The People's Republic of Bangladesh

Ministry of Power, Energy and Mineral Resources

Integrated Energy and Power Master Plan Project in The People's Republic of Bangladesh

Final Report

Appendix

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Appendix A

Status and Issues of Energy and Power Sectors

Appendix A analyzes the present status and issues of primary energy supply, electricity demand/supply and energy utilization and efficiency, including relevant laws and institutions, in Bangladesh.

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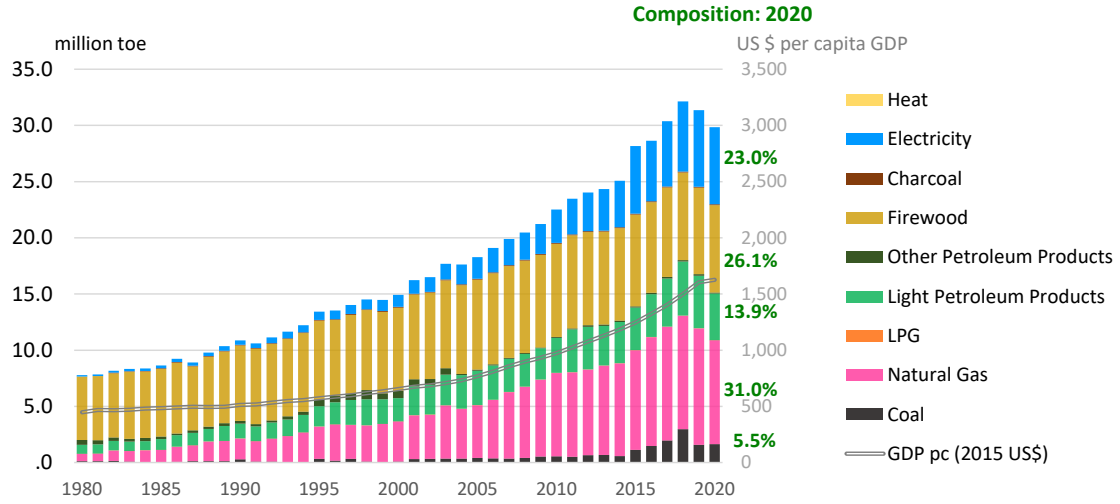
1. Energy in Bangladesh

1.1 Overview

In the People's Republic of Bangladesh (hereinafter referred to as "Bangladesh"), per capita total energy supply in 2020-21 was 331kg in oil equivalent, which was less than one-fifth of the world average (1,801kgoe in 2020)[1]. In energy consumption, traditional firewood and natural gas, mostly produced indigenously, combined account for more than 50%, followed by electricity, and petroleum products as motor fuel. Bangladesh is pushing forward its economic growth aggressively under the Vision 2041, aiming to earn a high-income country status by the 70th anniversary of independence. Thus, the economy of Bangladesh will expand more than 5-fold from here on out. Energy demand will also grow rapidly. Among others, electricity consumption, which stayed at 560kWh/year in 2020-21 or 17.4% of the world average of 3,212kWh in 2020, will expand as the key driver to push the economic development while improving the quality of life.

In order to accommodate the increasing energy demand, various challenges must be overcome in relation to constraints on the indigenous energy resources, the country's energy security, climate change issues, and so on. To this end, Bangladesh has developed major long-term energy plans such as the Power System Master Plan 2016 (PSMP2016) / Revisiting Power System Master Plan 2016 (Revisiting PSMP2016), Energy Efficiency and Conservation Master Plan 2016 (EECMP2016), and Gas Sector Master Plan 2017 (GSMP2017).



Source: IEA World Energy Balances 2022

Figure 1.1-1 Final Energy Consumption of Bangladesh

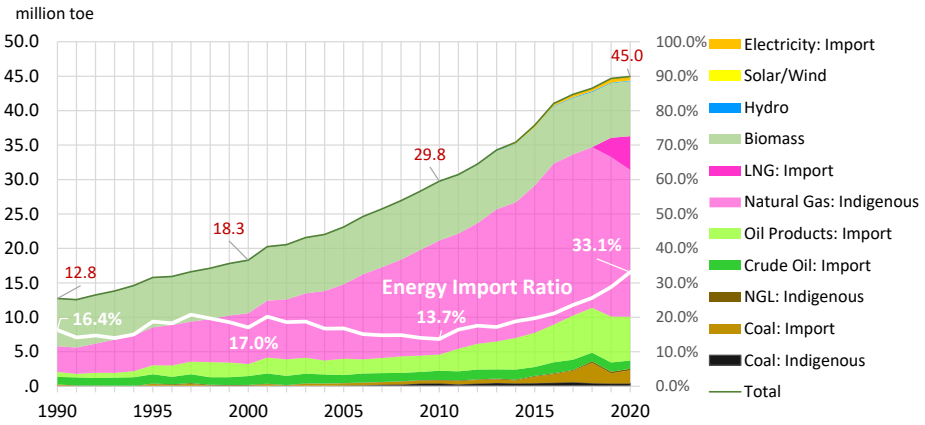
Today, with rising concerns on climate change, the world is coming into the age of energy transition. Considering the recent trends, Bangladesh wanted to review the existing plans and

[1] Numbers for Bangladesh cited from Hydrocarbon Unit "Energy Scenario of Bangladesh 2020-21" and the world average from the IEA World Energy Balances 2022. Same sources for the per capita electricity consumption.

consolidate them into a comprehensive national plan setting out a tangible and practicable development roadmap. Thus, the Bangladesh government requested Japan to support formulation of the Integrated Energy and Power Master Plan (IEPMP) with a view to set out middle/long term energy policies to establish a low carbon/decarbonized society. JICA (Japan International Cooperation Agency) and the Ministry of Power, Energy and Mineral Resources (MoPEMR) discussed the request and signed the Record of Discussion on 14 March 2021. In accordance with the agreement, the draft IEPMP has been prepared.

1.2 Outline of Primary Energy Supply

Until recent years, energy utilization in Bangladesh depended on a small system developed with indigenous energies; conventional biomass (mainly firewood) and natural gas combined comprising more than 3/4 of the total energy supply. A small amount of petroleum products as motor fuel and coal were imported but the import ratio remained below 20%. However, signs of peaking in natural gas production have created serious concern on the stable supply of energy and power leading to introducing import of LNG and coal since 2018. The import energy ratio jumped up to 33.1% in 2020. Since an increase in indigenous energy production is not expected in the near future, energy import will increase rapidly. In addition, while construction of fundamental energy infrastructure is essential to support economic development and a better quality of life, it is also an important issue for the government to implement efficient and lower-carbon use of energy to cope with the global climate change issues.



