36						36						
IDCOL	Solar(Solar Irrigation)	Complete	RDF-1	80				80								
IDCOL	Solar(Solar Irrigation)	Complete	RDF-1	0					0							
IDCOL	Solar(Solar Irrigation)	Complete	RDF-2	350					350							
IDCOL	Solar(Solar Irrigation)	Complete	RDF-2	0					0							

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	1,259						1,259						
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	0						0						
IDCOL	Solar(Solar Irrigation)	Under Construction	RDF-3	0						0						
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	380					380							
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	0					0							
IDCOL	Solar(Solar Irrigation)	Complete	Mazand-1	0					0							
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-2	100						100						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-2	0						0						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-3	220						220						
IDCOL	Solar(Solar Irrigation)	Under Construction	Mazand-3	0						0						
IDCOL	Solar(Solar Irrigation)	Complete	Grameen Shakti	11					11							
IDCOL	Solar(Solar Irrigation)	Complete	RCNSL	2					2							
IDCOL	Solar(Solar Irrigation)	Complete	AVA (6)	64					64							
IDCOL	Solar(Solar Irrigation)			0					0							

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)	Complete	NUSRA	39					39							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)	Under Construction	RREL (10)	196						196						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)			0						0						

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)	Complete	4SL	63					63							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)	Complete	GHEL-6	32					32							
IDCOL	Solar(Solar Irrigation)	Under Construction	GHEL-15	148						148						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)	Under Construction	GHEL-25	361						361						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)			0						0						
IDCOL	Solar(Solar Irrigation)	Under Construction	AID-1	76						76						
IDCOL	Solar(Solar Irrigation)	Under Construction	AID-2	170						170						
IDCOL	Solar(Solar Irrigation)			0					0							
IDCOL	Solar(Solar Irrigation)		SIPS @existing	0					0							

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IDCOL	Solar(Solar Irrigation)		SIPS @2015	0						0						
IDCOL	Solar(Solar Irrigation)		SIPS @2016	3,830							3,830					
IDCOL	Solar(Solar Irrigation)		SIPS @2017	3,653								3,653				
IDCOL	Bio	Under Construction	KKT	100					100							
IDCOL	Bio	Complete	Phenix	450					450							
IDCOL	Bio	Under Construction	SEAL	400					400							
IDCOL	Bio	Under Construction	United	25					25							
IDCOL	Bio	Under Construction	Zobaida	25					25							
IDCOL	Bio	Under Construction	Ummi Kulsum Agro Ltd.	36					36							
IPP(SunEdision Energy Holdings (Singapore) Pvt Ltd.)	Solar(Solar Parks)	Planning	200 MW (AC) Solar Park on BOO Basis at Teknaf, Coxes Bazar	200,000								40,000	40,000	40,000	40,000	40,000
IPP(Beximco Power Co. Ltd & TBEA XinJiang SunOasis Co. Ltd)	Solar(Solar Parks)	Planning	200 MW (AC) Solar Park at Gaibandha District, Bangladesh	200,000								40,000	40,000	40,000	40,000	40,000
IPP(HETAT-DITROLIC- IFDC Solar)	Solar(Solar Parks)	Planning	50 MW (AC) Solar Park at Sutiakhali, Mymensingh District	50,000								10,000	10,000	10,000	10,000	10,000

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
IPP(EDISUN – Power Point & Haor Bangla-Korea Green Energy Ltd.)	Solar(Solar Parks)	Planning	32 MW (AC) Solar Park, Dharmapasha, Sunamganj	32,000								6,400	6,400	6,400	6,400	6,400
IPP(Intraco CNG Ltd & Juli New Energy Co. Ltd.)	Solar(Solar Parks)	Planning	30 MW (AC) Solar Park, Gangachora, Rangpur	30,000								6,000	6,000	6,000	6,000	6,000
IPP(JPL)	Solar(Solar Parks)	Planning	20 MW (AC) Solar Park, Coxbazar	20,000								4,000	4,000	4,000	4,000	4,000
IPP(Eiki Shoji Co. Ltd. Japan & Sun Solar Power Plant Ltd)	Solar(Solar Parks)	Planning	10 MWp Grid-Tied Solar Power Project, Gowainghat, Sylhet	10,000								2,000	2,000	2,000	2,000	2,000
IPP(Blue Mountain Ltd.)	Solar(Solar Parks)	Planning	100 MW (AC) Solar Park Baradi , Naryanganj	100,000								20,000	20,000	20,000	20,000	20,000
IPP(Beximco Power Co. Ltd)	Solar(Solar Parks)	Planning	30 MW (AC) Solar Park Panchgarh	30,000								6,000	6,000	6,000	6,000	6,000
IPP(Golden Harvest and DREPL Consortium)	Solar(Solar Parks)	Planning	10 MW (AC) Solar Park Gowainghat, Sylhet	10,000								2,000	2,000	2,000	2,000	2,000
IPP(Green Housing & Energy Ltd.)	Solar(Solar Parks)	Planning	5 MW (AC) Solar Park, Patgram, Lalmonirhat	5,000								1,000	1,000	1,000	1,000	1,000
IPP(Greenswitch Elcon Bangladesh Ltd)	Solar(Solar Parks)	Planning	50 MW (AC) Solar Park, Bhola	50,000								10,000	10,000	10,000	10,000	10,000
BPDB	Solar(Solar Parks)	Planning	Installation of a 100 MWp Solar PV based grid connected Power generation plant at Sonagazi, Feni District	100,000								100,000				

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
BPDB	Solar(Solar Parks)	Planning	In Chittagong district at Rangunia near Karanafuli river 60 MW Solar park on BOO basis	60,000								60,000				
BPDB	Solar(Solar Parks)	Planning	Gangachara Solar Park	55,000							55,000					
BPDB	Solar(Solar Parks)	Planning	Dharala 30 MW Solar park on BOO basis near Dharala river of Kurigram District	30,000							30,000					
BPDB	Solar(Solar Parks)	Planning	Sarishabari, Jamalpur 3 MW grid connected solar PV power plant	3,000						3,000						
BPDB	Solar(Solar Mini Grid)	Planning	Tough to reach Haor area R/E based pilot project at Salna of Sunamganj of 650 KW Mini grid system	650								130	130	130	130	130
BPDB	Solar(Light)	Planning	Solar street lighting in 8 City Corporation (SSLPCC) project									0				
BPDB	Solar(Solar Rooftop)	Planning	Rooftop solar on govt buildings at Jamalpur District	813								163	163	163	163	163
BPDB	Waste	Planning	Keraniganj Municipal waste to Electricity Project	7,000								1,400	1,400	1,400	1,400	1,400
BREB	Solar(Solar Irrigation)	Planning		7,000								1,400	1,400	1,400	1,400	1,400
NWPGCL	Solar(Solar Parks)	Planning	Faridpur Solar Park	100,000								20,000	20,000	20,000	20,000	20,000

Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NWPGCL	Solar(Solar Parks)	Planning	Sirajganj Solar Park, Sirajgonj	7,600						7,600						
EGCB	Solar(Solar Parks)	Planning	Sonagazi 200 MW Wind Solar Hybrid Power Plant	200,000								200,000				
APCL	Solar(Solar Parks)	Planning	Ashuganj Solar Park	80,000								16,000	16,000	16,000	16,000	16,000
RPCL	Solar(Solar Parks)	Planning	Mollarhat 200 MWp Solar PV Power plant project	200,000								40,000	40,000	40,000	40,000	40,000
RPCL	Solar(Solar Parks)	Planning	Padma's Char Solar Park	200,000								40,000	40,000	40,000	40,000	40,000
RPCL	Wind	Planning	200 MW Wind based Power Project	200,000								40,000	40,000	40,000	40,000	40,000
DPDC	Solar(Solar Rooftop)	Planning	Solar rooftop system at other Government buildings rooftop as per Secretariat bldg. model									0	0	0	0	0
DESCO	Solar(Solar Rooftop)	Planning	Rooftop solar system installation at DESCO's distribution area Government organization									0	0	0	0	0
IPP(consortium of PIA group & Bangladesh Alternative Energy System Ltd.)	Wind	Planning	100 MW wind power project by consortium of PIA group & Bangladesh Alternative Energy System Ltd. At Anwara Chittagong	100,000								20,000	20,000	20,000	20,000	20,000
IPP(US-DK Green Energy (BD))	Wind	Planning	60 MW wind power project at Cox's	60,000								12,000	12,000	12,000	12,000	12,000

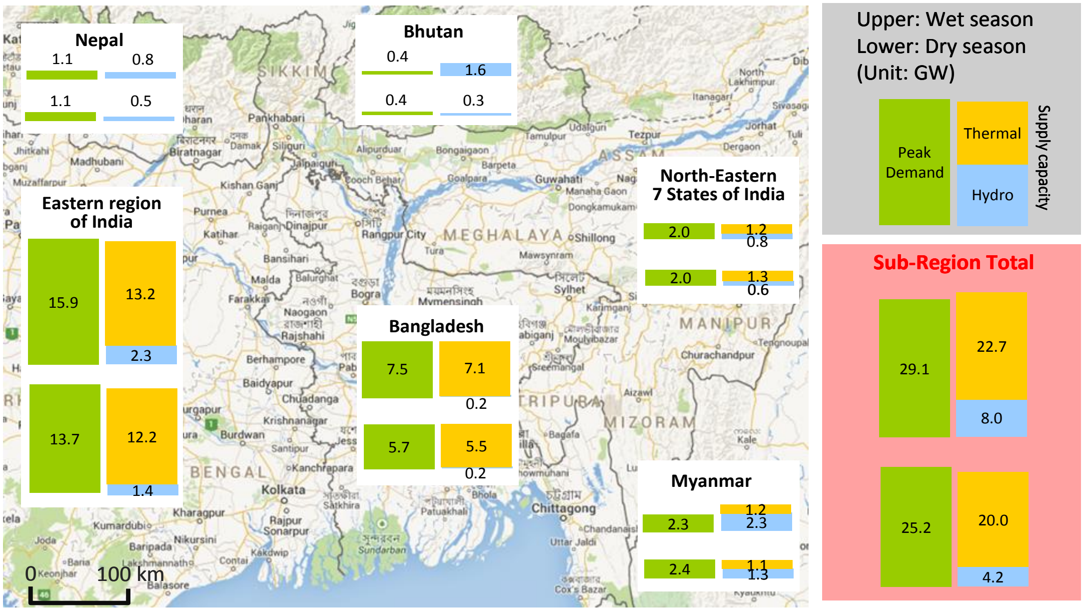
Company	Type	Status	Project Name	Capacity (kWp)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
			bazar by US-DK Green Energy (BD)													
IPP(M/s. ReGen Powertech Limited)	Wind	Planning	M/s. ReGen Powertech Limited solar-wind hybrid Power project	18,000								3,600	3,600	3,600	3,600	3,600
	Wind	Planning	Wind resourse Assesment project by Vestas Asia Pacific Wind Technology Pvt Ltd									0	0	0	0	0
BADC	Solar(Solar Irrigation)	Planning	Solar Irrigation Project by BADC	3,750								750	750	750	750	750
SREDA	Solar(Solar Home Systems)		SREDA Existing	0					28,338							
SREDA	Solar(Solar Irrigation)		SREDA Existing	0					430							
SREDA	Solar(Solar Rooftop)		SREDA Existing	0					11,000							
SREDA	Solar(Solar Rooftop)		SREDA Existing	0					2,300							
SREDA	Solar(Solar mini grid)		SREDA Existing	0					900							
SREDA	Wind(Wind)		SREDA Existing	0					2,000							
SREDA	Bio(Bio)		SREDA Existing	0					3,964							

Chapter 15 Power Import and Other Generations

Industrial diversification and advancement are essential in order to achieve further economic development in Bangladesh. To this end, improvement of the quality of the power supply, such as stabilization of network voltage and frequency, is a prerequisite. In addition, in anticipation of the growing share of coal-fired thermal power generation in the medium and long term, the exploitation of renewable energy resources with low environmental burden under the climate change perspective is envisaged.
On-grid large-scale hydropower development seems to be an effective measure to overcome the aforementioned issues. However, due to its flat geographical features, Bangladesh lacks prospective hydropower potential over 1 MW apart from the existing Kaptai hydro power plant (230MW). In contrast, there is abundant water power resource potential in the countries surrounding Bangladesh, namely Bhutan, Nepal, Myanmar, and the Indian States of the North East and West Bengal (collectively “neighboring countries”). Thus, it is expected that Bangladesh imports electricity out of such hydropower generation via power interconnections with such neighboring countries for stable base load supply, energy fuel diversification, and climate change mitigation.

15.1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh

The neighboring countries of Bangladesh have rich hydropower potential. However, the amount of development at present is small, and a great amount of development can be expected in the future.
The electric power supply and demand situations in the rainy season and dry season in 2014 in the neighbouring countries (Eastern region and Northeastern states in India) of Bangladesh are shown as follows.

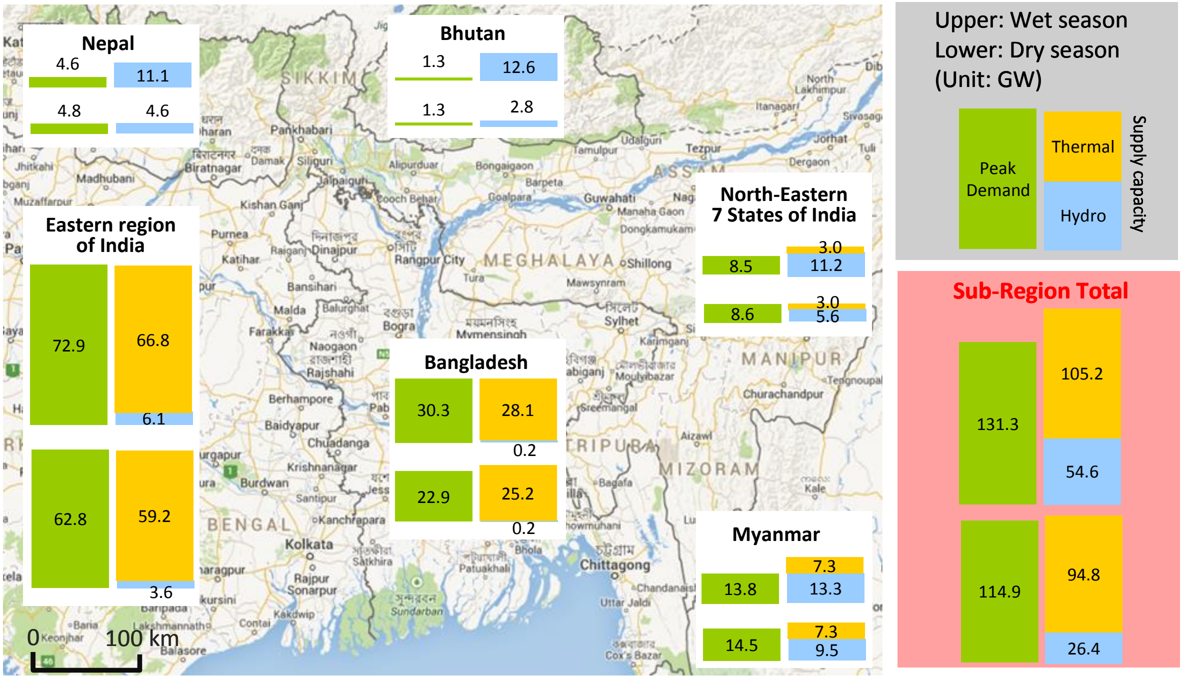


“Map data©2014 AutoNavi Google” Source: JICA Survey Team

Figure 15-1 Electric Power Supply and Demand Situation in the Neighboring Countries of Bangladesh (2014)

The supply capacity from hydropower is about 25% of the whole supply capacity in this area at present because there is not a lot of hydropower development yet. Because a lot of hydroelectric power plants in these regions are the run-of-river type, the amount of power generation decreases below half in the dry season, though a lot of power generation can be expected in the rainy season. Therefore, the supply capacity is slightly insufficient in the dry season because the supply capacity from hydropower decreases remarkably, though power demands also decrease a little.

The electric power supply and demand situation forecast in 2030 is shown below in addition to that mentioned above.



"Map data©2014 AutoNavi Google"

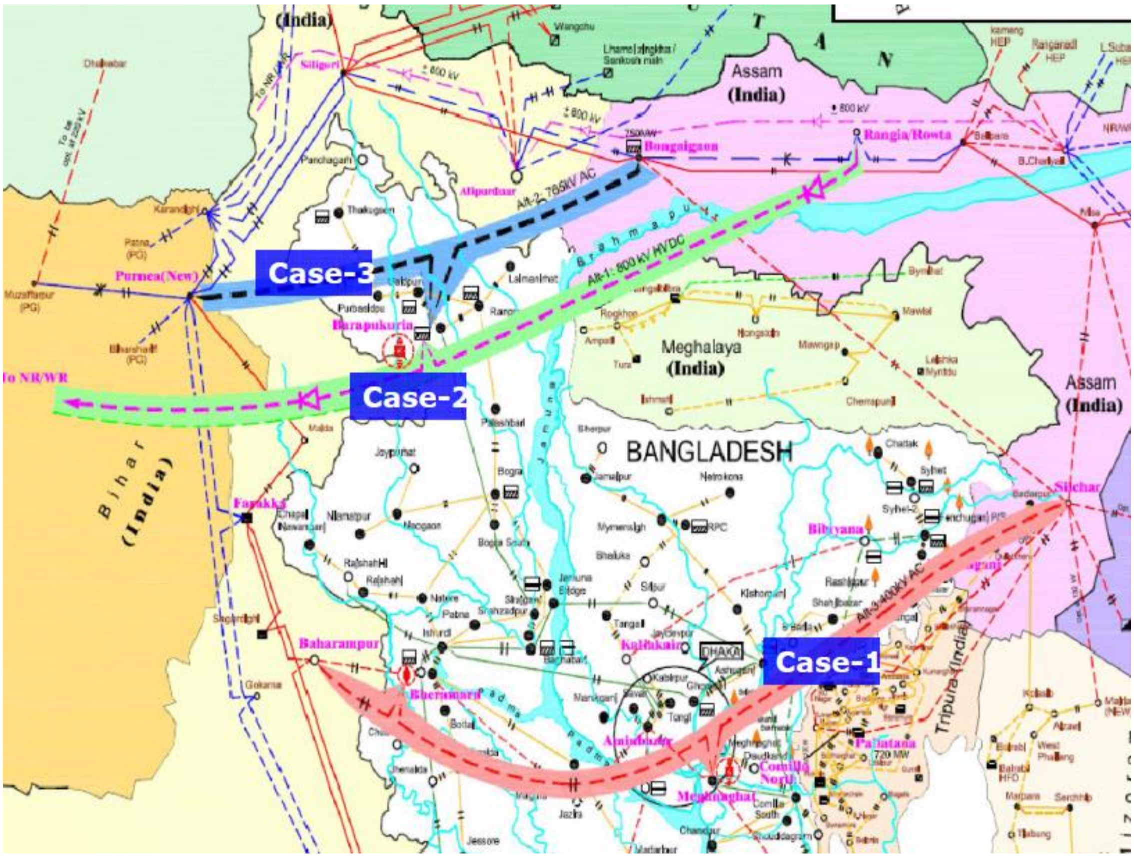
Source: JICA Survey Team

Figure 15-2 Electric Power Supply and Demand Situation in the Neighbouring Countries of Bangladesh (2030)

Hydropower development can be actively executed in Nepal, Bhutan, India's northeastern states, and Myanmar, and the capacity of the hydropower plants is expected to increase approximately by 10GW in each. As a result, the supply capacity from hydropower will increase to about 35% of the whole supply capacity in the rainy season. On the other hand, the supply capacity of hydropower in the dry season decreases below half, and a lack of supply capacity is feared in Nepal, which mainly supplies electricity by hydropower. However, because demand decreases greatly and the reserve capacity of thermal power can be secured in Bangladesh, which mainly supplies electricity by thermal power, enough supply capacity can be secured in the region as a whole.