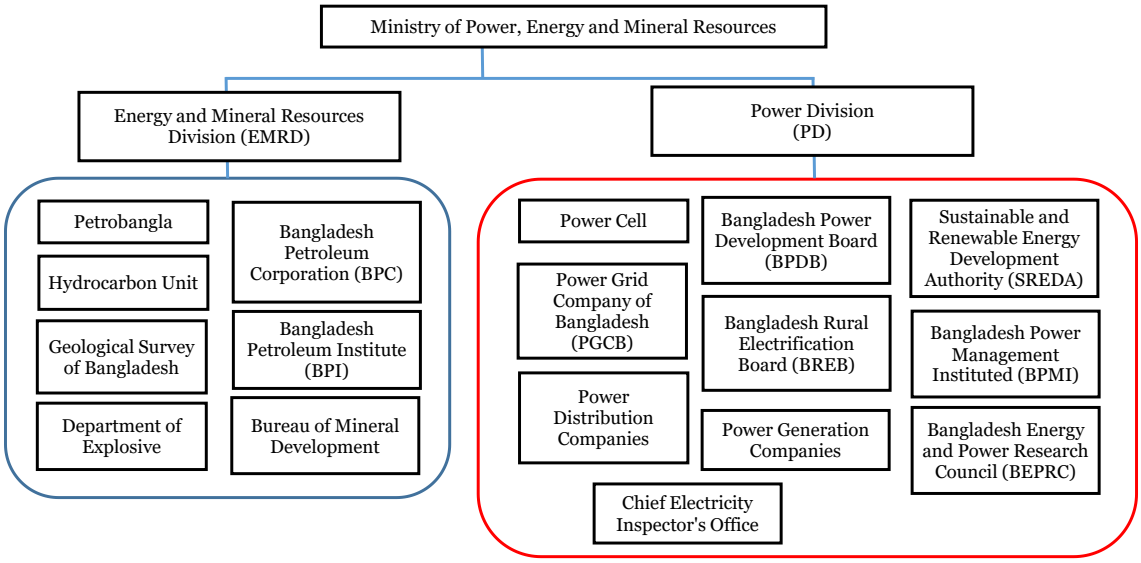
Source: IEA World Energy Balances 2022

Figure 1.2-1 Primary Energy Supply in Bangladesh

The residential sector has been the dominant energy consumer over the history of Bangladesh, where traditional biomass (firewood and dung) and natural gas produced within the country were the main energy sources. Energy consumption in the industry sector began rising only after the turn of the century; natural gas and electricity are dominant energies in this sector. Motor vehicles are not widely used, and consumption of petroleum products remains only at 125,000 barrels per day (BD).

1.3 Organization for Energy Management

The energy and power sector in Bangladesh is under the jurisdiction of the Ministry of Power, Energy and Mineral Resources (MPEMR). Under the ministry are the Power Division (PD) and Energy and Mineral Resources Division (EMRD). PD is responsible for electricity, while EMRD is responsible for oil, natural gas and mineral resources.



Source: Ministry of Power, Energy and Mineral Resources

Figure 1.3-1 Ministry of Power, Energy and Mineral Resources Organization Chart

Petrobangla is one of the state-owned corporations under the EMRD and has jurisdiction over mineral resources including natural gas, LPG and coal. Another public institution is the Bangladesh Petroleum Corporation (BPC), which supplies oil to the country.

Most of the energy operations in Bangladesh are run by the state-owned companies under the MPEMR except for a small amount of import and sale of coal and LPG as below.

a. PetroBangla:

Exploration, development and production of oil, natural gas and coal. Operation of natural gas pipeline network. Sale of natural gas and coal. Import and regasification of LNG.

b. Bangladesh Petroleum Corporation:

Import of crude oil and petroleum products. Refining and sale of petroleum products.

In the long run, how to consider introduction of private sectors into these operations in the course of developing the country's energy infrastructure will be another important issue.

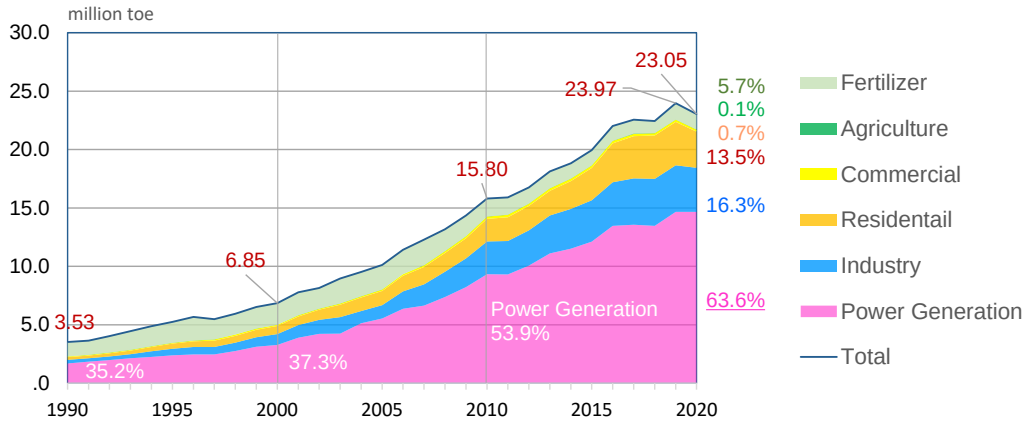
2. Primary Energy Supply

2.1 Natural Gas

Historically natural gas has been the core energy source for Bangladesh comprising more than half of the primary energy supply. However, exploration activities in recent years have not been so successful and production is apparently peaking. Nevertheless, natural gas is deemed to play an important role to accommodate the increasing energy demand as a low-carbon clean fuel. To this end, LNG import started in 2018 and is on an increasing trend.

2.1.1 Natural Gas Consumption

Natural gas consumption in Bangladesh has kept increasing reflecting population growth and economic development. It increased 27.4% from 798.1Bcf in FY2012-13 to 1,017.4Bcf in FY2020-2021. More than 60% is used for power generation, followed by industry and households. Compressed natural gas (CNG) is used by motor vehicles as an alternative to petrol. In other sectors, natural gas is used for production of fertilizer and irrigation pumps. Natural gas comprises 76% of fuel for power generation; the power sector heavily relies on natural gas. A continued increase of natural gas consumption is expected in power, industry and residential sectors.



Source: IEA World Energy Balances 2022

Figure 2.1-1 Natural Gas Demand (IEA)

Table 2.1-1 shows the natural gas consumption data announced by Hydrocarbon Unit in its Annual Report. These figures are compiled for the Bangladesh fiscal years from July to June next year and hence there are some mismatches with other statistics. It declined in 2019 due to the Covid-19 pandemic, but has been returning to the previous trend recently. We should note that the gas supply for 3 wheelers (CNG) has been curbed in recent years in view of the stagnant production tendency in the indigenous natural gas production.

Table 2.1-1 Natural Gas Sales: Hydrocarbon Unit

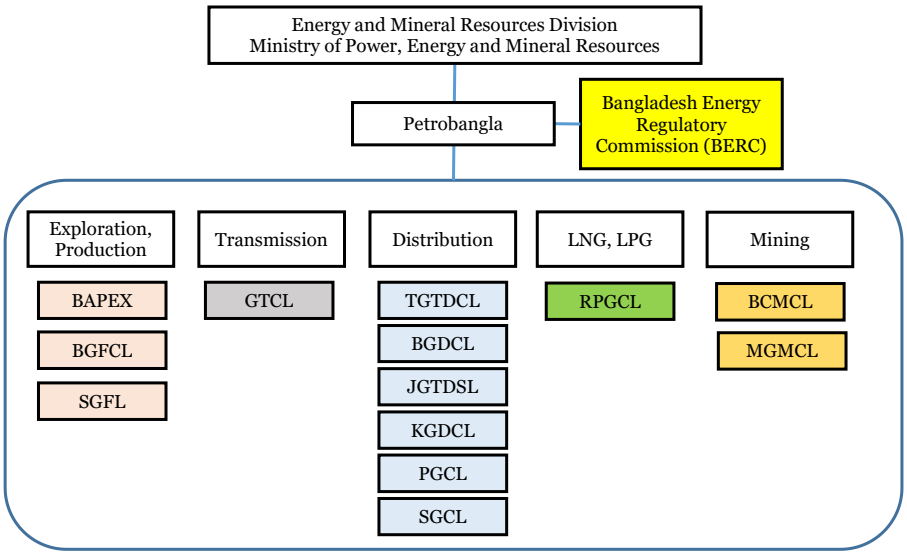
	Power	Captive	Industry	Fertilizer	Commercial	Domestic	CNG	Tea Estate	Total
	Bcf	Bcf	Bcf	Bcf	Bcf	Bcf	Bcf	Bcf	Bcf
FY2012-13	328.8	134.1	135.7	59.9	8.8	89.7	40.2	0.8	798.1
FY2013-14	333.4	136.0	137.6	60.8	8.9	91.0	40.7	0.8	809.2
FY2014-15	354.7	150.0	147.7	53.8	9.1	118.2	42.9	0.8	877.2
FY2015-16	399.6	160.8	156.0	52.6	9.0	141.4	46.5	0.9	966.8
FY2016-17	403.5	160.5	163.1	49.1	8.7	154.4	47.0	1.0	987.2
FY2017-18	398.6	160.5	166.5	43.0	8.2	147.9	46.2	0.9	971.8
FY2018-19	450.8	157.5	164.5	57.7	7.9	158.9	43.4	1.0	1041.7
FY2019-20	455.9	151.6	155.7	54.6	6.7	132.7	36.1	1.1	994.3
FY2020-21	425.7	169.1	181.8	64.7	6.0	134.2	35.1	1.0	1017.4
(Composition)									
FY2012-13	41.2%	16.8%	17.0%	7.5%	1.1%	11.2%	5.0%	0.1%	100.0%
FY2013-14	41.2%	16.8%	17.0%	7.5%	1.1%	11.2%	5.0%	0.1%	100.0%
FY2014-15	40.4%	17.1%	16.8%	6.1%	1.0%	13.5%	4.9%	0.1%	100.0%
FY2015-16	41.3%	16.6%	16.1%	5.4%	0.9%	14.6%	4.8%	0.1%	100.0%
FY2016-17	40.9%	16.3%	16.5%	5.0%	0.9%	15.6%	4.8%	0.1%	100.0%
FY2017-18	41.0%	16.5%	17.1%	4.4%	0.8%	15.2%	4.8%	0.1%	100.0%
FY2018-19	43.3%	15.1%	15.8%	5.5%	0.8%	15.3%	4.2%	0.1%	100.0%
FY2019-20	45.8%	15.2%	15.7%	5.5%	0.7%	13.3%	3.6%	0.1%	100.0%
FY2020-21	42.8%	17.0%	18.3%	6.5%	0.6%	13.5%	3.5%	0.1%	102.3%

Source: Hydrocarbon Unit "Annual Report on Gas Production, distribution and Consumption FY2020-2021"

2.1.2 Gas Sector Overview

Petrobangla and its affiliated state-owned companies have jurisdiction over and operate all natural gas projects in Bangladesh.

Gas field development is conducted only by Bangladesh Petroleum Exploration and Production Company Limited (BAPEX). Gas production is conducted by BAPEX, Bangladesh Gas Fields Company Limited (BGFCL) and Sylhet Gas Fields Limited (SGFL). The trunk pipeline is planned, constructed and operated by Gas Transmission Company Limited (GTCL). There are six regional gas companies; Titas Gas Transmission and Distribution Company Limited (TGTDCL), Bakhrabad Gas Distribution Company Limited (BGDCL), Jalalabad Gas Transmission and Distribution System Limited (JGTDSL), Karnaphuli Gas Distribution Company Limited (KGDCL), Pashchimanchal Gas Company Limited (PGCL), and Sundarban Gas Distribution Company Limited (SGCL). In recent years, to cope with depleting gas fields in the country, LNG import started in 2018; LNG operation is entrusted to Rupantarita Prakritik Gas Company Limited (RPGCL), which is historically engaged in production and sale of LPG and CNG.

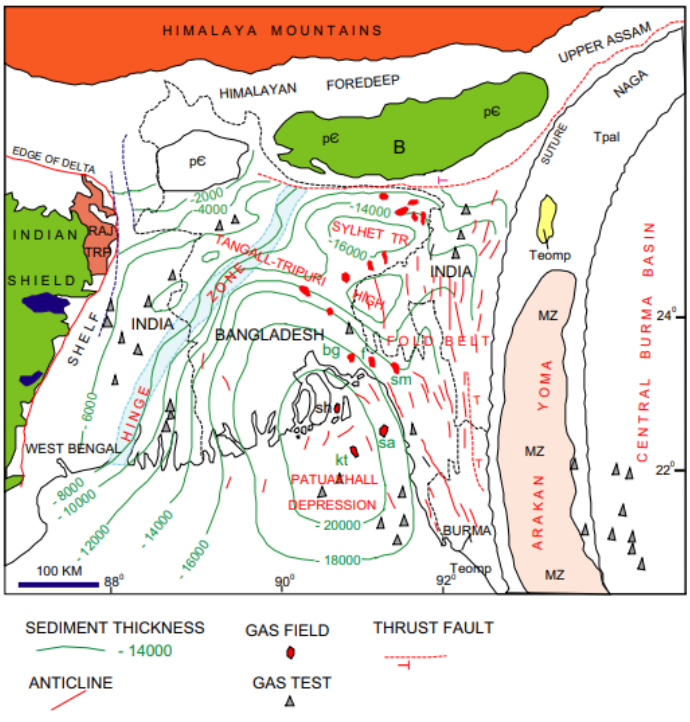


Source: Petrobangla

Figure 2.1-2 Petrobangla Gas Business Organization Chart

2.1.3 Natural Gas Production and Reserves

Bangladesh is roughly classified into three regions with different geological structure: (1) the folded region in the eastern part of the country, (2) the foredeep region in the central part of the country, and (3) the stable land mass region in the western and northwestern parts of the country (Figure 2.1-3).



Source: U.S. Geological Survey-Petrobangla

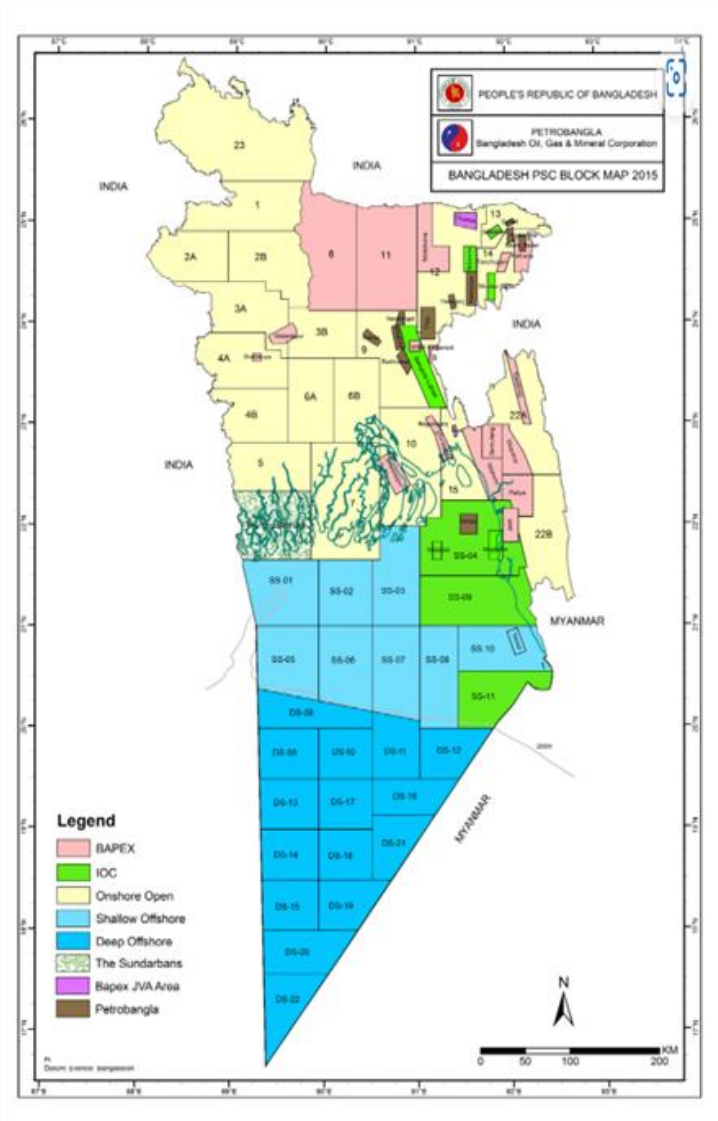
Figure 2.1-3 Geological structure and location of gas