15.2 Possibility of International power trading in Bangladesh

Transmitting hydropower from Bhutan and Nepal to Bangladesh is impossible without the consent of India, which is geographically located between Bangladesh and these countries. In order to tackle this problem, three new cases of inter-connection have begun to be planned.



Source: JTT Report

Case 3	765 kV HVAC Line from Bongaigaon (Assam) to Purnia of India via Jamalpur or Barapukuria dropping 500-1000 MW to Bangladesh by HVDC BTB Station.
Case 2	±800 kV HVDC 6000 MW Bi-pole Line from Rangia/Rowta (Assam) to NR/WR of India Via Jamalpur or Barapukuria dropping 500-1000 MW Power to Bangladesh by HVDC Station.
Case 1	Shilchar-Meghnaghat/Bhulta-Bahrampur High Capacity 400kV Line (Dropping of 500 MW by HVDC BTB Station at Meghnaghat/Bhulta)

Figure 15-3 Grand Design of Bangladesh – India Interconnection Line

In June 2015, Bangladesh and India published a joint declaration, following a summit meeting between Prime Ministers from each country. Among other things, both PMs welcomed the consensus between Bangladesh and India to evacuate power from the North-eastern region of India (Rangia/Rowta) to Muzaffarnagar of India through Bangladesh, constructing a ±800 kV, 7000 MW HVDC multi-terminal bi-pole DC grid line with suitable power tapping points at Barapukuria in Bangladesh. Prime Minister Modi agreed in principle to consider Bangladesh's request to provide adequate power from this line for Bangladesh keeping in view the grid security of both countries. Noting Bangladesh's interest in importing power in the BBIN framework, the Indian PM agreed to favorably consider such imports subject to grid security, transmission, interconnection and the applicable laws, rules and regulations of the respective countries.

15.3 Selection of Hydropower Development Candidate Area for Bangladesh

15.3.1 Evaluation Criteria Setting

The JICA Survey Team proposes a set of evaluation criteria for the selection of candidate areas for hydropower development for Bangladesh, as is shown in the following table.

Table 15-1 Evaluation Criteria for Candidate Area Selection for Hydropower Development

	Evaluation Items	Evaluation Viewpoint	Importance
1	Political willingness for power trades with Bangladesh	Including hydropower development policy and institutional supporting measures	High
2	Demand-Supply Balance in hydropower development host country	The more surplus energy (even during the dry season) the host country secures, the more points earned. (with more opportunity to receive energy for Bangladesh)	Medium
3	Hydropower development potential volume	The more potential there is, the more opportunity to identify economically viable sites. Thus, higher score earned.	Medium
4	Interconnection modality with Bangladesh	Direct connection to Bangladesh is preferable over indirect connections through other network systems.	Medium
5	Proximity to the connection point in Bangladesh	The closer the better. This criterion includes ease of transmission line construction.	High
6	The value of electricity at the receiving point in Bangladesh	Connection to an area where there are fewer power sources is favored.	Low

Source: JICA Survey Team

All these evaluation items are of great importance in selecting candidate areas for hydropower development for Bangladesh. However, “political willingness for power trades with Bangladesh” and “proximity to the connection point in Bangladesh” are considered to be the most important.

15.3.2 Possible Candidate Areas for Hydropower Development to be connected with Bangladesh

(1) Possible Areas for Interconnection

The JICA Survey Team considers the following six areas to be possible candidate areas for hydropower development to be connected with Bangladesh.

Table 15-2 Candidate Areas for Hydropower Development to be Connected with the Bangladesh System

	Hydropower Development Area	Connecting point in Bangladesh	Connection Modality
1	Eastern Nepal	West (Bheramara)	To transmit energy to the closest substation in India and to connect the existing BTB in West Bangladesh through the Indian domestic network.
2	Western Bhutan	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
3	Eastern Bhutan	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
4	Meghalaya State, India	East (Bibiyana)	To directly connect with Bibiyana S/S
5	Arunachal Pradesh State, India	North (Barapukuria)	To transmit energy to Rangia S/S in India and to connect with the Bangladesh grid in North Bangladesh through ±800kV HVDC link.
6	Western Myanmar	South (Anowara)	To directly connect with Anowara S/S

Source: JICA Survey Team

(2) Connection Illustration of Potential Hydropower Development Areas

The following map shows an illustration of the connection of hydropower development areas with Bangladesh.

Source: JICA Survey Team

Figure 15-4 Connection Illustration of Hydropower Development Areas with Bangladesh

15.3.3 Screening Based on the Evaluation Criteria

(1) Political Willingness for Power Trades with Bangladesh

In all the areas except Myanmar, the Governments are very much willing to undertake power trading with Bangladesh. It should be noted that the Government of Bhutan has the intention to prioritize hydropower development in the eastern area over the western area, where hydropower development is rather active, in order to seek balanced economic development in the country.

(2) Demand-Supply Balance in hydropower development host country

Nepal currently faces severe power shortages due to its lack of supply capacity, exercising rotational load shedding routinely. It is expected that large hydropower plants will start operating in the near future, improving the demand-supply situation in the wet season. However, as this will not solve the demand-supply balance in the dry season, the securing of an energy surplus to sell to the rest of the region would not be envisaged. On the other hand, both in Bhutan and the State of Arunachal Pradesh, where there is enough supply capacity, it is possible to sell their surplus capacities to the rest of the region. In the State of Meghalaya, where it sells wet season surplus to other states and purchases power back in the dry season on a regular basis, surplus capacity in the dry season cannot be expected.

(3) Hydropower development potential volume

There is huge hydropower development potential in all the areas except for the State of Meghalaya. However, from the viewpoint of pumped-storage, there is prospective potential in Meghalaya.

(4) Interconnection modality with Bangladesh

It is possible to connect with the Bangladesh power system directly from the State of Meghalaya and Myanmar. On the other hand, transmitting energy through the Indian grid is prerequisite when Bangladesh receives power from Nepal or Bhutan. In the case that Bangladesh imports hydro energy from Bhutan or Arnachal Pradesh, Bangladesh can tap energy at the northern receiving point though a proposed ±800kV HVDC link between Northeast and Central India via Bangladesh. When Bangladesh purchases energy from Nepal, it would receive it at Bheramara BTB, where capacity augmentation is envisaged, passing a long way through Indian domestic power transmission network.

(5) Proximity to the connection point in Bangladesh

If hydropower in the State of Meghalaya is connected directly to Bibiyana S/S in Bangladesh, only 50km of transmission I lines are required. In the case of smaller capacity, such as 132kV transmission, the distance to the nearest substation may be approximately 20 to 30km. In transmitting hydro energy from Bhutan or Arunachal Pradesh, it will be prerequisite to be connected to Rangia S/S where an eastern AC/DC conversion station is located for the proposed ±800kV HVDC link between Northeast and Central India via Bangladesh. Because eastern Bhutan is close to Rangia S/S, transmission distance is within 100km. However, in evacuating hydro energy from western Bhutan, the transmission distance may exceed 200km. Also, receiving hydro energy from Arunachal Pradesh may require transmission lines over 200km. In the case of receiving hydro energy from Nepal, connection to the nearest substations in India allows Bangladesh to use the Indian domestic power networks. Therefore, transmission distance is considered to be less than 100km. Connection of hydro energy from Myanmar may require a transmission distance of over 200km.

(6) The value of electricity at the receiving point in Bangladesh

Connection to the load center may be the most valuable. However, each of the hydropower potential target areas in question is distant from the load center in Bangladesh. The next favorable case is connection to areas with supply capacity deficit. Because power plants are concentrated to the east of the Jamuna River, any supply capacity west of the Jamuna River will be highly appreciated. The currently proposed power receiving point along the proposed ±800kV HVDC link between Northeast and Central India is located at Barapukuria, east of the Jamuna River. Therefore, the value of electric power with this link is considered to be a little bit higher than that of electricity to be received east of the Jamuna River from the Indian State of Meghalaya or Myanmar. The value of hydro energy from Myanmar in particular may be relatively lower at the power receiving point because thermal power development at a larger scale is envisaged in southern Bangladesh.

(7) General Evaluation

The results of the screening mentioned above are summarized in the following table.

Table 15-3 Screening Results

		Weight	Nepal	Bhutan		India		Myanmar
			East	West	East	West	Arunachar	West
1	Political will for electricity export	3	5	3	5	2	5	2
2	Demand & supply balance	2	2	5	5	2	5	2
3	Hydro power potential	2	5	5	5	4	5	4
4	Connection method	2	3	2	2	5	2	5
5	Distance to connecting point	3	4	2	4	2	2	2
6	Value of electricity at connecting point	1	4	4	4	2	4	2
	Total		51	43	55	36	49	36

Source: JICA Survey Team

As a result of the above comparison, it is considered that hydropower development in the Indian State of Meghalaya and Bhutan is relatively promising. As for Nepal, when its supply-demand situation improves, the area would become promising.

With regard to Myanmar, without having an opportunity to visit, the JICA Survey Team can hardly confirm detailed information such as the Government’s willingness to undertake power trading with Bangladesh. However, depending on the results of the confirmation on local situations, Myanmar may become a good candidate area for hydropower development for Bangladesh.

15.4 Selection of Hydropower Development Candidate Sites

Previous Chapter confirms two areas, namely East Bhutan and the Indian State of Meghalaya, as the most prioritized areas for hydropower development for Bangladesh.

15.4.1 Evaluation Criteria Setting

The following table shows a set of evaluation criteria to score potential hydropower sites and select development candidate sites.

Table 15-4 Evaluation Criteria for Hydropower Development Candidate Sites

	Items to be evaluated	Evaluation Viewpoint	Weight
1	Preference of the Government of Bangladesh	Larger generation capacity is preferable	5
2	Economy of the potential site	Evaluated by unit construction cost (USD/MWh) based on computation of construction cost and annual generation volume	5
3	Required construction cost of dedicated transmission lines for energy evacuation	Unit transmission cost (USD/MWh) being calculated with construction cost estimate based on transmission line length and voltage level	2
4	Environmental issues	Evaluated on whether there is an existence of environmentally protected areas, endangered species or indigenous population nearby	4
5	Geological issues	Evaluated on whether there is a possibility of landslide during construction and sedimentation during operation	4
6	Issues for power export to Bangladesh	Evaluated by possibility of utilization of related transmission lines for power transmission to Bangladesh and energy output volume	3
7	Ease of construction and implementation	Status for construction access road, and availability of utilities/infrastructure such as electricity for construction	2
8	Operational flexibility	Evaluated by water storage capacity – the point is higher in the case of seasonal output adjustment	1
9	Project status	Evaluated by credibility of project feasibility based on progress of project preparation	1
10	Prospects for future JICA assistance	Evaluated on whether there is another sponsor for development funding and on total project cost (size)	3

Source: JICA Survey Team

Each of the potential sites is evaluated and scored alongside each of the above evaluation criteria with the highest score being five points. However, any potential sites with their scores in 4) Environmental issues and 5) Geological issues being two points or below will not be selected as candidates due to serious risk exposure, even if the total scores are relatively larger than others.

15.4.2 Comparison and Screening of Hydropower Development Sites alongside the Evaluation Criteria

(1) East Bhutan

In the eastern part of Bhutan, there are three sites and five power plants, Kuri-I (formerly known as Rotpashong), Gamri-I, Gamri-II, Nyera Amari-I and Nyera Amari-II for which pre-feasibility studies (Pre-F/Ss) have been conducted. The following table summarizes the techno-economic comparison among these five proposed power plants.

Table 15-5 Hydropower Development Potential Candidate Sites in East Bhutan

	Kuri-I	Gamri I	Gamri II	Nyera Amari I	Nyera Amari II
Installed caopacity Unit size × Units	1,230MW (205MW×6)	45MW (22.5MW×2)	85MW (42.5MW×2)	125MW (62.5MW×2)	317MW (105.67MW×3)
Design annual energy	5,265GWh	215.69GWh	399.90GWh	614GWh	1,556GWh
Construction cost (million)	USD 1,686.5	BTN 3,620 (USD 56.6)	BTN 5,587 (USD 87.3)	BTN 12,490 (USD 195.2)	BTN 22,291 (USD 348.4)
Unit construction cost per annual energy	USD 320/MWh	USD 262/MWh	USD 218/MWh	USD 318/MWh	USD 224/MWh
Length of T/L	400kV 140km	132kV 8km	132kV 36km	220kV 16km	220kV 66km
Construction cost of T/L	USD 70 million	USD 11 million		USD 22 million	
Unit construction cost	USD 13.3/MWh	USD 17.9/MWh		USD 10.1/MWh	

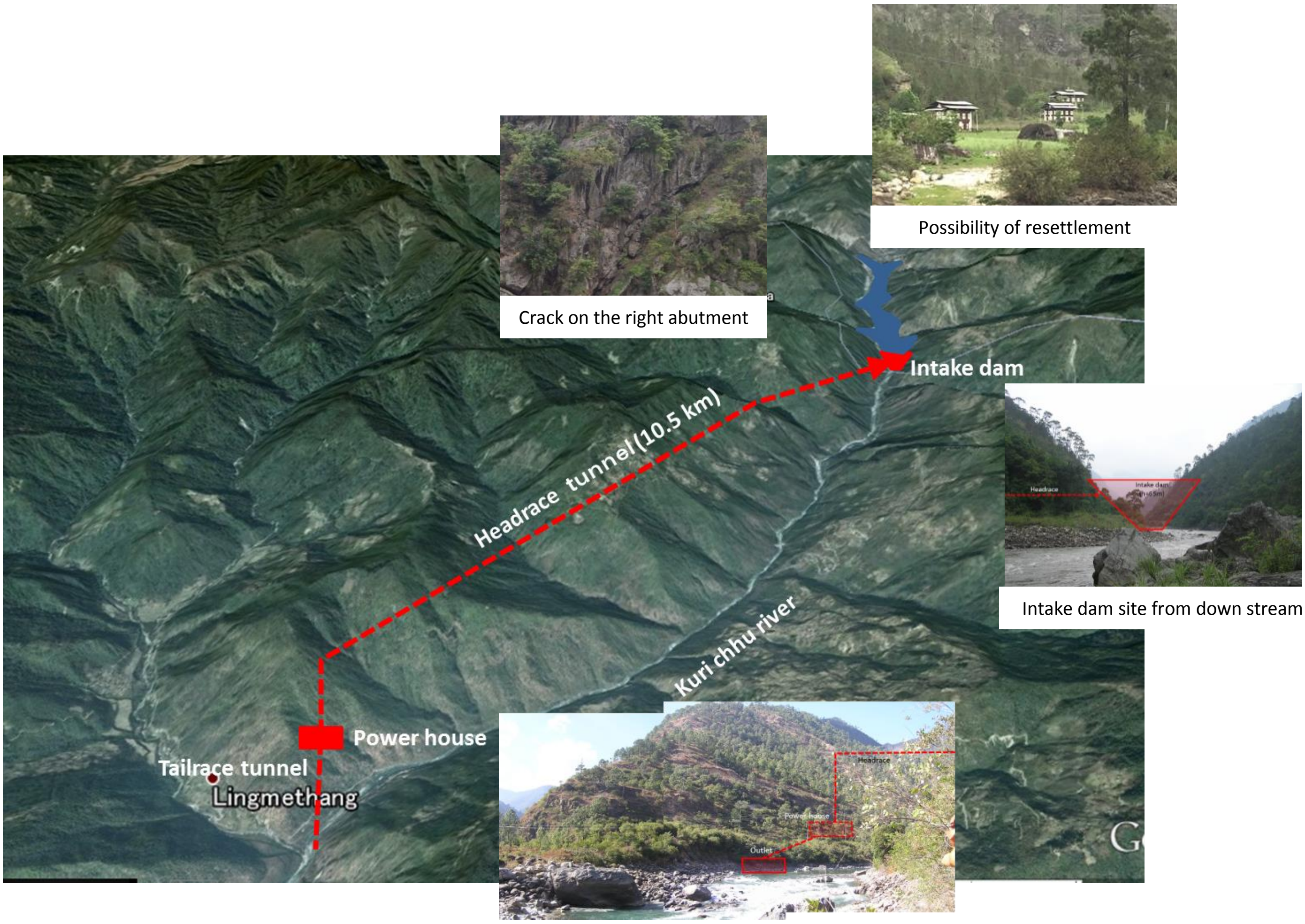
Source: JICA Survey Team

Table 15-6 Evaluation Results for Potential Hydropower Sites in East Bhutan

	Evaluated items	Weight	Kuri-I	Gamri I, II	Nyera Amari I, II
1	Preference of the Government of Bangladesh	5	5	1	3
2	Economy of the potential site	5	3	4	4
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	4	4
4	Environmental issues	4	3	2	3.5
5	Geological issues	4	4	3	2
6	Issues for power export to Bangladesh	3	3	2	3
7	Ease of construction and implementation	2	4	2	3
8	Operational flexibility	1	2	2	2
9	Project status	1	4	3	3
10	Prospects for future JICA assistance	3	2	4	3
	Total (weighted)		105	80	94

Source: JICA Survey Team

Kuri-I records the highest total score, followed by Nyera Amari and, in turn, Gamri. Kuri-I fits the expectation of the GOB in terms of its larger scale of development. Because there seem to be no significant impediments to development, the JICA Survey Team selects Kuri-I as the most prioritized development candidate.



"Image©2015CNES/Astrium, Image© 2015AutoNavi, Image ©2015Google" Source: JICA Survey Team

Figure 15-5 Outline of Kuri I Project

- All the facilities except the intake dam are constructed underground. However, the JICA Survey Team considered that a ground or semi-underground type powerhouse would be possible, so placement position of the powerhouse is an essential study point at the detailed design stage.
- Numerous trends of joints and cracks are seen on the rock surface on both the right and left river side. Detailed investigation and examination for these cracks on the right bank should be conducted in the FS stage.
- There are no settlements at the dam site, but part of the highway along the reservoir near the intake dam needs to be relocated due to the reservoir, and 3 permanent houses and other small facilities in Autsho village need to be resettled.

(2) The Indian State of Meghalaya

In the State of Meghalaya, there are three potential sites for conventional hydropower development with sizable capacity and considerable progress in project preparation, namely Mintdu Leshka-II, Umngot and Nongkohlait. The following table summarizes the techno-economic comparison among the three proposed power plants.