Most of the gas fields discovered to date have been found in (1) the folded area developed at the boundary with the eastern Himalayan massif and (2) the foredeep (plate front subduction) area originating from the central Gondwana continent. This area extends in a north-south band in the eastern part of Dhaka City and from Sylhet to Comilla, Chittagong, and Cox's Bazar. In these areas, natural gas is produced in sedimentary formations 6,000 to 8,000 m below the surface and stored in Miocene/Pliocene sandstone formations 1,000

to 4,000 m below the surface. Some of the gas is also stored in sandstone layers below 1,000 m, called gas pockets. In the Sylhet area, large-scale blowouts have occurred four times. According to the USGS (U.S. Geological Survey) / Petrobangla 2001, geological potential to bear oil and gas is not so high compared with the eastern fold-belt. So far, no commercial discovery is made in this region.

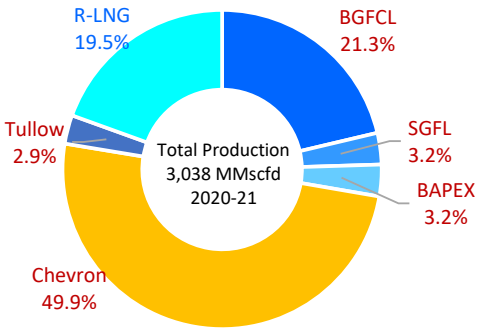
For oil and gas exploration and production activities, PSC blocs are set out as shown in Figure 2.1-4. In addition to the workover on producing wells and development drilling on the existing gas fields, new exploration is expected in onshore and offshore blocks. Outlook of future gas production is discussed in Section 6.2.2 of the principal report.

Natural gas in Bangladesh is produced by BAPEX, BGFCL and SGFL, three subsidiaries of Petrobangla, and Chevron and Tullow as IOCs. Chevron and Tullow signed Production Sharing Contract (PSC) with Petrobangla in 1996 and are operating several gas fields; all the produced gas is sold to



Source: Petrobangla

Figure 2.1-4 Oil and Gas Exploration/Production Blocks



Source: Hydrocarbon Unit Annual Report 2020-21

Figure 2.1-5 Natural Gas Sale by Supplier

Petrobangla.

Figure 2.1-5 shows the share of gas production by company in FY2019-2020. Chevron supplies almost half, while imported LNG amounts to almost 20%.

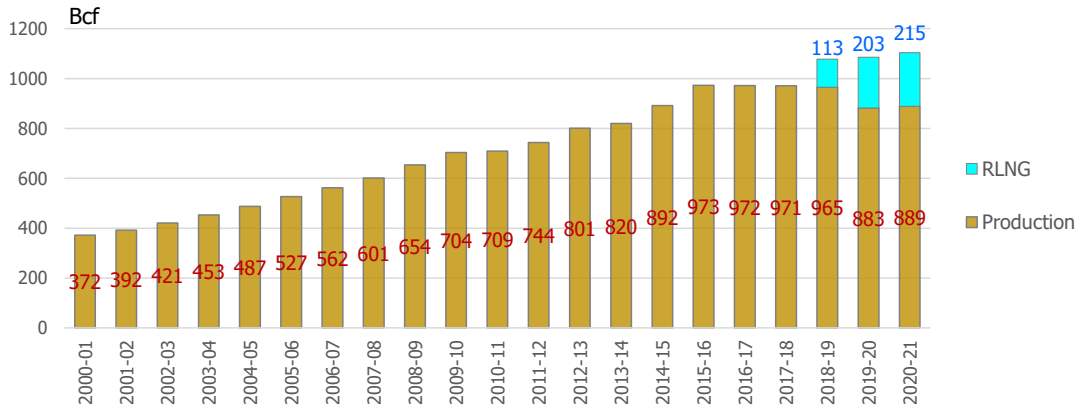
As of the end of December 2020, there are 20 producing gas fields in the country; 16 gas fields are held by the three subsidiaries of Petrobangla, 3 gas fields held by Chevron, and 1 gas field held by Tullow. While some of them are located offshore, most of the gas fields are found in the eastern folded areas near the foredeep bordering with India. The Bibiyana gas field operated by Chevron, which has the largest gas production capacity in the country, is located in this region.

Figure 2.1-5 shows the trend of gas production in Bangladesh. Thanks to the aggressive development of gas fields by BAPEX, Chevron and others, and with increasing demand for gas in the power generation and industrial sectors, gas production in Bangladesh increased steadily in the early 2010s. In recent years, however, domestic gas production has been on a downward trend peaking at 973.2 Bcf in FY2015-2016, due to declining production in existing gas fields as well as stagnation in new gas field development. Domestic gas production in FY2019-2020 was 882.6 Bcf, a decrease of 90.6 Bcf (9.3%) from the peak. In order to supplement the declining production, LNG import started in 2018 and is expected to increase in coming years.

Table 2.1-2 Domestic Developed Gas Fields and Production Capacity

As in December 2021				Unit：MMcfd
Company	No.	Gas Field	Production Capacity	Production
BGFCL	1	Titas	408	398
	2	Bakhrabad	35	35
	3	Habiganj	153	157
	4	Narsingdi	27	27
	5	Meghna	7	7
		Sub-total	630	625
SGFL	6	Sylhet	7	6
	7	Kailashtila	36	29
	8	Rashidpur	44	45
	9	Beanibazar	7	7
		Sub-total	87	87
BAPEX	10	Saldanadi	2	3
	11	Fenchuganj	17	14
	12	Shahbazpur	85	61
	13	Semutung	1	1
	14	Sundalpur	8	8
	15	Srikail	38	39
	16	Begumganj	9	8
	17	Rupganji	0	0
		Sub-total	160	133
Chevron	18	Jalalabad	197	206
	19	Moulvibazar	14	15
	20	Bibiyana	1,170	1,189
		Sub-total	1,381	1,410
Tullow	20	Bangora	55	48
Total			**2,313**	**2,303**

Source: Petrobangla Annual Report 2021



Source: Petrobangla

Figure 2.1-6 Natural Gas Production and LNG Import

2.1.4 LNG Import

In Bangladesh, LNG import has been promoted as a national policy to accommodate increasing gas demand while national production is stagnant. Two floating storage and vaporization (regasification) units (FSRU) started operation one after another in 2018 and 2019, and construction of two more FSRUs and an onshore LNG terminal is progressing. Recent LNG import was 4.04 million tons in 2019 and 4.18 million tons in 2020[2].

Table 2.1-3 LNG Import/Regasification Terminal

Location	Terminal	Capacity → Expansion	Start-up
		MMcfd	
Moheskhali	#1 FSRU (Operating)	500 → 630	Expnasion: 2023
	#2 FSRU (Operating)	500 → 630	Expnasion: 2023
	#3 FSRU	500-750	2024
Payra	#4 FSRU	630-1,000	2027
Matarbari	Land-based	1,000	2028-29
Total	3,430~4,010 MMcfd (24.0~30.7 million tonnes)		

Source: Rupantarito Prakritik Gas Company Limited (RPGCL)

There are several challenges for constructing LNG receiving terminals:

The coastline of the Bay of Bengal is very shallow, with a 10-meter depth contour line 100 km off the mouth of the river. This requires dredging to remove sediments from the seabed to receive large LNG carriers according to the JICA report (2016).

Bangladesh is in the estuary of three major international rivers, the Ganges, the Brahmaputra and the Meghna, and about 80% of the country's land area is floodplain, about 50% of which is low-lying land with an elevation of less than 5 meters. In addition, as the central part of the Bangladesh coast is located at the deep end of the Bay, this coastal topography causes an

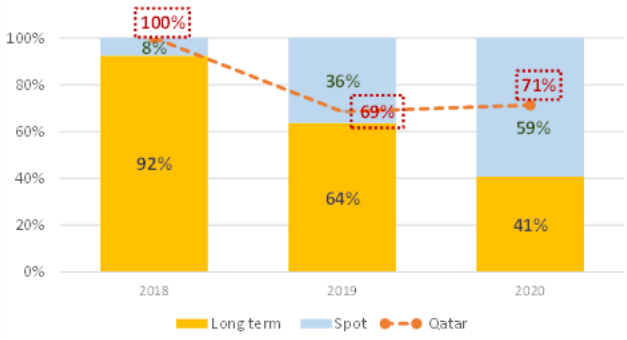
[2] GIIGNL Annual Report (2020, 2021)

accelerated impact of strong wind and high wave when hit by a cyclone. Therefore, both onshore and offshore LNG receiving terminal plans are centered so far in Moheskhali and Matarbari areas in the southeast of the country. For better balancing of the gas supply system, it is desirable to have a terminal on the western side of the country. Thus, construction of another LNG terminal in the west is scheduled in the long-term gas network plan.

Source: Hydrocarbon Unit (HCU), Mitsubishi Corporation

Figure 2.1-7 Summit LNG FSRU

Petrobangla has signed two long-term LNG contracts with RasGas of Qatar and Oman Trading International (now OQ Trading); prices for these long-term contracts are crude oil-linked. The company also procures LNG on a spot basis having sale/purchase contracts with 14 suppliers and traders. Figure 2.1-8 shows the share of long-term contracts and spot contracts in LNG imports, which has increased from 8% in 2018 to 59% in 2020. Presently the country is highly dependent on Qatar.



Source: GIIGNL

Figure 2.1-8 LNG Import by Contract Term and share of Qatar

2.1.5 Gas Pipeline

The gas trunk pipeline in Bangladesh is operated by GAS TRANSMISSION COMPANY LIMITED (GTCL) as shown in Table 2.1-4 and Figure 2.1-8. GTCL is exclusively engaged in the planning, construction and operation of gas trunk pipelines and transports gas produced by gas producers to six regional gas companies (TGTDCL, BGDCL, JGTDSL, KGDCL, PGCL and SGCL).

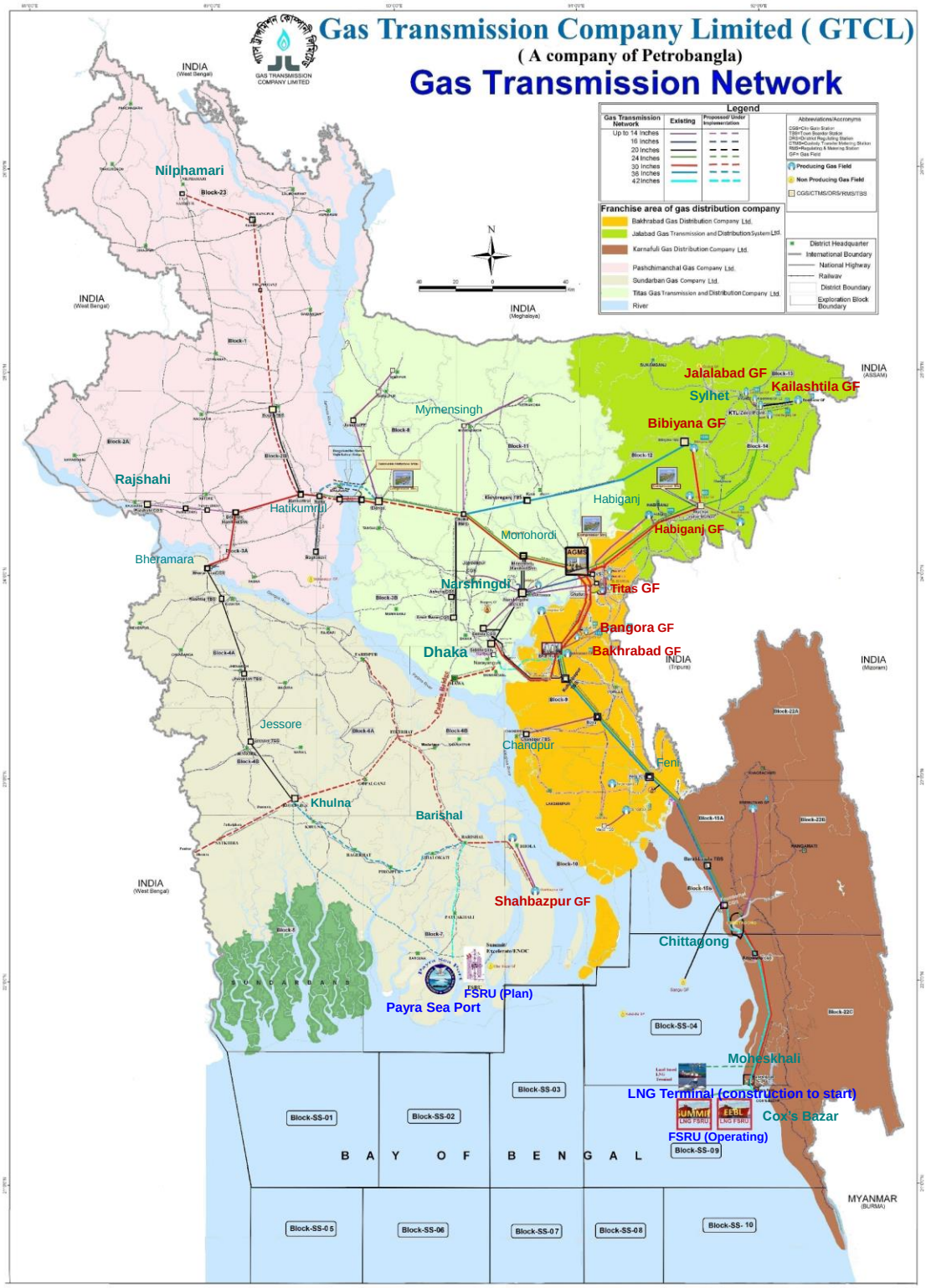
A list and map of the existing gas pipelines of GTCL is given below. The ongoing and planned pipelines are also described later in Chapter 7 Primary Energy Supply Plan, "7.3.4 Pipeline Plan".