Table 15-7 Hydropower Development Potential Candidate Sites in Meghalaya

	Mintdu Leshka II	Umngot	Nongkohlait
Installed caopacity Unit size × Units	280MW (70MW x 4)	240MW (80MW x 3)	120MW
Design annual energy	895.29 GWh	838.73 GWh	379.34 GWh
Construction cost	INR 29,400 million (USD 460.5 million)	INR 15,646 million (USD 245 million)	INR 3,262 million*[1)] (USD 51.1 million)
Unit construction cost per annual energy	USD 514/MWh	USD 292/MWh	USD 135/MWh*[1)]
Length of T/L	220kV 98km	220kV 111km	220kV 95km
Construction cost of T/L	USD 27 million	USD 31 million	USD 27 million
Unit construction cost	USD 30.2/MWh	USD 37.0/MWh	USD 71.2/MWh

*[1)]: Data from Pre-F/S in 2004 Source: JICA Survey Team

The southern part of Meghalaya state has very steep geographical features, and has a lot of appropriate site of PSPP. Moreover, it is assumed that the optimal scale of the power plant will be 1,500MW class because it can expect a high head that exceeds 600m. However, a concrete site survey has not been done for the PSPP of Meghalaya state up to now.

Table 15-8 Evaluation Results for Potential Hydropower Sites in Meghalaya

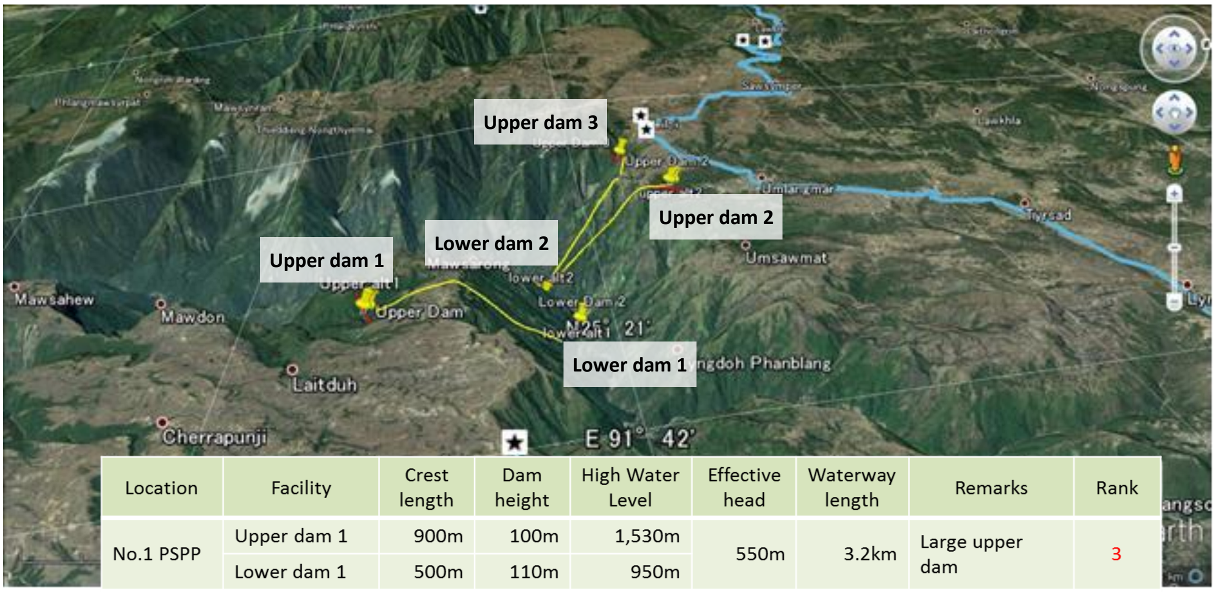
	Evaluated items	Weight	Mintdu Leshka II	Umngot	Nongkohlait	PSPP
1	Preference of the Government of Bangladesh	5	3	3	2	5
2	Economy of the potential site	5	2	3	4	4
3	Required construction cost of dedicated transmission lines for energy evacuation	2	4	3	2	4
4	Environmental issues	4	4	3	2.5	4
5	Geological issues	4	2	4	4	4
6	Issues for power export to Bangladesh	3	4	4	4	4
7	Ease of construction and implementation	2	4	3	3	3
8	Operational flexibility	1	2	4	2	5
9	Project status	1	4	4	3	1
10	Prospects for future JICA assistance	3	4	4	4	3
	Total (weighted)		95	102	95	118

Source: JICA Survey Team

When the hydropower of Meghalaya state is developed, it will be difficult for Bangladesh to import the whole quantity of power in order to transmit part of it to Meghalaya state and states in the vicinity. In short, because Bangladesh can only receive almost half of the amount of development, the development of a larger scale site is more preferable. Conventional hydropower is a development scale of about 200MW, so the amount of receipt in Bangladesh is only about 100MW. On the other hand, because the

PSPP is a development scale of 1,500MW class, almost 1,000MW can be expected for receipt in Bangladesh.
Based on the above-mentioned view, the JICA Survey Team selects PSPP as a development priority site in Meghalaya state.

The JICA Survey Team has conducted site surveys of candidate pumped storage power plant sites, and the three potential sites are proposed as suitable sites for a pumped storage power plant site in Meghalaya. However, this proposal is based on visiting and watching from the road on the plateau and desk study.



Location	Facility	Crest length	Dam height	High Water Level	Effective head	Waterway length	Remarks	Rank
No.1 PSPP	Upper dam 1	900m	100m	1,530m	550m	3.2km	Large upper dam	3
	Lower dam 1	500m	110m	950m				
No.2 PSPP	Upper dam 2	550m	40m	1,550m	690m	3.2km	Excavation of upper pond	2
	Lower dam 2	300m	140m	830m				
No.3 PSPP	Upper dam 3	450m	100m	1,500m	640m	4.1km		1
	Lower dam 2	300m	140m	830m				

 Source: JICA Survey Team

Figure 15-6 Three Candidate Sites for PSPP in Meghalaya

Because of the very steep geographical features, there are many suitable sites which satisfy the conditions of a location for the PSPP in the southern part of Meghalaya state, and a high head that exceeds 600m can be expected. Therefore, it is assumed that the optimal scale of the power plant will be 1,500MW class. However, no concrete survey on PSPP in Meghalaya state has been performed up to now at all. That is to say, sites that have geological issues or environmental issues etc. can be excluded, and an excellent, economical site can be selected.

A 400kV double-circuit transmission line with a length of 90km from the power plant to Bibiyana S/S in Ba Transmission Line Development Plan will be constructed. If the line is connected to the India system, it is an option to extend it to Killing substation in India by constructing an additional 100 km transmission line in a northerly direction.

15.5 Recommendations on Regional Power Interconnection

15.5.1 Challenges and Countermeasures of Power Imports

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

(1) Energy Security

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

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

The power import plan through India hinges on commercial operation of the Case 2 HVDC (±800kV) interconnection line or the Case 3 HVAC (765kV) interconnection line. These interconnection lines shall be constructed in close cooperation with India after fully understanding and confirming India's needs.
When hydropower capacity exceeds 3,000MW in Arunachal Pradesh, the ±800kV inter-state transmission line currently under construction reaches its full transmission capacity, giving rise to a need for the construction of the Case 2 interconnection line. On the other hand, there seems to be no reason for India to realize the need for the Case 3 line for the time being. However, need for the Case 3 line's construction will arise if construction of the Case 2 line is delayed due to a delay in the hydro power development in Arunachal state, or high construction costs etc.

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

It is desirable to import as much power as possible through one connecting point from the viewpoint of economic efficiency. However, if a huge amount of power is transmitted through one connecting point, it can lead to the risk of massive blackout, such as blackout across the entire country during the shutdown of the connecting line. Massive blackout occurred on 1st November 2014, triggered by 500MW power loss of the BTB break down on the inter-connection line from India. In order to avoid this risk, the limit of the power loss level needs to be worked out, by checking sufficiently continuous power generators' operation during frequency drop and the load shedding scheme during large scale power supply loss. Based on this result, the maximum level of import capacity in one inter-connection point has to be decided. In concrete terms, it is preferable that the amount of imported power through one connecting point is within 10% of the demand.

(4) Mutual Interference due to Grid Accidents

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

15.5.2 Proposals on Power Import Planning

Reflecting the aforementioned issues, the Survey Team proposes the following two power import plans for Bangladesh.

(1) High Case Scenario

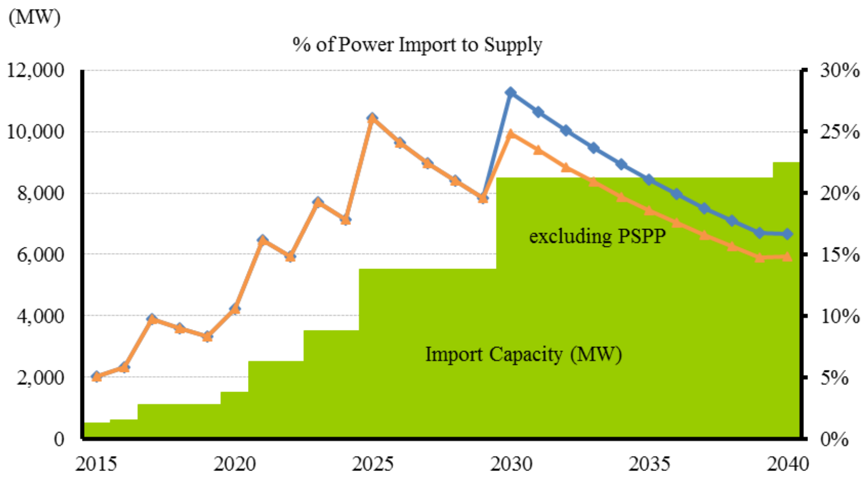
The High Case Scenario, in which more electric power can be expected due to operation of the Case 2 line and Case 3 line starting on schedule, is shown below.

Table 15-9 Power Import Plan (High Case Scenario)

		MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100	2016	Some load (100MW) in Comilla (N) S/S will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	1,000	2021	Additional extension of Bheramara HVDC Power import from Nepal (including GMR)
5	Tripura - Comilla	400	2020	Construction of HVDC (500MW) in Comilla (N) S/S. Some load (100MW) in Comilla (N) S/S will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	1,000	2023	Power import by using Case 2 T/L (±800kV DC)
7	Rangia/Rowta - Barapukuria	1,000	2025	Power import by using Case 2 T/L (±800kV DC)
8	From Nepal (Purnea - Barapukuria)	1,000	2025	Power import by using Case 3 T/L (initially 400kV AC)
9	Bongaigaon/Rangia - Jamarpur	1,000	2030	Power import from Bhutan
10	Bibiyana - Meghalaya (PSPP)	1,000	2030	PSPP in Meghalaya State
11	From Nepal	1,000	2030	Power import by using Case 3 T/L (upgrade to 765kV AC)
12	Cox's Bazar - Myanmar	500	2040	Power import from Myanmar
	Total	9,000		

Source: JICA Survey Team

The following figure shows the import volume and its share against the total supply capacity in the high case scenarion power import plan.



Source: JICA Survey Team

Figure 15-7 Future Power Import Volume and its Share (High Case Scenario)

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

(2) Low Case Scenario

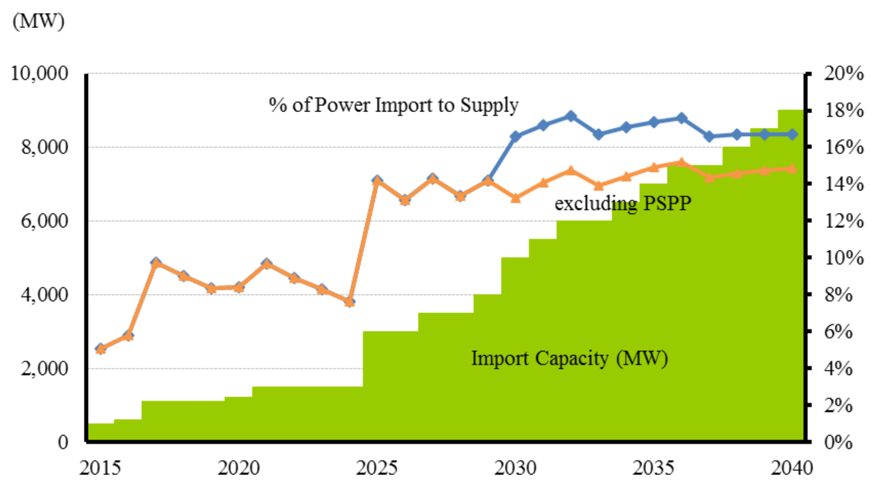
The Low Case Scenario, in which excessive import of electric power from neighboring countries is not expected, is shown below.

Table 15-10 Power Import Plan (Low Case Scenario)

		MW	Year	Remarks
1	Bheramara - Baharampur	500	2013	Existing
2	Tripura - Comilla	100 100	2016 2020	Some load (100MW+100MW) in Comilla will be connected to Indian system.
3	Bheramara - Baharampur	500	2017	Extension of Bheramara HVDC.
4	Bheramara - Baharampur	500 500	2027 2031	Additional extension of Bheramara HVDC Power import from Nepal
5	Tripura - Comilla	300	2020	Construction of HVDC (500MW) in Comilla. Some load (100MW+100MW) in Comilla will be disconnected from Indian system.
6	Rangia/Rowta - Barapukuria	1,000	2025	Power import by using Case 2 T/L (±800kV DC)
7	Rangia/Rowta - Barapukuria	500 500	2036 2039	Power import by using Case 2 T/L (±800kV DC)
8	From Nepal (Purnea - Barapukuria)	500 500	2025 2029	Power import by using Case 3 T/L (initially 400kV AC)
9	Bongaigaon/Rangia - Jamarpur	500 500	2032 2034	Power import from Bhutan
10	Bibiyana - Meghalaya (PSPP)	1,000	2030	PSPP in Meghalaya State
11	From Nepal	500 500	2035 2038	Power import by using Case 3 T/L (upgrade to 765kV AC)
12	Cox's Bazar - Myanmar	500	2040	Power import from Myanmar
	Total	9,000		

Source: JICA Survey Team

The following figure shows the import volume and its share against the total supply capacity in the low case scenarion power import plan.



Source: JICA Survey Team

Figure 15-8 Future Power Import Volume and its Share (Low Case Scenario)

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

(3) Power import situation

The power import from neighboring countries situation in 2025, 2030 and 2035 is shown below.

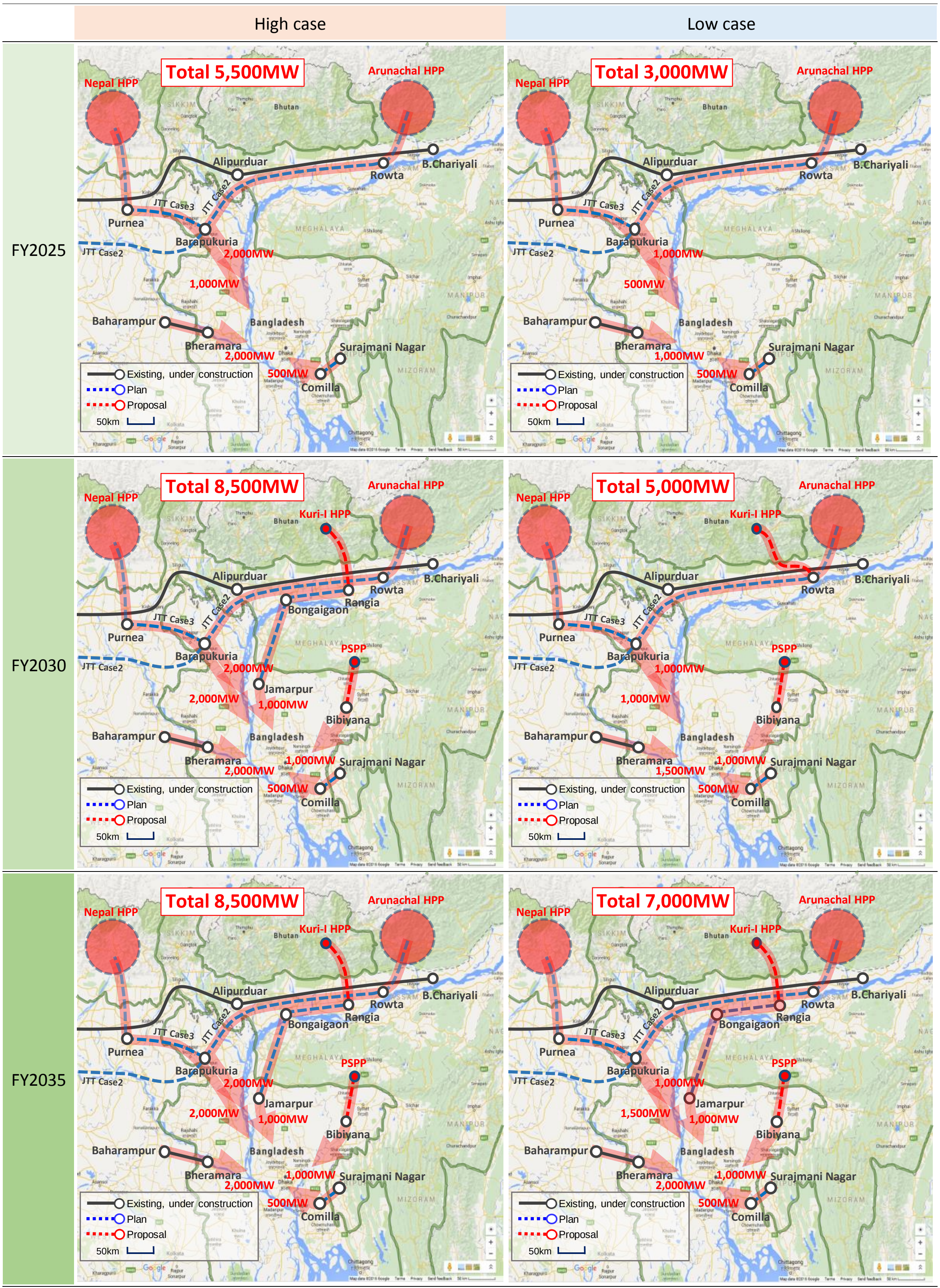


Figure 15-9 Power Import Situation

15.5.3 Implementation Arrangement

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

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

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

To provide a discussions platform of this kind, a group of countries comprising Bangladesh, Bhutan, India and Nepal (BBIN) has been formulated. BBIN holds Joint Working Groups (JWGs) twice a year. Therefore, it seems to be most effective to discuss regional power trades and interconnection in JWGs for the implementation of specific projects.