Table 2.1-4 Existing Gas Pipelines and Completed Projects of GTCL

	Name	Size	Length	Project Period
1	Ashuganj-Bakhrabad Gas Transmission Pipeline Project	30”	58.5 km	April 1994 to Dec. 1997
2	GTCL-Twining Project	–	–	June 1996 to May 1999
3	Paschimanchal Gas Transmission Project (a) Bangabandhu (B-B) Bridge, (b) Elenga-Nalka, (c) Nalka- Baghabari	(a) 30” (b) 24” (c) 20”	(a) 9 km (b) 28.5 km (c) 35.5 km	July 1997 to June 2000
4	Beanibazar-Kailashtila Gas Transmission Project	20”	18-km	June 1997 to Sept. 2001
5	Rashidpur-Ashuganj Gas Transmission Pipeline (1st Phase): Rashidpur-Habigonj	30”	28 km	July 1997 to May 2005
6	Rashidpur-Ashuganj Gas Transmission Pipeline (2nd Phase): Habigonj-Ashuganj	30”	54 km	July 2002 to May 2005
7	SCADA Telecommunication Project	–	–	Jul 1995 to Nov. 2003
8	Nalka-Bogra Gas Transmission Pipeline (a) Nalka-Hatikumrul (b) Hatikumrul-Bogra	(a) 30” (b) 20”	(a) 6 km (b) 54 km	July 2003 to June 2006
9	Ashuganj-Monohordi Gas Transmission Pipeline Project	30”	37 km	July 2003 to June 2007
10	Dhaka Clean Fuel Gas Transmission Pipeline (GTCL Part) Project	20”	60 km	July 2002 to June 2008
11	Titas Gas Field (Location-G)-AB Pipeline Gas Transmission Pipeline Project	24”	8 km	Jan 2009 to July 2012
12	Srikail Gas Field (Location-2)-AB Gas Transmission Pipeline Project	20”	1.5 km	Oct 2012 to March 2013
13	Monohordi-Dhanua & Elenga-Bangabandhu Bridge East Gas Transmission Pipeline Project (2nd Phase)	30”	51 km	July 2006 to June 2014
14	Bonpara-Rajshahi Gas Transmission Pipeline Project	12”	53 km	July 2006 to Dec. 2014
15	Bibiyana-Dhanua Gas Transmission Pipeline Project	36”	137 km	April 2011 to June 2015
16	Titas Gas Field (Location- C, B & A) To Titas-AB Gas Transmission Pipeline Project	10”	7.7 km	July 2013 to June 2015
17	Bheramara-Khulna Gas Transmission Pipeline Project	20”	163.03 km	July 2007 to Dec 2015
18	Hatikumrul-Ishardi-Bheramara Gas Transmission Pipeline project	30”	84 km	July 2006 to Dec 2016
19	Gas Transmission Capacity Expansion-Ashuganj to Bakhrabad Gas Transmission Pipeline (2nd phase)	30”	61 km	Jan. 2010 to Dec 2017
20	Head Office Building of Gas Transmission Company Limited at Sher-e-Bangla Nagar Administrative Area, Agargaon, 13 Storied with 2 basements	–	–	July 2012 to Dec 2017
21	Titas Gas Field Well No. 2.1, 24 (Sorail) To	20”	3.30 km	Jan 2016 to

	Khatihata and Well No. 25, 26 (Malihata) To Khatihata Gas Transmission Pipeline Project			Dec 2017
22	Installation of Ashuganj & Elenga Compressor Stations Project	–	–	Jan 2006 to June 2018
23	Moheshkhali-Anwara Gas Transmission Pipeline Project	30”	91 km	July 2014 to June 2018
24	Rehabilitation & Expansion of Existing Supervisory Control and Data Acquisition (SCADA) System of National Gas Grid under GTCL (Component B of Bheramara Combined Cycle Power Plant Development Project)	–	–	June 2013 to Dec 2018
25	Bakhrabad Siddirgonj Transmission Pipeline Project	30”	60 km	July 2007 to Dec 2018
26	Anwara-Fouzdarhat Gas Transmission Pipeline Project	42”	30 km	April 2016 to March 2020
27	Maheshkhali Zero Point (Kaladiar Char) – CTMS (Dhalghat Para) CTMS Gas Transmission pipeline Project	42”	7 km	Oct. 2018 to March 2021
28	Maheshkhali-Anowara Gas Transmission Parallel Pipeline Project	42”	79 km	July 2016 to June 2021
29	North-South Gas Transmission Pipeline Project	24”	175 km	July 1987to June 1992
30	Ashuganj-VS3 Gas Transmission Pipeline Project	20”	1.6 km	July 1984 to June 1987
31	Ashuganj-Elenga (Brahmaputra Basin) Gas Transmission Pipeline Project	24”	124 km	July 1984 to June 1990
32	Bakhrabad-Chittagong Gas Transmission Pipeline Project	24”	174.65 km	July 1980 to June 1986
33	Bakhrabad-Demra Gas Transmission Pipeline Project	20”	68.72 km	July 1984 to Dec. 1987
34	Chittagong-Feni-Bakhrabad Gas Transmission Pipeline Project	36”	181 km	Jan. 2016 to Dec. 2021
35	Dhanua-Elenga & West side of Bangabandhu Bridge-Nalka Bakhrabad-Chittagong Gas Transmission Pipeline Project	30”	67 km	July 2014-June 2022

Source: GTCL

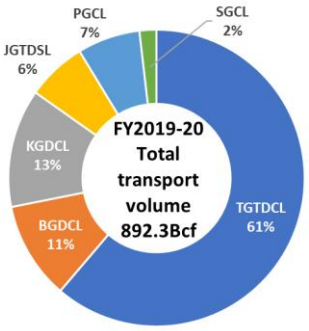


Source: GTCL

Figure 2.1-9 Natural Gas Pipelines in Bangladesh

Together with construction of LNG receiving terminals, construction of pipelines to connect to the domestic gas grid in Bangladesh was also considered and implemented. According to Petrobangla's Annual Report 2020, GTCL has constructed the (No. 26-28) pipelines listed in Table 2.1-4 to deliver 202.8 Bcf of RLNG to the domestic grid in FY2019-2020. Fouzdarhat is a valve station that serves as a hub to send gas to Chittagong and greater Dhaka areas, which are major gas consumption areas.

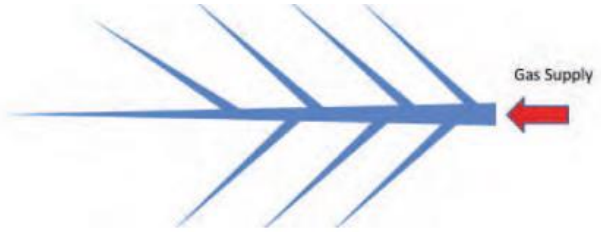
In FY2019-2020, GTCL transported 892.1 Bcf of gas, an increase of 1.97% year-on-year. The reported gas transportation amounts include TGTDCL: 546.56 Bcf, BGDCL: 94.78 Bcf, KGDCL: 115.24 Bcf, PGCL: 61.03 Bcf, and SGCL: 16.53 Bcf.



Source: PetroBangla

Figure 2.1-10 GTCL's Gas Transportation Performance

Bangladesh's gas infrastructure, including gas pipelines, faces a number of problems. The first issue is the buried status of gas pipelines and their management methods. The current gas supply system in Bangladesh is the so called Fish Bone supply system. It is a typical one for initial stage of the gas infrastructure development. The upstream pressure near gas fields is the highest, and the downstream pressure gradually decreases. In principle, higher pressure is required at the inlet of the system to maintain the overall pressure system properly. Since the supply system relies on a certain level of high pressure, operational flexibility is limited. The system is also vulnerable to disruption in the trunk line. Once part of the trunk line is damaged or closed, all the downstream customers are affected, and backup capability is limited. In case of demand increase or pipeline extension, it is necessary to install additional compressors and/or raise the inlet gas pressure. In addition, the management and updating of basic asset registers such as process flow diagrams and route diagrams, which are important for the proper management of gas infrastructure, is also considered inadequate.



Source: JICA

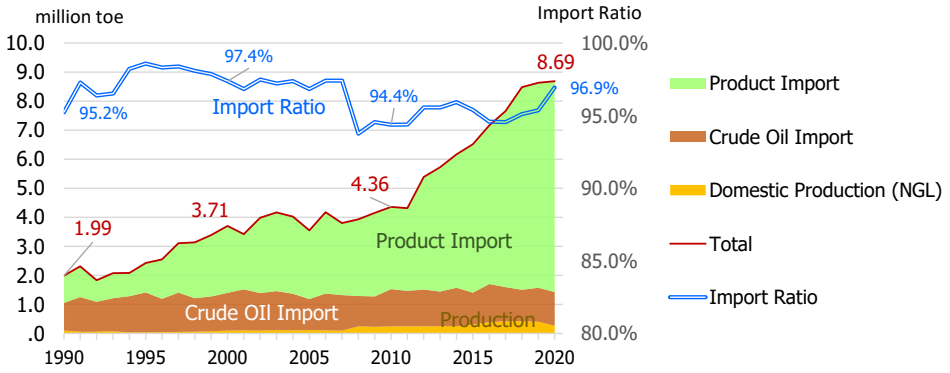
Figure 2.1-11 Concept of Fishbone Type Gas Infrastructure

The second issue is gas leakage, caused by the aging of the existing gas infrastructure. Some of the pipelines and indoor pipes of local gas companies are more than 50 years old, and there have been a series of incidents caused by gas leaks. One factor is the lack of a sense of danger

regarding maintenance and safety management. The TGTDCL handled 5,605 gas leakage incidents in pipelines and 119 gas leakage incidents in indoor piping in 2020. Gas leakage is detected by methane cameras at many operation points, which is dangerous and must be fixed as soon as possible[3]. Gas leak response after the gas meter exit is left to the contractor by the facility owner. Presently local gas companies do not take the initiative in managing the safety of indoor piping.

2.2 Petroleum

Oil consumption is relatively small at around 210,000 barrels per day (BD) and is mostly used as fuel for automobiles and irrigation pumps. Oil is mostly imported except for a small amount of condensate associated with natural gas production. Oil consumption for power generation has increased after 2010.



Source: IEA World Energy Balances 2022

Figure 2.2-1 Oil Supply in Bangladesh

There is a small refinery at Chittagong with a refining capacity of 30,000BD and very small condensate fractionators around natural gas fields, while 2/3 of petroleum products are imported. To cope with future demand increase, expansion of the Chittagong refinery is planned but with a total capacity of 100,000BD. Construction of a large refining capacity is scheduled in PP2041, but a tangible project plan is yet to be confirmed. How to secure expanding supply of petroleum products against fast increasing demand is an important issue for the country's energy policy.

(1) Crude Oil Production

Indigenous oil production is limited to condensate only associated with natural gas production. According to the Hydrocarbon Unit, production was 3,357 thousand barrels in FY2020-2021 (530,000kL or 9,199 BD). Condensate is used as it is or processed at fractionators built near gas fields into petroleum products such as petrol and diesel gas oil, and sold in the market. According

[3] JICA study team on Gas Network System Digitalization and Improvement of Operational Efficiency in Gas Sector in Bangladesh

to IEA, crude oil production was 1,164 ktoe in 2020, while condensate production was 265 ktoe. Of them, 1,133ktoe was processed at refineries while 206ktoe was transferred to petroleum products after easy treatment.

(2) Crude Oil Import

Bangladesh Petroleum Corporation, the controlling corporation of the Eastern Refinery Limited operating the Chittagong Refinery, purchases crude oil from Saudi ARAMCO and ADNOC(UAE). Composition for the period since 2011 through 2020 was Arabian Light 53% and Murban 47%.

Table 2.2-1 Crude Oil Import by Type Since 2011(tons)

Year	Arabian Light		Murban		Total
2011	627,535	52%	583,960	48%	1,211,495
2012	682,039	54%	583,494	46%	1,265,533
2013	592,054	50%	591,091	50%	1,183,145
2014	592,865	45%	714,746	55%	1,307,611
2015	697,667	64%	395,006	36%	1,092,673
2016	728,307	56%	579,848	44%	1,308,155
2017	497,907	43%	667,861	57%	1,165,768
2018	597,338	55%	482,260	45%	1,079,598
2019	592,711	51%	573,717	49%	1,166,428
2020	698,694	60%	457,436	40%	1,156,130
2021(Jan-Jun)	398,938	53%	352,129	47%	751,067
Total	6,706,055	53%	5,981,548	47%	12,687,603

Source: BPC

(3) Crude Oil Processing

Eastern Refinery Limited (ERL) operates a small refinery in Chittagong with processing capacity of 1.5 million tons a year (approximately 30,000BD). According to IEA, it processed 1,397ktoe of crude oil (23 kBD) in 2020. It processes Middle East light crude oils as explained above and delivers to the domestic market. The refinery is equipped with hydro treating units for light products but does not have any equipment for desulfurization and/or cracking of heavy components. 90% of the petroleum products supplied are coming from import.

(4) Activity of BPC and ERL

a. History of ERL

ERL, a subsidiary of Bangladesh Petroleum Corporation (BPC), was established in 1963 as a public limited company with participation of East Pakistan Industrial Development Corporation (EPIDC) 35%, Burmah Oil Company (BOC) 30% and the remaining 35% were owned by private companies. Since November 1985, BPC has held a 100% stake. Presently, ERL is run by a board appointed by the government (Managing Director, ERL's CHIEF EXECUTIVE - is one of the directors).

ERL plays an important role in supplying about 40% of Bangladesh's demand for petroleum products and maintains the stability of Bangladesh's oil products market. At present, ERL is the only fallback system to cope with a crisis in petroleum products in the case of cut-off in imports of petroleum products.

b. Crude Oil Treatment

Crude oil processing and petroleum production by ERL in recent years is summarized in Table 2.2-2.

Table 2.2-2 ERL Crude Oil Treatment volume and Oil Product Production

Unit: ton

YEAR	2016-17	2017-18	2018-19	2019-20	2020-21
PROCESSED QUANTITY	1,391,665	1,241,730	1,410,400	1,078,570	1,545,240

LPG	11,454	9,793	12,831	8,902	11,583
NAPHTHA	153,249	96821	100,572	77,015	143,561
MS	39,896	57,885	90,694	82,099	75,231
JET A-1	0	1,403	0	895	0
SKO	149,179	126,856	95,196	83,157	72,956
HSD	539,508	495,295	632,808	447,426	719,961
JBO	17,733	210,249	11,052	13,112	8,587
LDO+LDO (RF)	4,818	3,967	5,320	4,035	5,805
FO+FO (RF)	374,046	301,141	344,038	275,312	416,115
BITUMEN	55,635	58,162	69,877	30,500	52,786
TOTAL	1,345,518	1,264,751	1,362,388	1,022,453	1,506,585

(Source : BPC)

Due to the shallow water depth off the coast of Chittagong, large tankers transfer crude oil off the coast and crude oil is transported by barge to the refinery. This is inefficient and expensive. To solve the issue, a single-point mooring system (SPM) is being constructed by BPC. The SPM buoy is located about 10 km west of Matarbari. 36-inch diameter pipeline of about 30 km will be used to transport to Moheskhali island's storage tanks and 18-inch diameter pipeline to the ERL refinery in Chittagong, with a total length of about 214 km. The pipeline consists of two systems, one for crude oil and one for petroleum products (diesel). The oil transfer capacity is 20.0 million tons per year. Construction is scheduled to be completed in June 2023.

c. Import of Petroleum Products

BPC relies on import for about 70% of its domestic demand for petroleum products. It imports the following products from state-owned organizations around the world through intergovernmental contracts and international public tenders.