15.6 Nuclear Power Generation

15.6.1 Abstract

It was planned to construct nuclear power plant in the then East Pakistan (now Bangladesh) in 1961. For this the Government of the then Pakistan took 253.90 acres of land in that year to build the plant at Ruppur, on the banks of the Padma River, in the Ishwardi subdistrict of Pabna, in the northwest of the country. In 1963 the plant was approved. Discussions took place with the Canadian government in 1964 and 1966. Discussions with the governments of Sweden and Norway were also going on in those years. After the independence of Bangladesh, the Government of Bangladesh started discussion with the Soviet Union in 1974, however no agreement was reached. Meanwhile, the Bangladesh Atomic Energy Commission (BAEC) was established in 1973 after independence of Bangladesh. A TRIGA research reactor was installed at the Atomic Energy Research Establishment in Savar, Dhaka. It is now operating.
In 2001 Bangladesh adopted a national Nuclear Power Action Plan. On 24 June 2007, Bangladesh's government announced plans to build a nuclear power plant to meet electricity shortages. In May 2010, Bangladesh entered into a civilian nuclear agreement with the Russian Federation. It also has framework agreements for peaceful nuclear energy applications with the US, France and China.
In 2009 the Bangladesh government again started discussion with the Russian government and on 13 February 2009 the two governments signed a memorandum of understanding. Rosatom said they would start construction by 2013.
Finally, in February 2011, Bangladesh reached an agreement with Russia to build the 2,000 megawatt (MW) Ruppur Nuclear Power Plant with two reactors, each of which will generate 1,200 MW of power. The nuclear power plant will be built at Ruppur, on the banks of the Padma River, in the Ishwardi subdistrict of Pabna, in the northwest of the country, already acquired by the Government. The RNPP is estimated to cost up to US$2 billion, and start operating by 2021. The inter-governmental agreement (IGA) was officially signed on 2 November 2011.
But, in 2013 a group of Bangladeshi scientists and the global diaspora voiced profound concern over the safety and economic viability of the plant. Several separate issues were raised, from the unsuitability of the site to the obsolescence of the VVER-1000 model proposed, questionable financing arrangements and a lack of agreement with Russia over nuclear waste disposal.
In 2015 the proposal was delayed by a year. Rosatom offered a two VVER-1200 reactor power plant, increasing output to 2.4 GWe. By December 2015 the estimated cost of the plant had climbed to US$13 billion, from statements of around US$4 billion made earlier in the same year.
Bangladesh and Russia have reportedly agreed to invest $12.65 billion in a project to build two 1200 MWe nuclear power units at Ruppur. The agreement was signed on 25 December 2015 by Bangladesh Atomic Energy Commission (BAEC) and Russia's Rosatom. Russia will finance up to 90% of the total cost of the project as credit with an interest rate of Libor plus 1.75%. Bangladesh will pay off the loan within 28 years with a 10-year grace period. Work is expected to start at Ruppur early 2016. The first unit is to start operations by 2022 and the second by 2023. Rosatom will maintain the plant for the first year of its commercial operation before handing over to the Bangladesh authorities, and will bear fuel costs for the first year of operation, according to the report.
In 2016 ground preparation work commenced. The $12.65 billion contract is 90% funded by a loan from the Russian government. The two units generating 2.4 GWe are planned to be operational in 2023 and 2024. Rosatom will operate the units for the first year before handing over to Bangladeshi operators. Russia will supply the nuclear fuel and take back spent nuclear fuel.
In order to run the RNPP, a company, Nuclear Power Company of Bangladesh, will be set up under the Act. A bill was passed in parliament in August 2014 to establish a company to run the plant. Bangladesh Atomic Energy Commission will own the plant while the Nuclear Power Company will run it.
Very recently, a Bangladesh delegation comprising representatives of the Finance and Science and Technology Ministries and the Economic Relations Division (ERD) is set to visit Russia between May 18 and 20 to sign an agreement to finalize the terms and conditions of US $12.65 billion credit from Russia to materialize country's dream project - Ruppur Nuclear Power Project (RNPP).
Although Nuclear power plays an important strategic role in enhancing energy security for some

countries like Bangladesh and avoiding almost four years' worth of global energy-related carbon-dioxide (CO2) emissions by 2040, nuclear power faces major challenges in competitive markets where there are significant market and regulatory risks, and public acceptance remains a critical issue worldwide. Many countries must also make important decisions regarding the almost 200 nuclear reactors due to be retired by 2040, and how to manage the growing volumes of spent nuclear fuel in the absence of permanent disposal facilities.

15.6.2 Background

Bangladesh is a historically agrarian country. But the agricultural sector has shrunk from over 30% in the 1980s to under 20% a decade into the millennium. On the other hand, industry is growing from under 20% in the 1980s to over 30% currently. With highly industry national economy, the generation of electricity will be linearly related to the national GDP. With lesser agriculture and more industry, not only more emissions will be given off to the atmosphere but lack of trees and plants will hinder any chance of carbon sequestration.

The underdeveloped and mismanaged energy infrastructure of Bangladesh has inhibited economic growth. With a derated capacity of around 5500 Megawatt (MW) on an installed rating of over 6000 MW, only around 4000 is actually available. With a maximum generation of 4500 MW in mid-2010 to 4700 MW in late 2010, the peak is anywhere from 5700 MW to 6000 MW and only about 40% to 48% of the total population have access to electricity. The per capita consumption of 218-230 kWh and the availability is the lower among any developing country in the world.

The main source of national energy is in its natural gas reserves 55% of it goes to the power generation sector while 27% goes to factories and industry, 10% to household purposes and 5% in the automotive sector. Furthermore, the government has a targeted six, 5-year plans from 2010 to 2021 where it would try to produce 8,500 MW in 2013, 11,500 MW in 2015 and 20,000 MW by 2021. It is a part of the 'Digital Bangladesh' scheme's Vision 21 where the government would seek universal electrification around the nation. The plan also targets an increase in domestic and important coal based power plants, and more on-shore or off-shore gas exploration. Ruppur Nuclear Power Plant Implementation Project (RNNP) is also one such scheme to reach an addition capacity of 9000 MW.

Currently, around 88% of energy used for power generation is from natural gas sources and 4% from coal, 6% from oil and just 2% from Hydro-based power plants in Chittagong. Renewable Energy sources are totally excluded from any contributions. By 2021, the target plans to reduce gas imports to 30%, while raising coal contributions to 53%. This will have disastrous effects. Finally by 2030, renewable energy contributions would by increased to a mere 6%, while nuclear power was increased to around 30%.

15.6.3 History of Nuclear Power Development in Bangladesh

Bangladesh first conceived building a nuclear power plant in 1961. The Bangladesh Atomic Energy Commission was established after independence in 1973. The country currently operates a TRIGA research reactor at the Atomic Energy Research Establishment in Savar.

More recently, in 2001 Bangladesh adopted a national Nuclear Power Action Plan. On 24 June 2007, Bangladesh's government announced plans to build a nuclear power plant to meet electricity shortages. In May 2010, Bangladesh entered into a civilian nuclear agreement with the Russian Federation. It also has framework agreements for peaceful nuclear energy applications with the US, France and China.

In February 2011, Bangladesh reached an agreement with Russia to build the 2,000 megawatt (MW) Ruppur Nuclear Power Plant with two reactors, each of which will generate 1,200 MW of power. The nuclear power plant will be built at Ruppur, on the banks of the Padma River, in the Ishwardi subdistrict of Pabna, in the northwest of the country. The RNPP is estimated to cost up to US$2 billion, and start operating by 2021. The inter-governmental agreement (IGA) was officially signed on 2 November 2011. On 29 May 2013 Bangladesh's Prime Minister declared that a second nuclear power plant will be constructed on an inland river island in southern region of the country.

15.6.4 Establishment of Ruppur Nuclear Power Plant

(1) Location

The nuclear power plant will be built at Ruppur, 200 km north-west of Dhaka, at Paksey union on the bank of the river Padma in the Ishwardi subdistrict of Pabna District, in the northwest of the country. The Coordinates of the proposed nuclear power plant is 24° 03′ 58″ N, 89° 02′ 49″ E. Map of Bangladesh showing location of RNPP is given in Figure 15-10

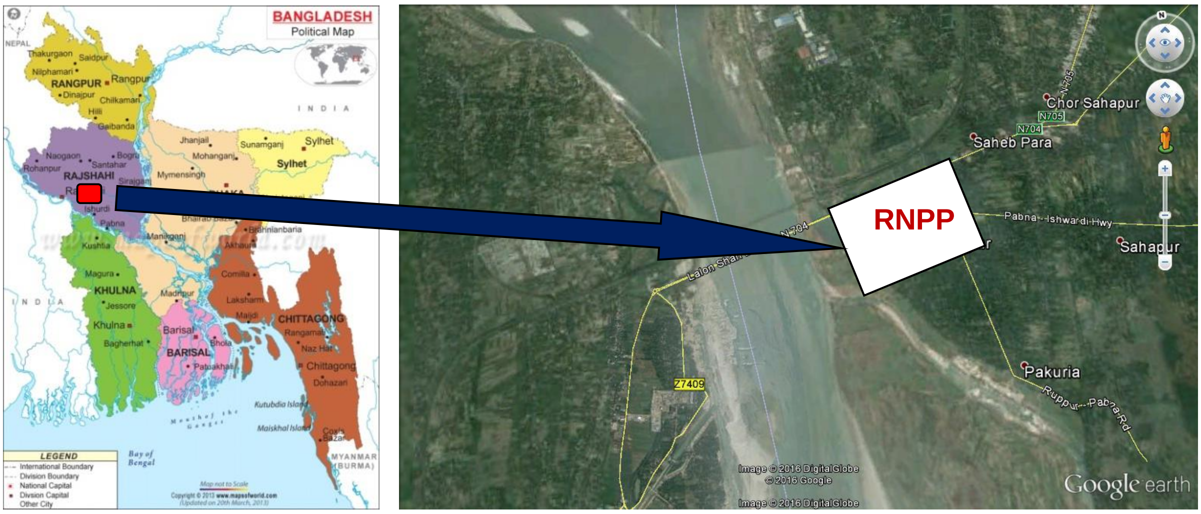


Figure 15-10 Location of RNPP

(2) Planning of RNPP

The proposal for construction of Ruppur Nuclear Power Plant (RNPP) was made in 1961. Government of the then Pakistan took 253.90 acres of land in that year to build the plant. In 1963 the plant was approved. Discussions took place with the Canadian government in 1964 and 1966. Discussions with the governments of Sweden and Norway were also going on in those years. However, no real progress was achieved. After the independence of Bangladesh, the Government of Bangladesh started discussion with the Soviet Union in 1974, however no agreement was reached. In 2001 the government adopted a national Nuclear Power Action Plan.

In 2009 the Bangladesh government again started discussion with the Russian government and on 13 February 2009 the two governments signed a memorandum of understanding. Rosatom said they would start construction by 2013.

In 2013 a group of Bangladeshi scientists and the global diaspora voiced profound concern over the safety and economic viability of the plant. Several separate issues were raised, from the unsuitability of the site to the obsolescence of the VVER-1000 model proposed, questionable financing arrangements and a lack of agreement with Russia over nuclear waste disposal.

In 2015 the proposal was delayed by a year. Rosatom offered a two VVER-1200 reactor power plant, increasing output to 2.4 GWe.

By December 2015 the estimated cost of the plant had climbed to US$13 billion, from statements of around US$4 billion made earlier in the same year. Transparency International Bangladesh expressed concern on 28th December 2015 about the safety of the proposed plant, stating "Even reputed Russian environmentalists consider Russian nuclear reactors unsafe".

In 2016 ground preparation work commenced. The $12.65 billion contract is 90% funded by a loan from the Russian government. The two units generating 2.4 GWe are planned to be operational in 2023 and 2024. Rosatom will operate the units for the first year before handing over to Bangladeshi operators. Russia will supply the nuclear fuel and take back spent nuclear fuel.

(3) Implementation of RNPP

A company, Nuclear Power Company of Bangladesh, will be set up under the Act.
The prime minister laid the foundation of this power project at Ruppur in October 2013. A bill was passed in parliament in August 2014 to establish a company to run the plant. Cabinet Secretary M Musharraf Hossain Bhuiyan told reporters that the government expected the plant to start production in 2021. He said Bangladesh Atomic Energy Commission will own the plant while the Nuclear Power Company will run it. The science and technology ministry proposed the new law in order to give the matter a legal foothold, he said. According to Bhuiyan, the law details the provision to set up the independent company, role of the government's control to run the company and the role of Russia which is providing technology for the plant. He said the company will have a board like others. Its authorised capital will be Tk 10 million with 1,000 shares of Tk 100 each, he said. The science and technology secretary will be the director and chairman of the company, the cabinet secretary said. The other directors will include Atomic Energy Commission chairman, an additional or joint secretary from the science and technology ministry, Finance Division and the Economic Relations Division, a representative from FBCCI, Power Development Board chairman and Power Grid Company of Bangladesh Limited managing director. Power-starved Bangladesh inked an agreement with Russia for constructing a nuclear power plant in Ruppur. Russia will provide all assistance for setting up the plant, including providing the fuel and taking back the used fuel. Each of the two units at Ruppur is expected to cost $1.5 billion to $2 billion. Bangladesh will bear 10 percent of the cost while Russia provides the rest as loan.The plant will be in operation for 60 years but its life can be extended by another 20 years.Hasina's government aims to boost power production to 20,000MW by 2021. The plant will be built with third-generation technology protected by five-layers of security. Accidents at nuclear power plants are not uncommon. Japan is still reeling from a nuclear accident at its Fukushima plant in 2011. Hasina, while inaugurating the plant in 2013, had said that Russian Atomic Energy Corporation would supply required energy for running the plant and take back the wastes. "So there is no need to worry about that," she had said.

Figure 15-11 Land Development at The Ruppur Power Plant Project

(4) Financing of RNPP

Bangladesh and Russia have reportedly agreed to invest $12.65 billion in a project to build two 1200 MWe nuclear power units at Ruppur. The agreement was signed on 25 December 2015 by Bangladesh Atomic Energy Commission (BAEC) and Russia's Rosatom.

Russia will finance up to 90% of the total cost of the project as credit with an interest rate of Libor plus 1.75%. Bangladesh will pay off the loan within 28 years with a 10-year grace period. Work is expected to start at Ruppur early 2016. The first unit is to start operations by 2022 and the second by 2023. Rosatom will maintain the plant for the first year of its commercial operation before handing over to the Bangladesh authorities, and will bear fuel costs for the first year of operation, according to the report.

The foundation stone was laid at the Ruppur site in October 2013 after Russia and Bangladesh signed an initial contract on the construction of the country's first nuclear power plant. The contract signed by NIAEP-ASE president Valery Limarenko and BAEC chairman Abu Sayed Mohammed Firoz is a technical agreement covering the design stage of the project, which is expected to take about two years to complete and will form the basis for obtaining the necessary licences and starting construction of the plant.

Ruppur's two reactors will be based on a modified version of the NPP-2006 VVER (pressurized water reactor), designed exclusively for the site on the eastern bank of the river Ganges 160 km from Dhaka. Russia agreed to build the Ruppur plant in an intergovernmental agreement signed in 2011, and agreed to provide $500 million to finance preparatory work including engineering surveys, and is to provide future loans to finance the actual construction project.

(5) Visit of High powered Team to Russia for RNPP

A Bangladesh delegation comprising representatives of the Finance and Science and Technology Ministries and the Economic Relations Division (ERD) is set to visit Russia between May 18 and 20 to sign an agreement to finalise the terms and conditions of US $12.65 billion credit from Russia to materialize country's dream project - Ruppur Nuclear Power Project (RNPP).

Prime Minister's Economic Affairs Adviser Dr Mashiur Rahman is expected to lead the financial team which has been tasked to ensure a credit to the tune of billion dollars for installing the RNPP in Pabna

district on the north-western Bangladesh. The government for the third time is sending the financial team to seek support of the Russian government for the credit.
It is the final negotiation for $11.385 billion Russian credit, the proposed credit amount is 90 per cent of the $12.65 billion (equivalent to Tk 101,200 crore) construction cost of RNPP, which Russian Federation will provide as state credit. It will also be the single largest foreign loan in the history of Bangladesh.
Executive Chairman of the Board of Investment (BoI) SA Samad, Principal Secretary to the PM and secretaries from the ministries of Power, Finance, Foreign Affairs and Law and the Economic Relations Division (ERD), Planning Commission and Chairman of the Bangladesh Atomic Energy Commission (BAEC) are the other members of the team.
Earlier, the same team visited Russia and agreed that Russia and Bangladesh would invest in this project on 90: 10 ratio.
Bangladesh agreed to take the new version of VVER -1200 technology (which has not been tasted outside Russia). It however complies with the International Atomic Energy Agency (IAEA) standards and is an evolutionary version of India's Kudankulum nuclear plant, to which the 'water cooling' was added. This is considered to be the safest nuclear power technology with active and passive safety systems.
Tthe credit (final) agreement is expected to be signed by this year (2016) to start the main construction by the end of 2016.
As per Prime Minister Sheikh Hasina's directive, the Ministry of Science and Technology and the RNPP authorities have to settle the monetary issue with Russia's Rosatom State Atomic Energy Corporation (ROSATOM). In line with the directive the same team visited Moscow and agreed that Bangladesh needs $US 12.65 billion to implement 1200 MW nuclear power plant with Russian technology.
Yafes said Russia would provide 90 per cent of the credit at 1.75% interest plus London Interbank Offered Rate. Bangladesh will have to pay back the credit in 28 years with a 10-year grace period.
According to sources, at Ministry of Science and Technology, Russian government has recently sent a letter inviting Bangladesh team to visit Moscow to start the negotiation to prepare a draft agreement for the credit.
The letter from the Russian government to start the discussion on the proposed credit agreement has been received. Now the government will form a negotiation team comprising representatives of different ministries.

15.6.5 Nuclear Risk & Safety

There are arguments in favor of nuclear energy when compared to the use of coal. For example, a single 1000 MW coal-fired plant produces over 300,000 tons of ash, 44,000 tons of sulphur dioxide, 22,000 tons of Nitrous Oxide and 6 million tons of carbon. In contrast, a 1000 MW of nuclear power plant produces 3 cubic meters of waste after reprocessing the spent fuel, 300 tons of radioactive waste and 0.20 tons of plutonium. However, a unit ton of nuclear waste is far more dangerous than the same amount of coal-fired plant waste, if not managed properly. At the same time, dealing with nuclear wastes is more expensive. Apart from nuclear waste, there is also severe risk of operating nuclear reactor which can cause disaster if any accident takes place in the reactor.
Although Nuclear power plays an important strategic role in enhancing energy security for some countries like Bangladesh and avoiding almost four years' worth of global energy-related carbon-dioxide (CO2) emissions by 2040, nuclear power faces major challenges in competitive markets where there are significant market and regulatory risks, and public acceptance remains a critical issue worldwide. Many countries must also make important decisions regarding the almost 200 nuclear reactors due to be retired by 2040, and how to manage the growing volumes of spent nuclear fuel in the absence of permanent disposal facilities
So, Nuclear safety remains the highest priority for the nuclear sector. Regulators have a major role to play to ensure that all operations are carried out with the highest levels of safety. Safety culture must be promoted at all levels in the nuclear sector (operators and industry, including the supply chain, and regulators) and especially in newcomer countries like Bangladesh.

Chapter 16 Power System Plan

16.1 Task of Power System Plan

The power network system planning will be examined by categorizing its phases into short-term (2015 to 2020), mid-term (2025) and long-term (2035) and reviewing PSMP2010. The required power system analysis will be carried out using PSS/E software. The Survey should take notice of the following issues.

Power Supply-Demand Imbalance among the Regions
The power interconnections to neighboring countries, the seaports for importing fuels and the mining points of domestic coal/gas will be scattered around the country, causing regional energy imbalance and requiring power trades among the regions. These kinds of trends seem to be enhanced and the transmission lines for regional connections will be further needed from the mid and long term points of view.

Power Imports and Exports by Interconnections
Power imports from the hydropower stations of neighboring countries such as India, Bhutan or Nepal are planned, in consideration of their possibility of economical energy supply due to the shortage of domestic gas supply and of broadening the energy sources for Bangladesh. The information regarding interconnections will be collected and related detailed power system analysis will be carried out.

The Transmission Lines Accrosing Rivers
There will be a restriction of power flows between the eastern and western sides of the country because Bangladesh has two large rivers in its center, Jamuna and Padma, with widths of 4.5km to 6km even at their narrowest points. It would entail much cost to construct power transmission lines across these large rivers.
A bridge across the Padma River was designed in detail in 2010 and the contractors that are currently under selection will also construct the seven bases of towers for the 400 kV transmission line connecting Khulna to Dhaka, located at its downstream side. This construction method may be applied for other river crossing transmission lines in Jamuna and Padma.

Optimal operation planning of power system
Through the local power systems connecting to each other, improvement of power supply reliability and economic merit will be expected. On the other hand, new issues such as concerns about accident impact from weak points in the system upon the whole system and the necessity of different know-how to operate a country-wide large connection system will be created. Countermeasures against the issues will be discussed and examined with the relevant counterparts.

16.2 Maximum Power Demand Forecast by PGCB

The maximum loads at substations are initially estimated based on the power demand forecast of 132 kV substations up to 2035 by PGCB. The applicable maximum loads of 132 kV substations for the study of the bulk power transmission lines should be matched with the maximum power demand in the whole national grid resulted in this Master Plan Study. The regional maximum loads after 2035 are also estimated according to the national power demand forecast. The following table shows the maximum power demand forecast of 132 kV substations up to 2035 prepared by PGCB.

Table 16-1 Maximum Power Demand Forecast of 132 kV Substations up to 2035 by PGCB

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Comilla	1,170	1,307	1,466	1,642	1,842	2,045	2,283	2,525	2,788	3,033	3,313
Chittagong	1,017	1,134	1,318	1,449	1,591	1,743	1,910	2,071	2,257	2,405	2,618
Khulna	1,341	1,453	1,596	1,747	1,943	2,141	2,354	2,602	2,791	2,988	3,212
Bogra	1,473	1,617	1,783	1,981	2,191	2,398	2,615	2,833	3,055	3,293	3,505
Dhaka	1,869	2,106	2,334	2,589	2,954	3,286	3,629	3,943	4,279	4,589	4,903
DESCO	956	1,058	1,230	1,367	1,483	1,647	1,795	1,958	2,140	2,374	2,578
DPDC	1,510	1,675	1,934	2,101	2,321	2,581	2,868	3,173	3,535	3,880	4,242
Total	9,336	10,350	11,660	12,874	14,325	15,841	17,454	19,106	20,844	22,562	24,370

	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Comilla	3,565	3,824	4,053	4,337	4,573	4,746	4,925	5,088	5,258	5,434
Chittagong	2,823	3,009	3,208	3,367	3,534	3,695	3,856	4,024	4,200	4,385
Khulna	3,407	3,595	3,805	4,036	4,262	4,424	4,557	4,712	4,865	5,024
Bogra	3,718	3,936	4,161	4,374	4,588	4,759	4,922	5,087	5,259	5,435
Dhaka	5,200	5,547	5,901	6,247	6,606	7,003	7,336	7,657	7,993	8,346
DESCO	2,807	3,032	3,274	3,580	3,853	4,081	4,326	4,565	4,818	5,089
DPDC	4,723	5,139	5,558	6,003	6,450	6,885	7,274	7,659	8,056	8,490
Total	26,243	28,082	29,960	31,943	33,866	35,593	37,195	38,793	40,449	42,203

16.3 Power System Network Study

The bulk power transmission lines and substations in the national grid will be studied in consideration of both the regional distribution of power generation units and the loads of substations. There will be large power stations located 200 to 300 km from Dhaka. Thus, 765 kV power transmission lines will be studied, as well as the introduction of a 400 kV system especially for Chittagong south and the Khulna area to secure power system reliability, to save the line routes and to save on their cost. The 400 kV transmission lines will still be needed because some amount of 400 kV substations will be required for regional power supply in future. The current plan for the national grid by PGCB shown in Figure 16-1 will be upgraded in the course of this study. PSS/E software will be used for the study of power flow, fault current and system stability to judge the power supply reliability satisfaction and technological system requirements. The cost of the required investment for the future bulk power transmission lines and substations will be estimated.

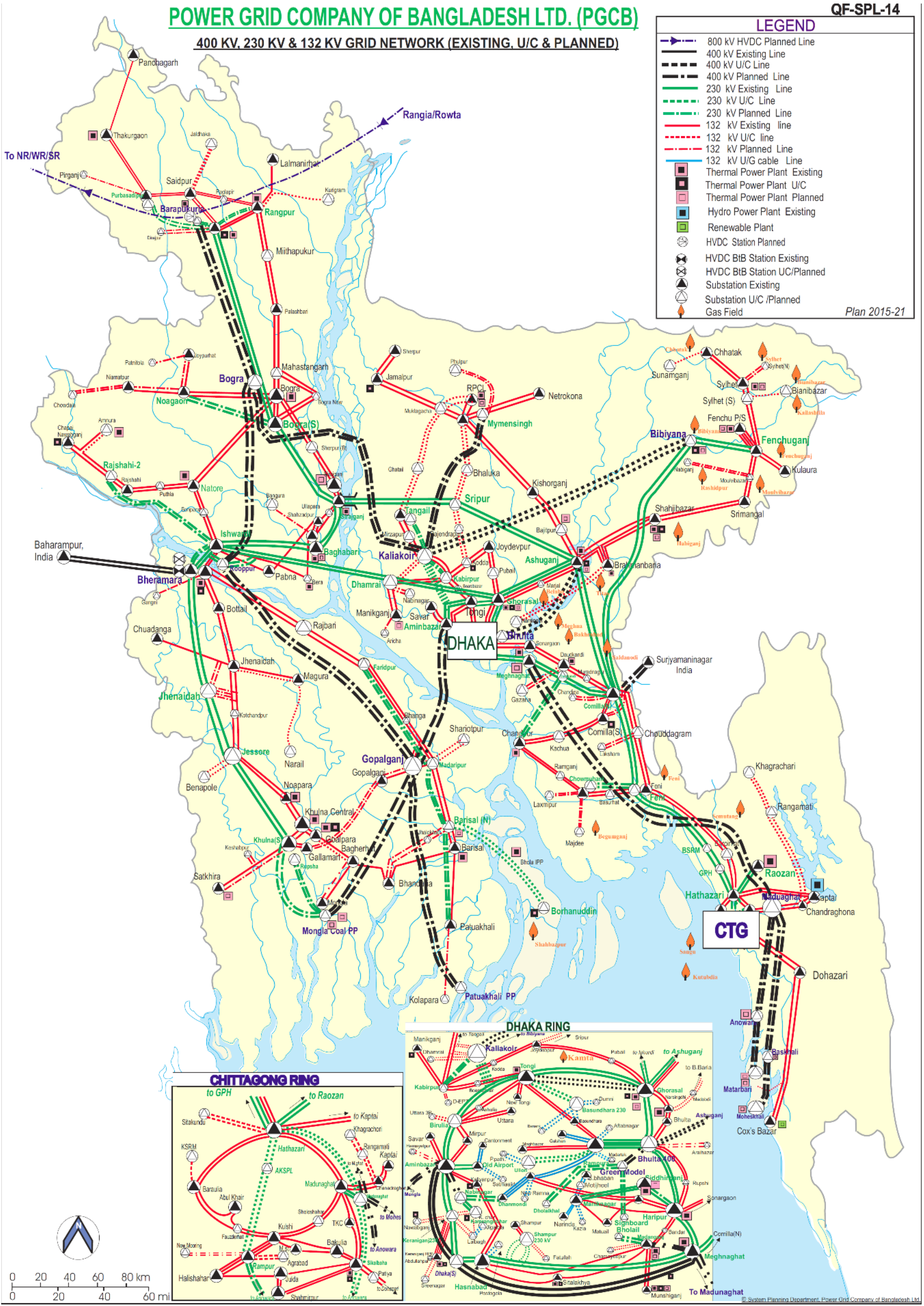


Figure 16-1 Power Network Plan by PGCB

16.4 Rural Electrification

16.4.1 Government Policy and Definition

While, the government has established the "Electricity for all" by 2021, in its Vision Statement, there is no single internationally-established definition for electricity access. However, IEA uses in its analysis "electricity access at the household level, that is, the number of people who have electricity in their home. It comprises electricity sold commercially, both on-grid and off-grid. It also includes self-generated electricity for those countries where access to electricity has been assessed through surveys by government or government agencies. The data does not capture unauthorised connections. The national, urban and rural electrification rates shown indicate the number of people with electricity access as a percentage of the total population" [45].

Bangladesh in fact adopts three different definitions and figures for "electrification rate" by three governmental institutions.

- BPDB Definition

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

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

Source: BPDB System Planning Division

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

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

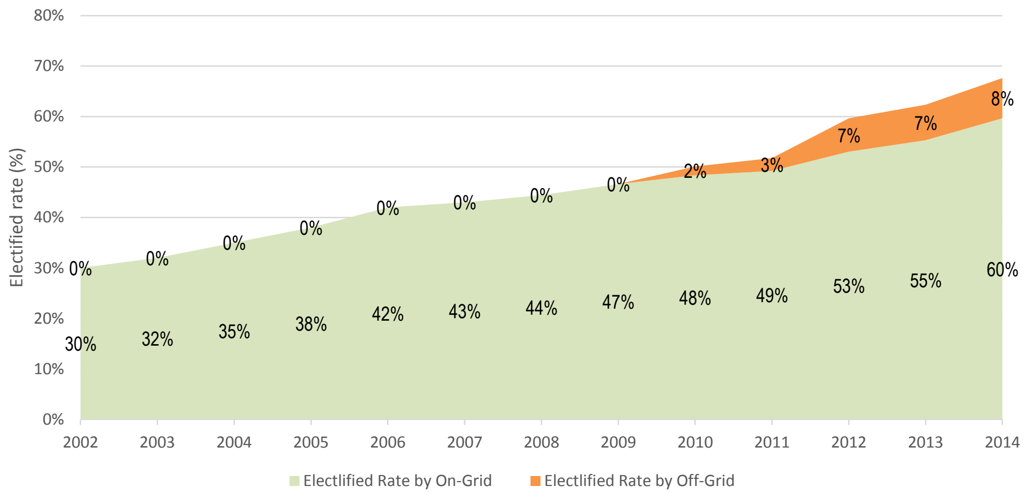
This BPDB definition indicates that the electrification rate improvement has two paths; one is on-grid connection, the other is off-grid connection (e.g. SHS).

Table 16-2 and Figure 16-2 shows the Access to Electricity provided by BPDB. According to Figure 16-2, 60% of population were electrified by grid connection; 8% of population was electrified by SHS installation. In total 68% were electrified in 2014 in Bangladesh.

45 https://www.iea.org/media/weowebsite/energydevelopment/Poverty_Methodology.pdf

Table 16-2 Annual Status of Power Sector (2005-2014)

Item (FY)	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Installed Capacity (MW)	4995	5245	5202	5305	5719	5823	7264	8716	9151	10416
Generation Capacity (derated), MW)	4364	4614	4623	4776	5166	5271	6639	8100	8537	9821
Maximum Generation (MW)	3721	3782	3718	4130	4162	4606	4890	6066	6434	7356
Net Energy Generation (MkWh)										
(a) Public Sector	13223	14456	14539	15167	15449	16072	14673	15201	17994	19644
(b) IPP & Mixed	7939	8286	8244	9138	10173	11398	14811	18196	18488	18386
(c) Power Import										2265
(d) REB	246	236	484	641	911	1777	1871	1721	1747	1899
Total Net Energy Generation (MkWh)	21408	22978	23267	24946	26533	29247	31355	35118	38229	42195
Transmission Line (400, 230 &132 kV)(Ckt. Km.)	6759 (ckt.km)	6844 (ckt.km)	7044 (ckt.km)	7848 (ckt.km)	8330 (ckt.km)	8465 (ckt.km)	8616 (ckt.km)	8949 (ckt.km)	9322 (ckt.km)	9536 (ckt.km)
Distribution Line (K.M)	244104	264891	271142	256143	259963	269877	274347	281123	288787	302760
Total Consumer Number (lacs)	88.47	97.33	104.2	107.9	115.05	119.88	123.51	135.427	142.32	154.41
Agricultural Consumer (lacs)	1.78	2.16	2.26	2.34	2.82	2.7	2.76	2.95	2.97	2.98
No. of Village Electrified	47612	49435	50360	50724	52334	53837	53925	54216	54638	56312
Population in Million	137	138.8	140.6	142.4	144.2	146	148	151.6	153.6	155.8
Access to Electricity (%) (Grid)	38	42	43	44.43	46.63	48.36	49.23	53.04	55.31	59.66
Access to Electricity (%) (Renewable)								7	7	8
Access to Electricity (%)	38	42	43	44.43	46.63	48.36	49.23	60.04	62.31	67.66
Per Capita Generation (kWh) (Grid)	158	165	165	175	184	200	212	232	249	271
Per Capita Generation (kWh) (Captive)				47	55	64	68	68	72	77
Per Capita Generatio (kWh)	158	165	165	222	239	264	280	300	321	348
Per Capita Consumption (kWh) (Grid)		131	134	143	152	168	180	198	213	233
Distribution Loss (%)		18.89	15.52	14.72	14.57	13.49	12.66	12.10	11.88	11.8
System Loss (Tr. & Dist) (%)	22.79	21.3	19.3	18.16	17.25	15.9	15.21	14.65	14.36	14.13



Source: JICA Survey Team

Figure 16-2 Development of Access to Electricity

- BREB

BREB defines the electrification rate as below:

Rural Electrification Rate = Current Distribution Line Distance (km) / Targeted Distribution Line Distance (km)

As of February 2016, the current distance 300,000km / Targeted distance 440,000km = 68% (the 300,000 km is the total distance of 33kV line, 11kV line and lower voltage lines). BREB does not use the BPDB's definition of rural electrification (the electrification rates of both organizations happen to be the same).

- Bangladesh Bureau of Statistics (BBS)

As discussed in the previous "Overview of Economy and Energy Balances of Bangladesh" Chapter, BBS adopts the electrification 86.4%. However, the definition of this figure is unclear and it might be over evaluated.

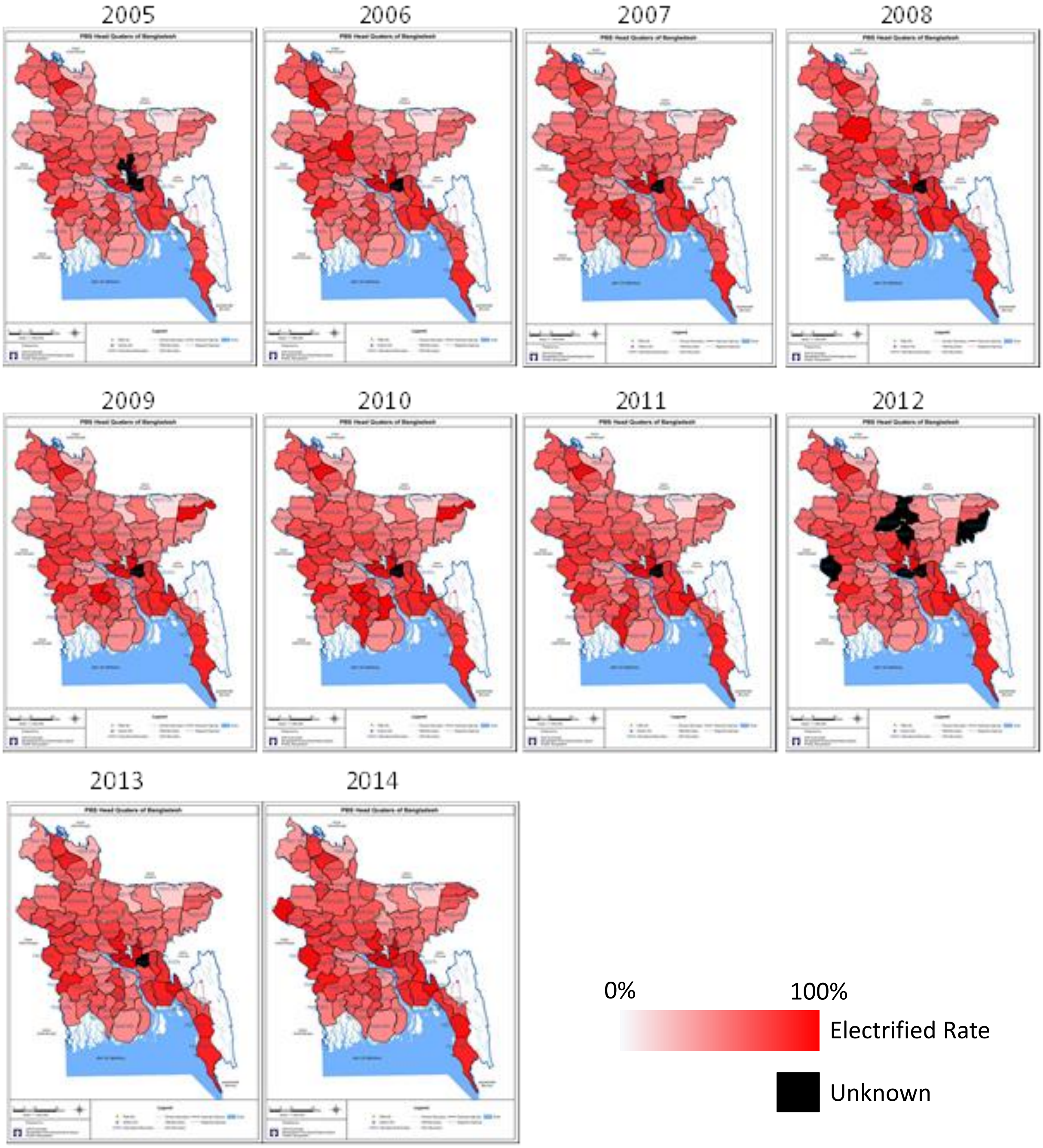
16.4.2 Power Distribution Entities in Bangladesh

Refer to "Power Sector Overview" in Chapter "Energy and Power Sector Overview".

16.4.3 On-Grid Electrification (Distribution line extension)

(1) BREB's distribution line extension plan

The following figures show the progress of electrification (approximately 300 thousand km). According to the BREB, if all of projects are completed, on-grid electrification will be 100%.



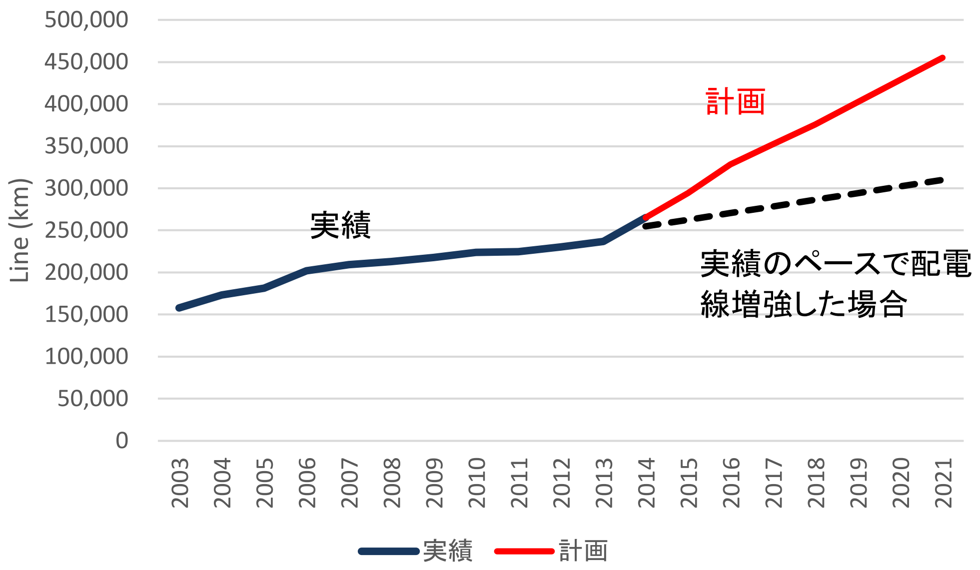
Source: JICA Survey Team based on the BREB information

Figure 16-3 BREB's Distribution Line Extension Progress

However, the completion of on-grid extension requires another 140,000km lines. The following table shows that BREB has already plans to add 120,000km and development partners indicate their interest for financing.

Table 16-3 List of Rural Electrification Projects

SL	Projects	Line (km)	Cost (million Tk)	Potential Funding Source
1	Prepaid meters (700,000 meters) in Dhaka Division (Phase 1)	-	4,360	ADB
2	1.5 million Consumer Connection	44,000	69,360	GoB
3	Rural Electrification Expansion Program I of Shylhet Division	7,000	13,820	
4	Replacement of Overhead Line X-Trs	-	10,550	
5	2.5 million Consumer Connection	-	12,320	AIIB
6	Rehabilitation & Inten (?) of Distribution System (Dhaka, Mymensingh, Chittagong and Shylhet)	24,000	31,200	ADB
7	Rehabilitation & Inten (?) of Distribution System (Rajshahi, Rangpur, Khulna and Barisal)	18,000	21,060	ADB
8	Prepaid meters (5 million meters)	-	47,500	China
9	Replacement of Overhead Line X-Trs	-	13,900	China
10	Rural Electrification and Upgradation Program 2	10,778	48,640	JICA?
11	Upgradatoin Rural Electrification and Distribution System 2	9,000	90,000	World Bank?
12	Solar Irrigation Pumps (375 nos.)	-	1,610	ADB
13	Upgradation of 33/11 kV Substations	4,400	30,000	ADB
14	Solar Irrigation Pumps (500 nos.)	-	16,450	
Total			410,770	



Source: JICA Survey Team

Figure 16-4 Growth of Distribution Line Length (BREB)

However, the above figure shows that BREB needs the substantial improvement of its project implementation speed, in order to achieve 100% electrification.

In addition, according to BREB, the rest 10% of 140,000 km (which is 14,000km) are population-scarce or river-crossing areas and thus low economic viability for grid extension. Furthermore these areas do not have PGCB transmission lines nearby, and transmission line expansion is the prerequisite for distribution line expansion.

For these difficult areas, BREB could extend their 33kV lines but not technically recommendable (huge voltage decline could occur). Otherwise, off-grid technologies such as SHS are required for electrification.

In this sense, a good communication and coordination between BREB and IDCOL is required; however, it is observed that such communication or coordination is not taking place. IDCOL is communicating to BPDB for project planning, but BPDB seems not liaising with BREB properly. If the Government seriously pursue the achievement of "Electrification for All" by 2021, the good communication and coordination between BREB and IDCOL must be taken, and both parties (and BPDB as a coordinator too) need to improve in this area.

(2) Estimation of BPDB

The following table shows the forecasts of Access to Electricity estimated by BPDB. According to the below Table, Access to Electricity reaches 90% by line extension by 2021.

Table 16-4 Power Utility Plan by Year

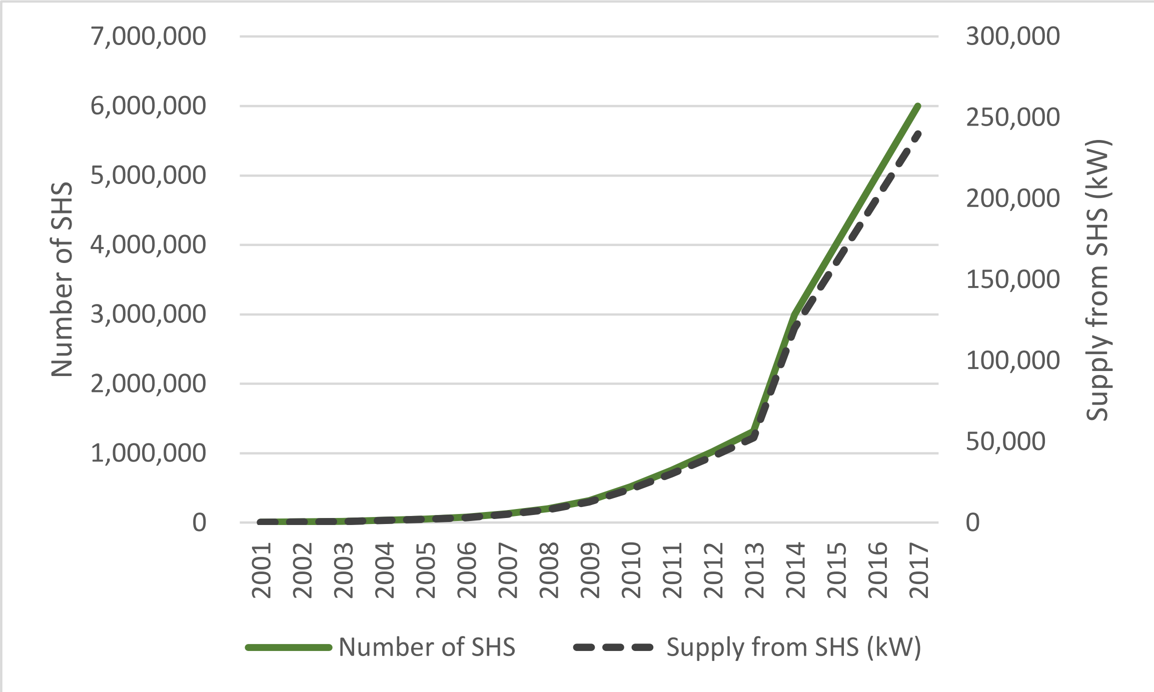
ITEM (FY)	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
GENERATION CAPACITY (DERATED), MW)	9631	12185	13640	15161	17111	18571	22571	24000
NET ENERGY GENERATION (MKWH) *	48713	54047	59945	66457	73658	81610	90950	99838
NET ENERGY GENERATION (MKWH) (REVISED)	42195	46200	51200	56200	62382	68620.2	75482.22	83030.44
TOTAL POPULATION IN MILLION	155.8	157.6	159.6	161.6	163.6	165.6	167.6	169.6
TOTAL DOMESTIC CONSUMER (IN MILLION)	13.28	14.2	15.1	16.2	17.6	18.9	20.3	21.8
ACCESS TO ELECTRICITY (%) (GRID)	60%	63%	66%	70%	75%	80%	85%	90%
PER CAPITA GENERATION (KWH) (GRID)	313	343	376	411	450	493	543	589
PER CAPITA GENERATION (KWH) (GRID) (REVISED)	271	293	321	348	381	414	450	490
PER CAPITA CONSUMPTION (KWH) (GRID)	269	295	324	356	391	429	473	514
PER CAPITA CONSUMPTION (KWH) (GRID) (REVISED)	233	254	279	304	336	367	401	441

* as per PSMP 2010
Source: BPDB

16.4.4 Off-Grid Electrification

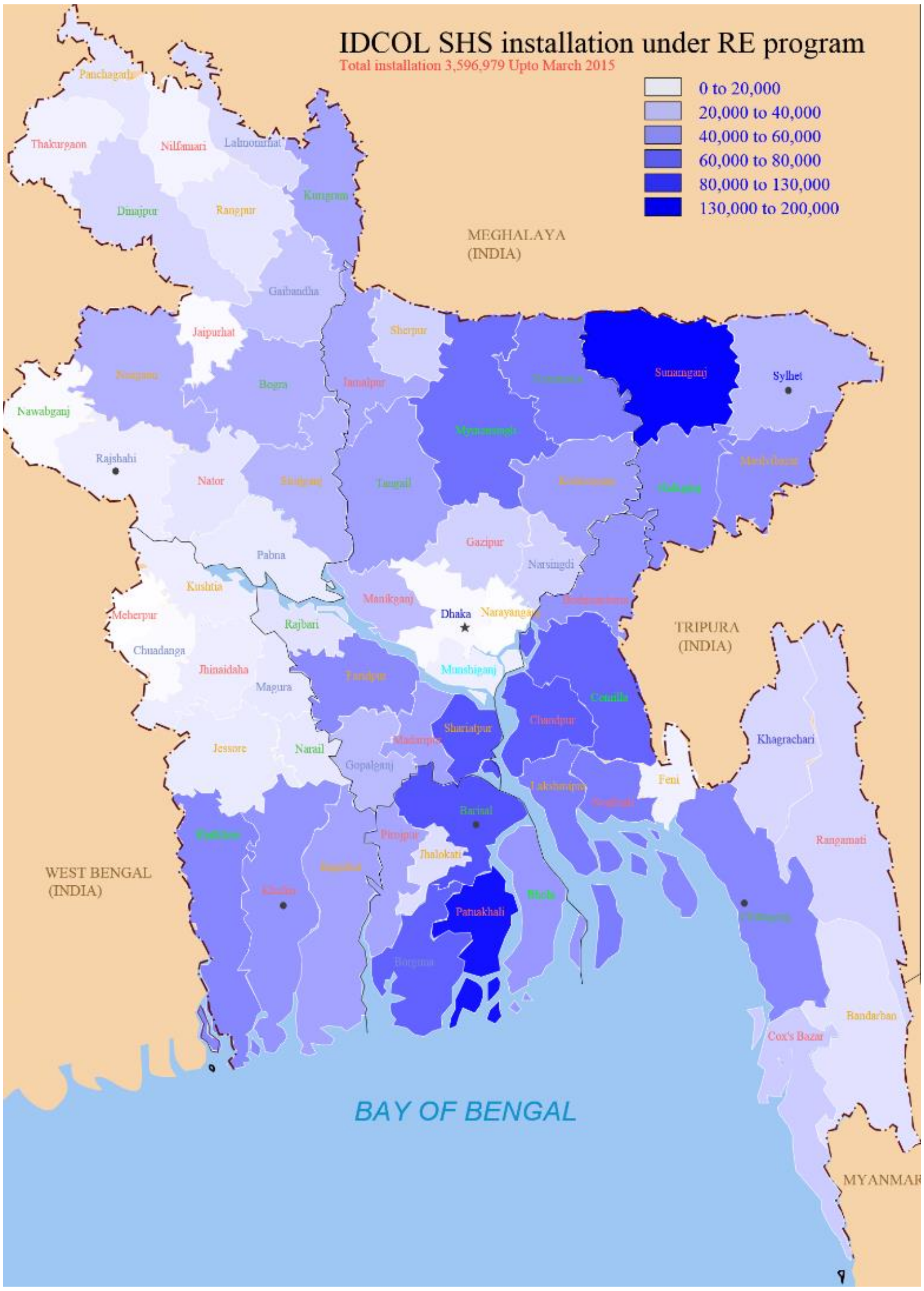
As discussed in the previous section, BREB's on-grid extension has technical limit. In order to achieve the electrification policy by 2021, off-grid technology needs to be employed to complement the on-grid extension.

The SHS installment has been implemented by IDCOL and the progress is world renowned pace (as seen in the below figure). IDCOL has a 6 million target by 2017. For solar micro-grid, IDCOL submits a plan to Power Division for project approval. On the other hand, the each installment for a household is selected by PO (refer to the Renewable Energy Chapter) and the coordination between BREB is not working effectively as described in the previous section. In order to achieve 100% electrification by 2021, more efficiency (including inter-institution coordination) is required for SHS implementation.



Source: JICA Survey Team

Figure 16-5 Number of SHS under IDCOL Program

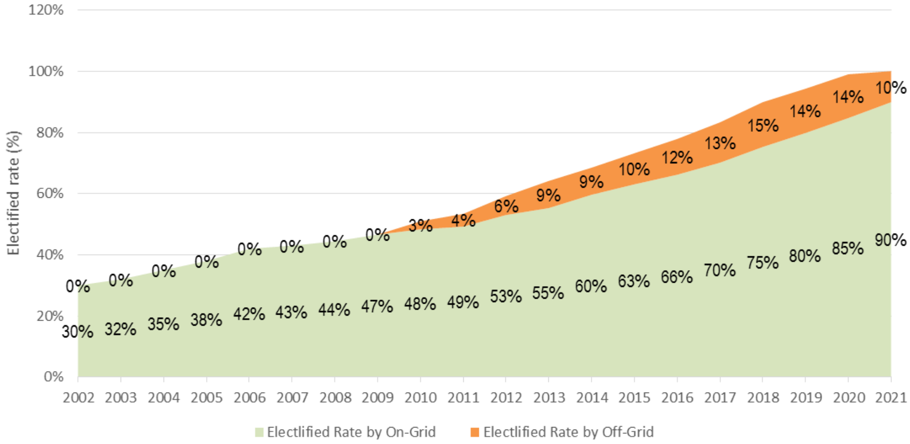


Source: IDCOL homepage

Figure 16-6 Status of SHS Installation

16.4.5 Approach for "Electricity for All"

Based on the estimation of Access to Electricity by BPDB (On-Grid) and SHS installation by IDCOL (Off-Grid), JICA Survey Team estimates the pace of "Electrification for All". It is assumed that the Access to Electricity becomes 100% in 2021. Figure below shows the path to achieve the target.

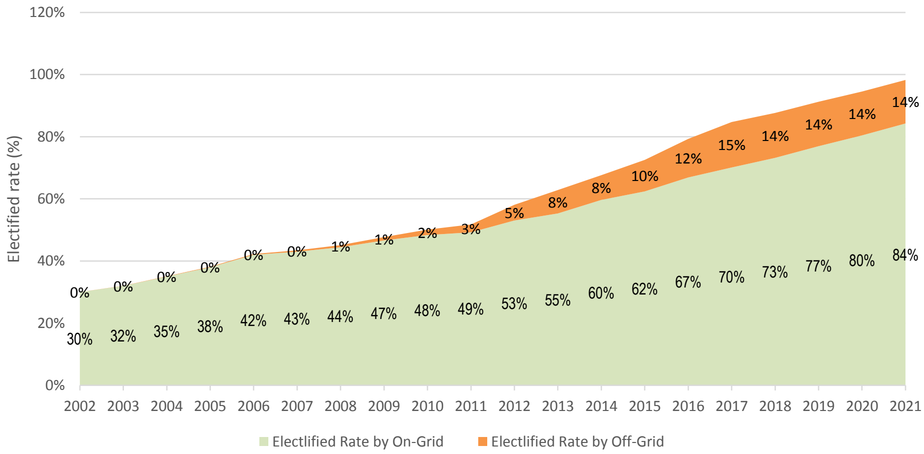


Source: JICA Survey Team

Figure 16-7 Growth of Access to Electricity (BPDB estimation + IDCOL)

On the other hand, the next Figure shows the Growth of Access to Electricity (BREB project + IDCOL). The projects of BREB are formed in accordance with the BPDB estimation. Therefor if BREB completes the projects as per the schedule, the target of Access to Electricity will be achieved, although coordination between BREB and IDCOL is not conducted well.

However, in order to realize the 100% electrification by 2021, there are two major issues. First of all, distribution line extension speed has to be doubled compared with the past. The study shows that BREB should take responsibility for implementation of construction work. Secondly, according to the interview with BREB, 10% of future electrification area is not economically viable due to the scarce population density or river-crossing areas. Because transmission lines are not extended to these area, if PGCB does not extend the transmission line, it is difficult to extend the line to these areas. From the view point of the information from BREB, there will be off-grid electrification areas at the first period of the 100% electrification.

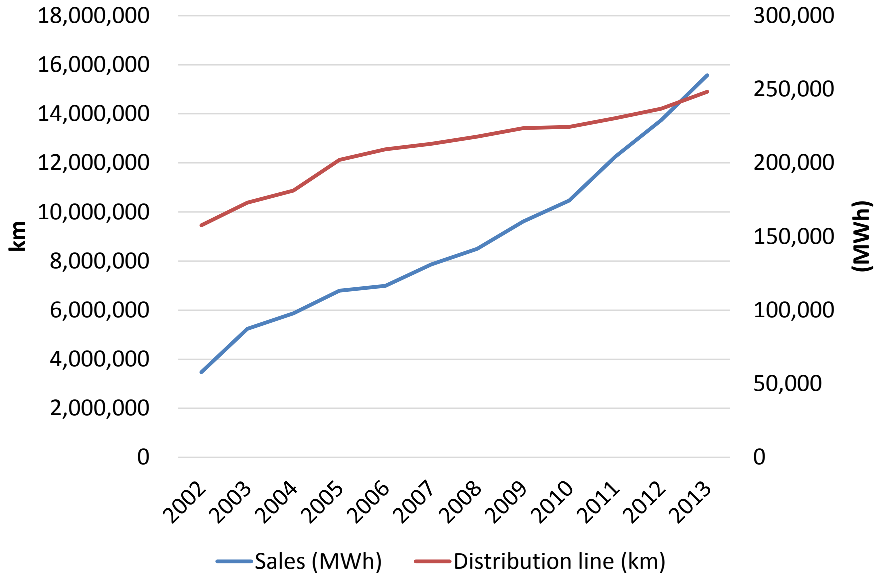


Source: JICA Survey Team

Figure 16-8 Growth of Access to Electricity (BREB project + IDCOL)

16.4.6 Demand Estimation from Electrification

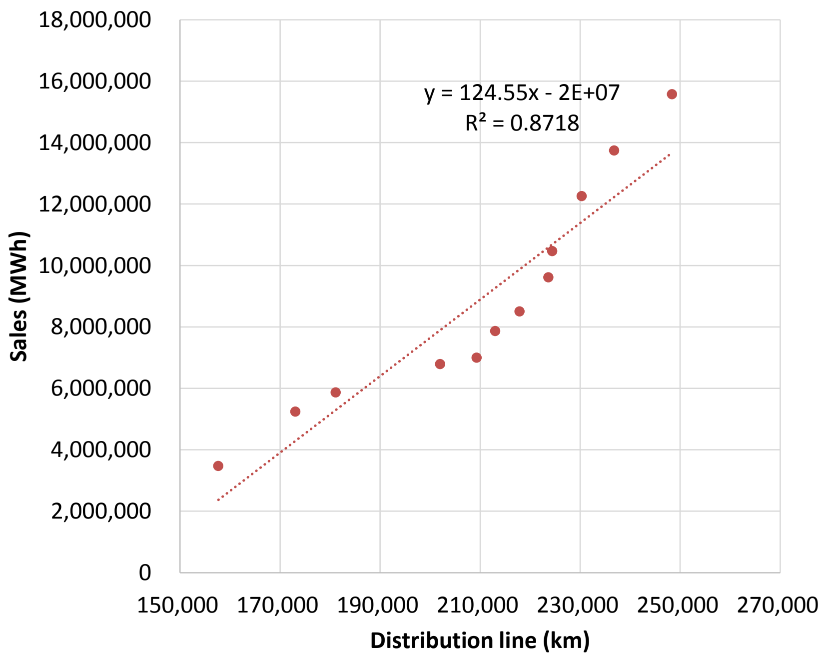
The below figure shows the pace of the line extension and the sales growth at BREB in the past 10 years.



Source: JICA Survey Team

Figure 16-9 Line Extension and Sales Growth

As shown in the below Figure, there is a correlation between line extension and sales growth.



Source: JICA Survey Team

Figure 16-10 Relation between Line Extension and Sales Grows

According to regression line, sales of 123.55MWh are increased by 1km distribution line extension. Therefore demand when electrification is completed is calculated by the below equation.

140,000 (km) x 124.55 (MWh/km) = 17,437 (GWh)

When load factor is 80%, maximum demand is estimated by the below equation.

17,437 (GWh) / 8760 (h) / 80% (LF) = 2,488 (MW)

According to the hearing from BREB, yearly average consumption per one customer (of residence customer type and non-residence customer type) is 372(kWh/person/year). According to the BBS statistics, because average number in one family is 4.6, consumption of one family is 1,71(kWh/contract/year). (371kWh/person*4.6person/contract=1.711kWh/contract/year) On the other hand, BSS statics estimates the contract will increase from 14.2 million to 24.0 million[46]. The consumption is calculated by the below equation based on the contract increment.

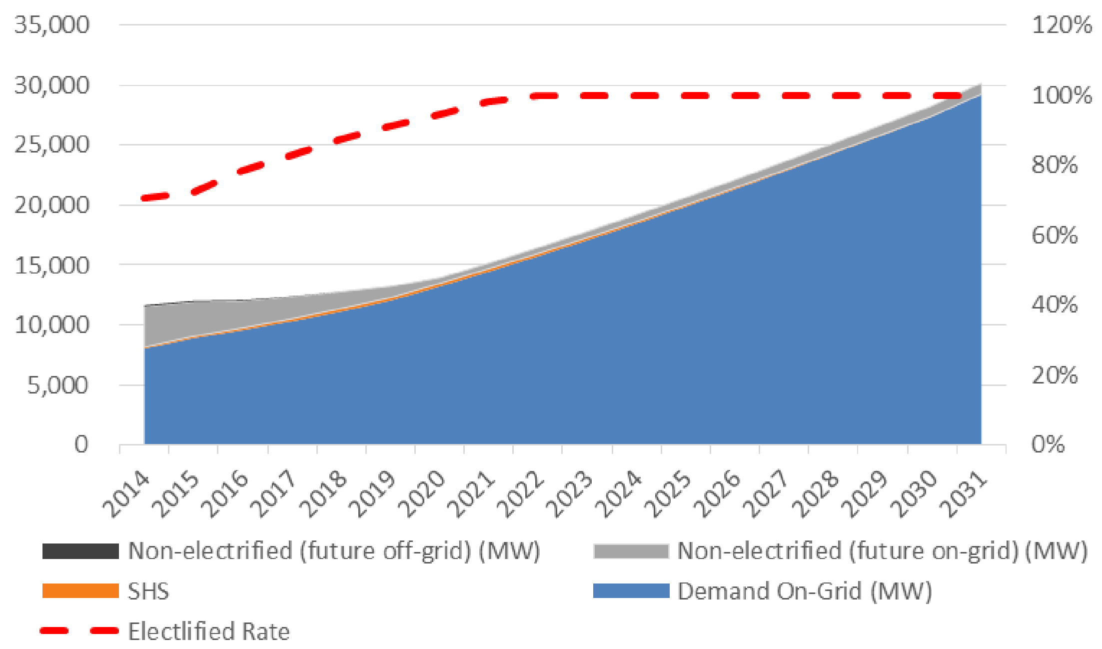
1,711 (kWh / contract / year) x (2,400(contract) - 1,420(contract)) = 16,770 (GWh)

Demand is calculated by the following equation, when load factor is 80%.

16,770 (GWh) / 8760 (h) / 80% (LF) = 2,417 (MW)

Because these two demands are similar, approximately 2,400 – 2,500MW demand will be increased when electrification rate becomes 100%.

Figure 16-11 shows the projection of the improvement of non-electrified capacity.



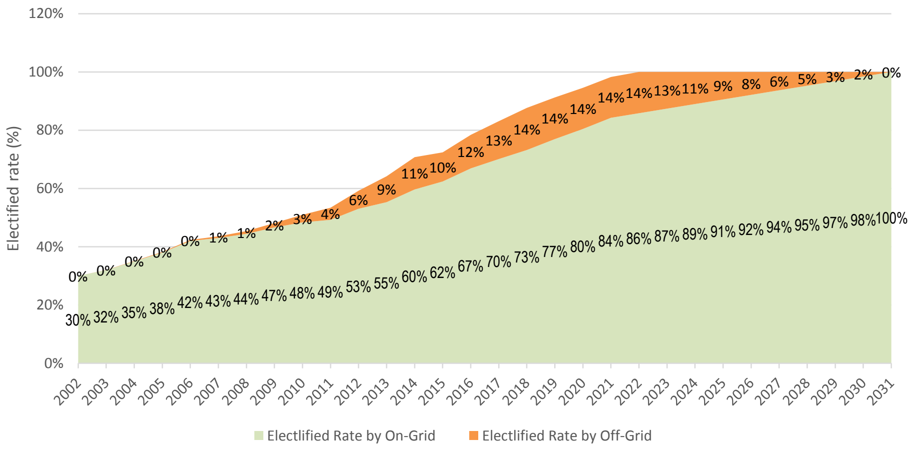
Source: JICA Survey Team

Figure 16-11 Relation between Non Electrified Energy and Demand

[46] Based on the PSMP2016 Survey Team interview with BBS, February 2016.

16.4.7 Future Grid Connection

If 2 issues described on the preceding paragraph can be cleared, electrification rate will be 100%. When distribution line extended to the area where SHSs were already installed, customer, which already installed SHS, will connect to the distribution line, because customer gets the merit according to the cost and limitation by the connection to the grid. When electrification rate extends by the growth rate shown in Figure 16-7 and Figure 16-8, almost all of the customer will be connected to the grid by 2031 as shown in Figure 16-12Figure 16-2.



Source: JICA Survey Team

Figure 16-12 Estimation of Progress of Grid Connection

16.4.8 Concerns on Future Wastes from SHSs

Once the stable power supply from grid is achieved, millions of SHSs would be disposed. Most of SHS substances are recyclable (e.g. glass and iron), but the popular SHS batteries in Bangladesh are inexpensive plumbic acid batteries, where lead and lead compounds are used for electrodes and dilute sulfuric acid are used for electrolyte.

Lead and lead compounds can have impacts to organs and nerve systems. Dilute sulfuric acid can cause respiratory disease if absorbed and chemical burn if contacted through skin. If the soil and ground water are contaminated with these substances, agricultural products and ecosystem in-taking these products (including human) would be effected. These substances will not be released to the environment as far as the battery is under usage; however, once a used battery is improperly treated the risk of substance release to the environment could occur. In addition, cadmium, extremely harmful to human body, can be contained in a small amount in a solar panel. It is also a risk of environmental contamination, if the used panel is improperly treated.

There is a report claiming the risk of these harmful substances in the solar generation system in India and China. In these countries, the handling of harmful substances is not very efficient nor well monitored. Such situation causes the loss of these harmful substances within manufacturing and recycling process, and may indicate the inappropriate exposure of these substances into the environment, resulting health risks of people living there[47]. Such loss is not necessarily caused by the illegal dumping or improper recycling of these substances; however, these cases has good implications to Bangladesh, for the importance of appropriate management of these substances.

[47] Gottesfeld, Perry and Christopher R. Cherry (2011): Lead emissions from solar photovoltaic energy systems in China and India, Energy Policy, 39(9), pp. 4939-4946

IDCOL recognized the issues of future SHS wastes and health and environmental risks and implements countermeasures[48]

- Used battery collection process by POs,
- Incentive for POs to bring batteries to a designated recycling facility,
- Acquisition of ISO14001:2004 and OHSAS 18001:2007 by all domestic battery manufactures (most of SHS batteries are domestically manufactured)
- Incentive for users (households) to comply with SHS battery recycling

16.4.9 Remaining points to clarify

- Only one definition of electrification rate should be selected. Also, the national census tells the average family member size is 4.6, while 7 adopted by BPDB.
- Grid extension in the next 5 years requires three times faster than the historical pace, which seems not feasible. Lowering target is recommended. Otherwise, a feasible alternative approach be proposed by BREB.
- BREB and IDCOL coordination and communication should be improved for efficient planning and implementation.
- SHS waste recycling needs will drastically increase after early 2020s. Is the current approve proven effective, and scalable?

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Chapter 17 Improvement of Demand/supply Operation of Electric Power and Frequency Quality

17.1 Fundamentals of Electricity Demand/supply Operation Process

“Demand/supply Operation” is to coordinate various kinds of power sources with its demand in order to realize the most economical dispatch under the conditions of maintaining the power system reliability or quality, such as system frequency and voltage.

To conduct an appropriate demand/supply operation, the work starts with plan and development of adequate power plants and transmission facilities based on the correct demand forecast for a long range of 10 to 20 years. And then, it is seamlessly brushed up with detailed information of demand forecast or planned/unplanned outages by year-ahead, month-ahead, week-ahead, day-ahead and the day plan.

The following is brief explanations of the demand/supply operation planning in Japan.

17.1.1 Demand/supply operation planning

(1) Yearly plan

In this phase, combination of various kinds of power sources such as hydro, thermal and nuclear power plants is optimized so that the economical dispatching is realized to the demand forecasted throughout the year. Development plans of power plants, periodical maintenance plans of thermal and nuclear power plants, fuel operation plans of oil or gas and water operation plans of reservoir are taken into consideration.

(2) Monthly plan

In this phase, fuel operation plans and maintenance plans of generation facilities are expected to become firm, and yearly plan is revised with these detailed plans.

(3) Weekly plan

Weekly start-and-stop plans for the thermal power plants and generating plans of hydro power plants (reservoir, pondage and pumped-storage type) are formulated because the accuracy of demand forecast will be improved and maintenance plans of generation facilities are expected to be finalized, in this phase.

(4) Day-ahead plan

Daily start-and-stop schedule of thermal power units, generating plans of hydro power units, economical load dispatching plans are formulated and final demand/supply operation plans are fixed because accuracy of demand forecast is highly improved.

17.1.2 Real-time operation

(1) Economical load dispatching control (EDC)

EDC is to operate the output of generators every ten-odd minute in order to realize an economically optimal allocation based on the past achievements.

In case of a power system connected with large amount and various kinds of generating units, and in the case where the system load is widely changing, EDC is largely dependent on the automatic calculation and online instruction by computers, and instructions by phone of manual operations by shift engineers are performed only when unforeseeable events occur, such as enormous change in weather, temperature, or sudden shut off of generators.

(2) Load frequency control (LFC)

LFC is to control generating output on a cycle of the range from several minutes to several tens of minutes in order to keep the system frequency constant.

LFC is almost completely dependent on the automatic and centralized control by computer system in national (central) dispatching center. It is an essential condition to realize the power frequency quality in developed countries (0.2-0.3Hz or less).

(3) Free governor mode operation (FGMO)

For more frequent load fluctuations ranging from several tens of seconds to several minutes, the free governor mode operation by generators is effective to absorb them.

FGMO is a kind of distributed control system, which can be performed by each units, independently. And it is also essential item for power quality.

(4) Self-regulating characteristics of load

For more fine fluctuations of several tens of seconds or less, it is impossible to control them artificially because of the delay or dead band of control system, such as LFC. Fortunately, these fine fluctuations can be absorbed by the inherent frequency-load characteristics or inertia of generators.

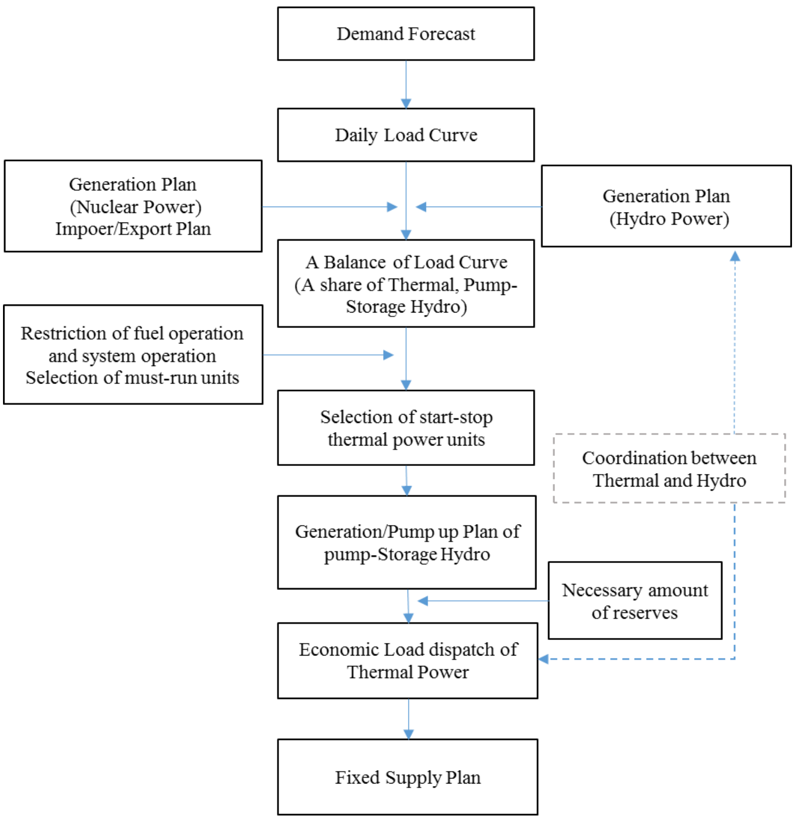


Figure 17-1 Flow Diagram of Day-ahead Demand/supply Planning Process

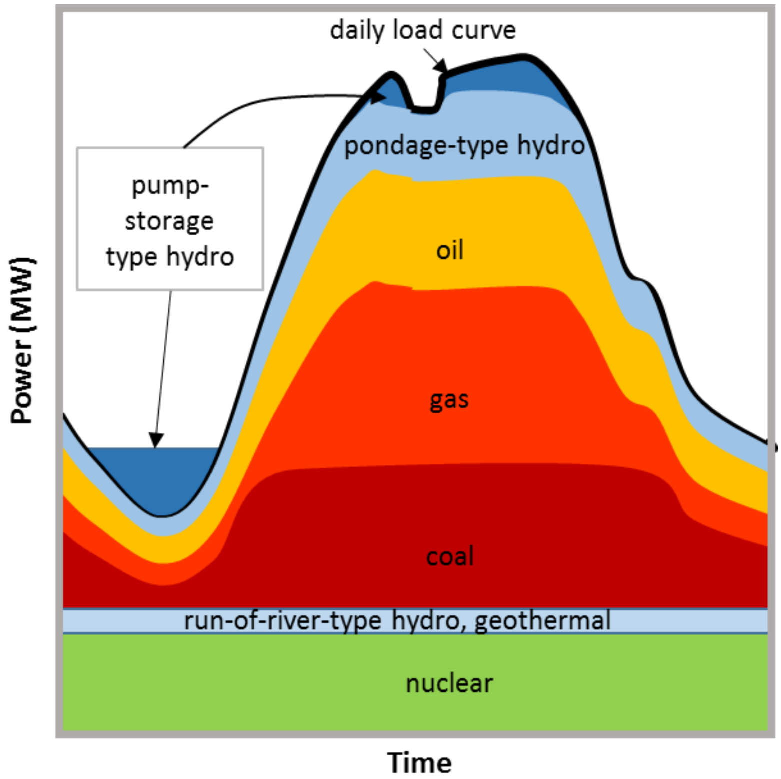


Figure 17-2 Example of Typical Daily Load Curve and Allocation of Power Sources in Japan

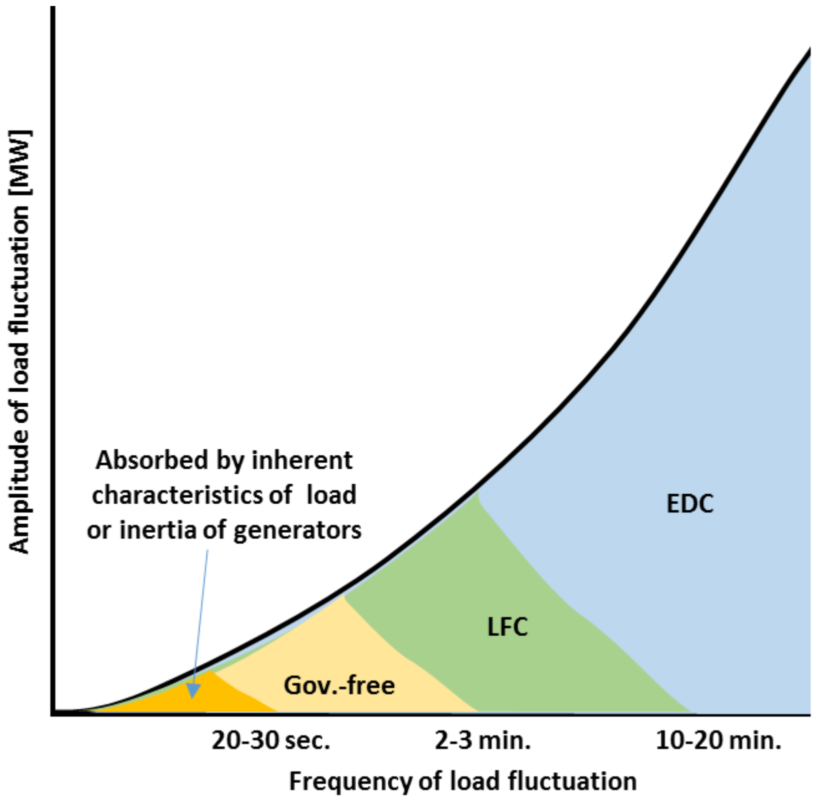


Figure 17-3 Conceptual Diagram of Role Sharing of Each Control Method

17.2 Present Status and Necessity of Improving Power Frequency Quality in Bangladesh

17.2.1 Electricity demand-supply operation in Bangladesh

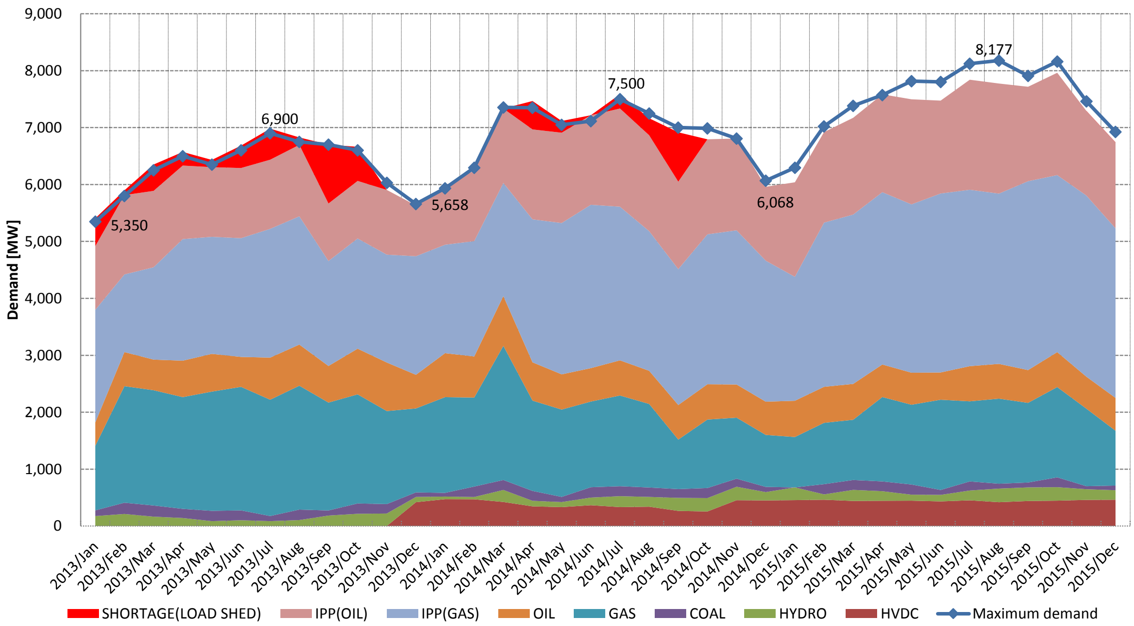
(1) Long-term planning

As shown in
Figure 17-4 Figure 17-4, load-shedding operations used to be conducted throughout the year in the past. However, it has gradually been limited to the peak load period and, in 2015, it is reduced to several days per year. (The graph in Figure
Figure 17-4 shows supply-demand balance of the day of maximum peak load for every month. Therefore, if the load-shedding operations were performed in the other days, they are not illustrated in this graph.)

As the results of interviews with key persons, it is found that following conditions were merely good at supply-demand balancing operations, and they are short-lived situations:

- Commencement of operation of newly installed generators
- Commencement of electricity import from India via HVDC interconnection
- Falling short of forecast demand

Therefore, load-shedding scheme is still one of the major solutions for deficiency of power source.



Source: Created based on daily reports in NLDC

Figure 17-4 Monthly Trend of Peak Load Power Sources in Bangladesh

(2) Short-term planning

The results of the site investigations give us a glimpse of how serious the situation of short-term supply/demand balance planning is. In the process of settling the short-term plan, NLDC, primarily, should have authority to gather necessary information, to integrate them for settling plans and to instruct according to the plans. As a matter of fact, BPDB or generating companies settle the generation plan, and NLDC has no authority to coordinate plans.

Variety of the Term of Planning

- A day plan and a day-ahead plan is formulated in NLDC. Weekly, monthly, yearly or longer term plans are not dealt with.

Integration of the Generation Plans (Maintenance Outage Plans)

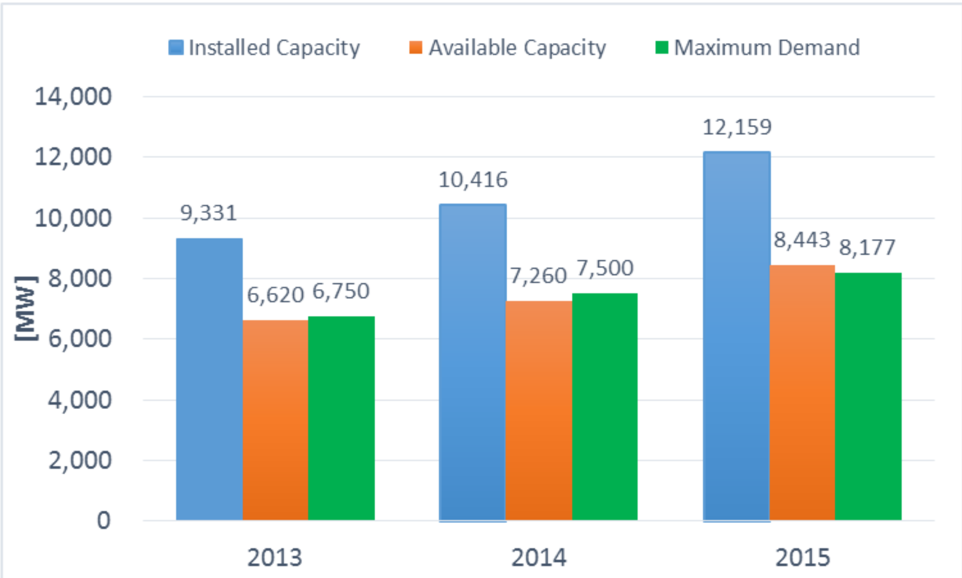
- Generation plans are not provided to NLDC until a previous day of actual operation.
- Coordination of the maintenance outage plans is performed by BPDB, and NLDC can't take part in the decision making process of the plan.

Plans of Demand-supply balancing and Unit Commitment

- The day-ahead plan is formulated at the timing of two peak hours in daytime and nighttime.
- The day plan is formulated on the hourly basis from 16:00 to 15:00 of next day.

(3) The actual conditions of existing generation plants

According to the Daily Report of Bangladeshi NLDC, the installed capacity of generators is gradually increased corresponding to the demand rise, Figure 17-5 shows the situation of supply- demand balance in the day of maximum peak demand from 2013 to 2015.



Source: Created based on daily reports in NLDC

Figure 17-5 Situation of Supply/Demand Balance in the Day of Maximum Peak Demand (from 2013 to 2015)

The installed capacity rate has been adequately secured at more than 130% every year. In reality, however, the available capacity is chronically insufficient due to decreases in the output and thermal efficiency and failures of power generators mainly due to the insufficient periodic maintenance, which results in a decrease in around 30% of installed capacity. Till 2014, in particular, load shedding had been performed due to the shortage of power sources.

In 2015, load shedding could be prevented because the available capacity barely exceeded the maximum demand.

However, the rate of capacity decrease is remaining unchanged and the risk of load shedding is still high.

Therefore, a drastic measures for securing power sources are urgently required to taken.

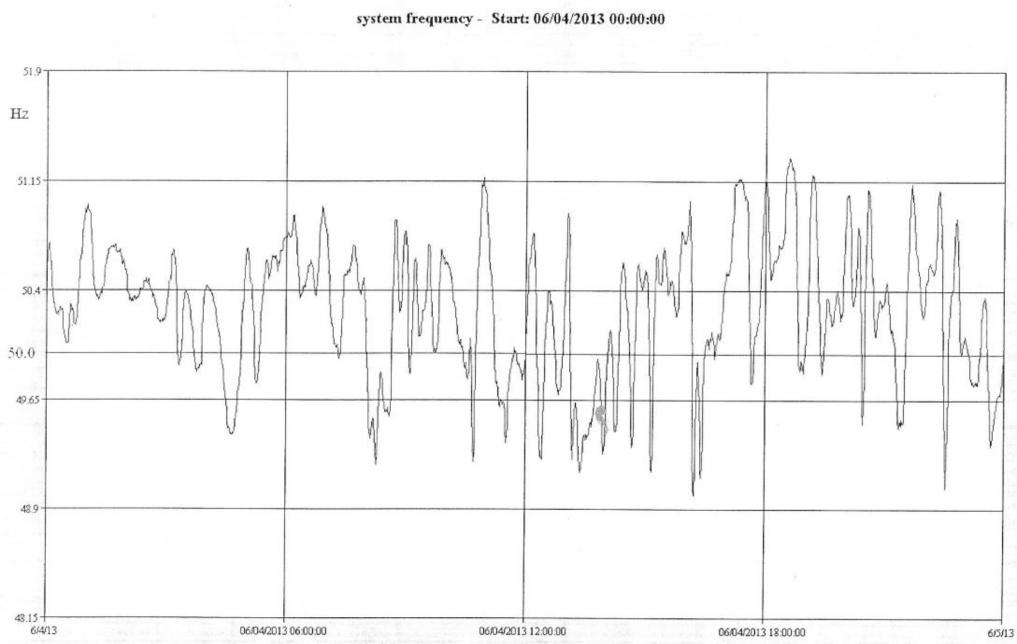
(4) Necessary actions for improving demand/supply balance

While steady development of power sources and repair of the existing power sources based on an appropriate demand forecast is hoped in the middle to long terms, in the short term, eliminating the causes that obstruct efficient demand-supply operations, such as a gap between a demand forecast and actual demand, a gap between generating plans and actual operation, an increase in loss of power transmission and electricity stealing, is important.

17.2.2 The Actual Conditions of Power Frequency Quality

(1) The actual conditions of power frequency control

At present, adjustment of the output of the generator is instructed by phone (online instructions from SCADA are not issued). As shown in the Figure 17-6, system frequency deviation from 50 Hz is often exceeding ±1.0 Hz even in the normal operating condition (Grid Code stipulates that the system frequency shall be controlled within 50Hz±1.0Hz under the normal condition.)



Source: Provided by NLDC

Figure 17-6 Actual Situation of Frequency Adjustments in Bangladesh

PGCB kindly provided us the following opinions in relation to actual situations:

- An installation of the nuclear power station is, now, planned in 2024, but it will be difficult to keep generating operation stable on the condition of existing quality of frequency. An enhancement of frequency quality is eagerly desired.
- Before the unbundling of an electricity industry in 1996, a fluctuation of the frequency was smaller than the present situation because about 50% of generators could offer reserves for frequency control, including generators in Kaptai hydro power station. However, since the unbundling, the number of generators which can offer the reserves has gradually decreased.
- PGCB estimates the following 2 causes of degradation of the frequency quality.
  1. There is almost no remaining power which can be offered for frequency control due to a

significant deficiency of power source. That is, all generators have no other choice except to keep their outputs at a maximum of available capacity.

2. The electricity industry was unbundled without rules and authorities for demand-supply control.

BPDB and Siddhirganj power station also gave us following comments for problems at present:

- It may be possible to operate in AGC (Automatic Generation Control) mode with the necessary modifications and testing conducted by manufacturer (GE), yet the generators have not set to respond to the LFC (Load-Frequency Control) signal from NLDC system, now.
- They are considering that a burden of FGMO should be shared among generators as many as possible, in order to reduce the power fluctuation of each generator.
- They have willingness to cooperate to the frequency control, if a system is developed that can make compensation for an opportunity loss of power selling.
- They have a strong desire to share a detailed information about the situation of a power system among the stakeholders, because this operation should be performed under the fair and transparent terms.

(2) Necessity of improving power frequency quality

To adjust the frequency, it is necessary to supply part of generator output as adjustment power, and the power generation operator that supplies the adjustment power needs to shoulder a specific loss of the opportunity to generate power and a fall in power generation efficiency. The resource to make up for the loss comes from electricity charges or tax, which means that the citizen eventually has to bear the burden. The economic effect brought by the technological power and improvement of frequency quality in a given era and the burden of the people are in a trade-off relationship.
Quantitative evaluation is extremely difficult in reality, and the target frequency deviation values of Japan, the U.S., and European countries vary as shown in the table below.

Table 17-1 Target Frequency Deviation Values of Japan, North America, and Europe

Region	Target frequency deviation value	Criteria
Bangladesh	50±1.0 Hz max.	Instantaneous
Hokkaido	50±0.3 Hz max.	Instantaneous
Eastern region (Tohoku & Tokyo Electric Power Co.)	50±0.2 Hz max.	Instantaneous
Mid-western region (Chubu Electric Power Co. & westward)	60±0.2 Hz max.	Instantaneous
North America (NERC)	East: 0.018 Hz max. West: 0.0228 Hz max. Texas (ERCOT): 0.020 Hz max. Quebec: 0.0212 Hz max.	Annual standard deviation (average in 1 minute)
Europe (UCTE)	50±0.04 Hz max., 90% min. 50±0.06 Hz max., 99% min.	Hour stay rate

Consumers, especially, general households use electric appliances and IT products that have an inverter circuit and distributed power source systems such as for solar and wind power generation are connected to an inverter in many cases. For this reason, the influences of frequency fluctuation on electric equipment are smaller than before. It is therefore becoming more difficult to dig out needs of suppressing frequency from general consumers than before.
On the other hand, however, industries are said to suffer from the adverse influences stemming from frequency fluctuation as shown in the table below, and potential needs for frequency fluctuation suppression are considered to remain high.

From the viewpoint of suppressing frequency fluctuation, it will be very effective to coordinate synchronization with other countries (coordination through AC transmission lines). In this case, however, there is a risk that a decrease in power quality or power outage in one country spreads the other countries. Realizing such coordination is therefore considered very difficult. However, potential needs of suppressing frequency fluctuation to the equivalent to that of developed nations are considered high in the future.

Table 17-2 Examples of Adverse Influences of Power Frequency Fluctuation on Industries

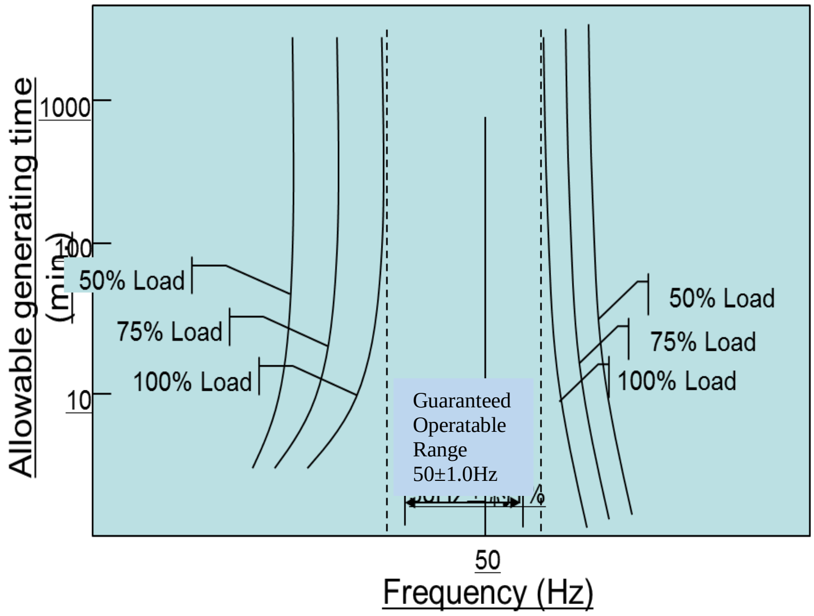
Industry	Influences of frequency fluctuation
Chemical fiber	Yarn may break or the thickness may become uneven because the speed of winding varies.
Paper manufacturing	Paper may break or the thickness may become uneven because the speed of winding varies.
Oil	Controlling pressure for decomposition and desulfurization may be affected and impurities cannot be removed.
Steel & aluminum	Rolling process may be affected, making the thickness of the product uneven.
Automobile	Welding strength and quality of appearance may be affected because the energization time of the body panel varies.

Thermal power generators and synchronous power generators have the following restrictions. These generators are designed not to operate continuously, from the viewpoints of generation of repetitive stress and member fatigue due especially to resonation of turbine moving blade and shaft vibration, unless the frequency fluctuation is kept to within a specific value (within ±1% in Japan). Therefore, the needs of suppressing frequency fluctuation are potentially high from the viewpoint of protecting machines and equipment. The effect of reducing failures of generators by suppressing frequency fluctuation can also be expected.

Table 17-3 Example of Operational Restrictions of Synchronous Generators

Turbine	Resonation of moving blade, shaft vibration
Generator	Over excitation, overload
Boiler, auxiliary device	Drop in capability of feed water pump, etc.

Figure 17-7 illustrates a conceptual diagram of a characteristic curve that indicates how long a generator is allowed to operate by the restrictions concerning resonation and shaft vibration of the turbine moving blade at a frequency (which is proportional to the number of revolutions of the turbine).
This generator can continuously run in the vicinity of the reference frequency (50 Hz) but the duration it can operate is rapidly shortened in the region outside the allowable limit. In addition, the lighter the load of the generator, the wider, though slightly, the frequency region where the generator can operate.
In general, the allowable range in the higher frequency region is narrower than in the lower frequency range because a problem of centrifugal force is added to the problem of resonation of the turbine moving blade.



Source: Created based on documents made public

Figure 17-7 Conceptual Diagram of Frequency vs Continuous Operable Time Characteristics of Synchronous Generator

Based on the information described above, it can be said that an existing status of the frequency quality is inadequate from the viewpoint of protection management of generators.
Particularly, in order to keep stable operation of a nuclear power generator planned to connect to a power system in around 2024, it will be eagerly desired to enhance the quality level of a frequency fluctuation to the global standard as shown in the Table 17-1.

According to "Electric Grid Reliability and Interface with Nuclear Power Plants", issued by IAEA, following frequency quality shall be required in the case of connecting the nuclear power plants:

- A generating unit is able to operate continuously at full output for the normal range of variation of grid frequency -- +/-1.0% (49.5Hz～50.5Hz).
- A generating unit is able to operate for a limited time, on a few occasions per year, perhaps at reduced output, for a range of frequency outside the normal range -- +4%, -5% (48.0Hz～r 52.0Hz).

In order to fulfill these requirements, frequency fluctuation must be improved to a half or less within the next decades, so, it is urgent problem for Bangladesh.

17.3 Scope of This Investigation

The scope of this project is as follows:

(1) Proposal for preparation of a legal framework, revision of rules and work procedures

- We will propose and support for preparation or amendment of various rules with reference to the rules in Japan (or Europe/America, if necessary) and TEPCO.
- We will check process of supply-demand balance planning and frequency control, and propose several improving points.

(2) Draft of plan for frequency quality improvement

- Estimation of frequency sensitivity in response to sudden change of power supply or demand, and evaluation of frequency quality improvement by introducing generators equipped with frequency control function.
- Development of future plan for securement of spinning reserve, such as FGMO and LFC considering generation development plan and roadmap for frequency quality improvement.

(3) Improvement plan of EMS/SCADA system in NLDC

- Confirming needs for introducing new function or adding data to the EMS/SCADA system, in order to realize an online output instruction order to power stations.

17.4 Investigation of the Regulatory Framework for Electricity Business

17.4.1 Regulatory framework for power system planning/operation

(1) The case of Japan

Majority of the electric power companies is profit-making corporation with a joint-stock (limited liability) company system. Therefore, their business managements are subject to / under protection of provisions of the general laws, such as civil laws, commercial laws or criminal laws.

In addition, they are regulated by a special law - the Electricity Business Act in order to control their sound development, to protect the consumers' interests, to secure the public safety and to preserve the environment.

As shown in Figure 17-8, the legal or regulatory structure in relation to the power system operation, in particular, the demand/supply operation or frequency control, consists of 3 stages.

Regulation by a Nation
- Electricity Business Act
  - Operational regulations concerning the law
  - Ordinance regarding the foundation of Organization of Cross-regional Coordination of Transmission Operations (OCCTO)

Regulation by OCCTO
- Rules of Services
  - Guidelines on Demand Forecast
- Detailed Rules of Network Operations

Self-management Rules of Transmission and Distribution Sector in General Electricity Utilities
- Rules of Power System Operation
- Rules of Information Publication

Figure 17-8 Regulatory Framework for Electricity Supply Industry in Japan