- Gas Oil 0.005% Sulphur (Diesel)
- Motor Gasoline (MOGAS)-95 RON
- Jet A-1
- High Sulphur Furnace Oil 180 CST (HSFO)
- Marine Fuel (Low Sulphur Furnace Oil)

As shown in Table 2.2-3, the main imported product was Gas Oil (High Speed Diesel = Automotive Diesel Oil), which had a 77% share of petroleum product imports since 2011. Since demand for kerosene for lighting is decreasing with the achievement of 100% electrification, kerosene has not been imported since 2014. Domestic kerosene supplied by ERL and other small fractionation plants seems to sufficiently meet the domestic demand.

For petroleum product import the following eight petroleum product suppliers are listed:

1) Kuwait Petroleum Corporation (KPC), Kuwait
2) PETCO Trading Labuan Company Limited (PTLCL), Malaysia
3) Emirates National Oil Company (Singapore) Pte. Ltd. (ENOC), Duabi, UAE
4) Petrochina (Singapore) Pte. Ltd, China
5) PT. Bumi Siak Pusako (BSP), Indonesia
6) Unipec Singapore Pte Ltd., China
7) PTT International Trading Pte, Thailand
8) Numaligar Refinery Limited (NRL), India

Table 2.2-3 Oil Products Imported by Oil Type since 2011

Unit: ton

Year	Petroleum products import								
	GAS OIL	Share	JET A-1	MOGAS	SKO	HSFO	LUBE	MARINE FUEL	Total
2011	2,955,798	70%	318,202	95824	153598	665260	4980		4,193,662
2012	2,618,685	70%	339,699	95824	20380	670899	4852		3,750,339
2013	2,608,746	64%	310,884	97641	28376	1005104			4,050,751
2014	2,903,928	70%	334,079	35596		869124			4,142,727
2015	2,974,749	79%	338,315	33842		414451			3,761,357
2016	3,130,052	76%	354,430	150601		481673			4,116,756
2017	3,716,349	79%	393,918	32837		563856			4,706,960
2018	3,457,987	84%	305,777	32550		343129			4,139,443
2019	3,410,937	81%	426,745	116603		274915			4,229,200
2020	3,535,572	88%	245,732	190509		22852		14906	4,009,571
2021(Jan-Jun)	1,981,186	86%	146,038	146722		25072		15058	2,314,076
Total	33,293,989	77%	3,513,819	1,028,549	202,354	5,336,335	9,832	29,964	43,414,842

Source: BPC

d. Domestic Sale of Petroleum Products

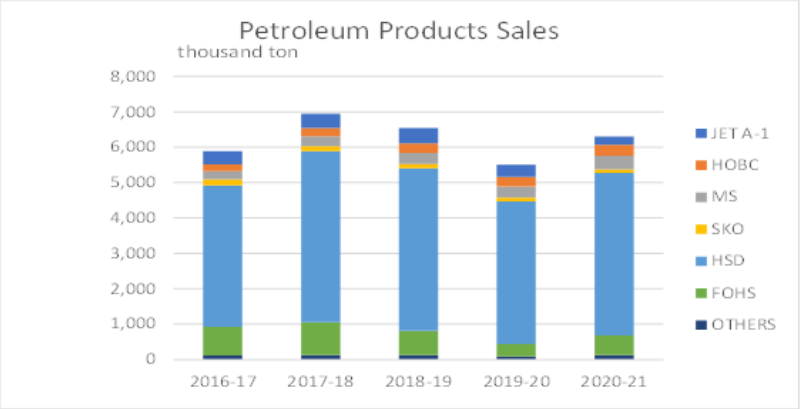
BPC's domestic oil sales fell for the second consecutive year, peaking at FY2017(2017-2018) due to COVID 19, but FY2020 turned to a recovery. Diesel oil, which is widely used in a wide range of sectors such as electricity, transportation, industry, and agriculture, is widely used, especially High-Speed Diesel, which accounts for more than 70%.

Table 2.2-4 Sales volume of petroleum products since 2016

Unit: ton

	2016-17	2017-18	2018-19	2019-20	2020-21
JET A-1	376,700	408,272	430,341	345,126	237,894
HOBC	186,911	230,280	266,988	262,825	303,917
MS	232,359	284,668	318,593	322,432	378,846
SKO	170,993	138,403	121,497	105,851	101,783
HSD	4,000,044	4,835,712	4,593,486	4,023,409	4,597,585
FOHS	806,440	925,150	683,880	364,241	559,032
OTHERS	115,283	125,851	123,126	79,207	120,673
	5,888,730	6,948,336	6,537,911	5,503,091	6,299,730
HSD share	68%	70%	70%	73%	73%

Source: BPC



Source: BPC

Figure 2.2-2 Petroleum Products Sales

e. Export of Petroleum Products

Because of the relatively low gasoline consumption compared with diesel in Bangladesh, BPC is exporting naphtha produced at the ERL through an international open tender. In recent years, the export volume of naphtha has decreased sharply compared to 10 years ago due to an increase in the supply volume to the petrochemical plants in Bangladesh. Naphtha export may cease in the future as gasoline demand expands rapidly reflecting a robust increase in mobility requirement and expanding domestic production of petrochemical products.

Table 2.2-5 Naphtha: Exports and Supply for Domestic Petrochemical Plants

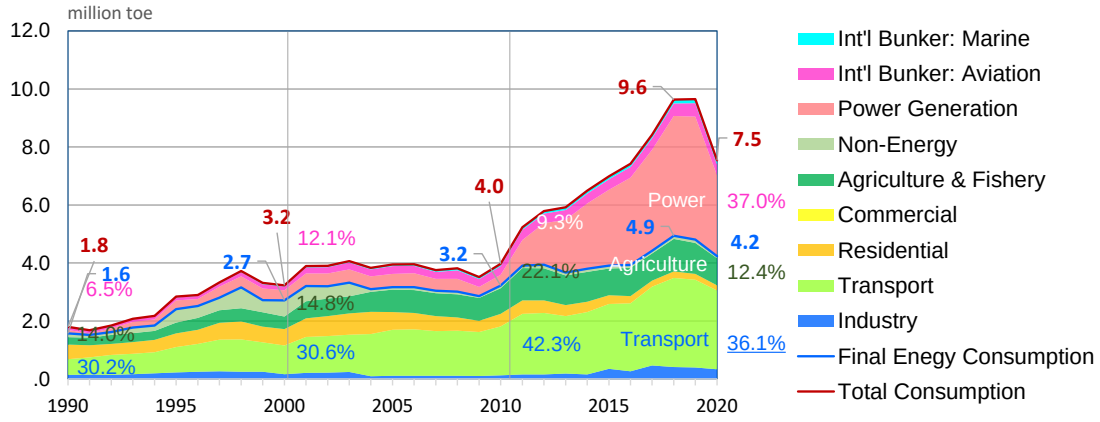
Unit: ton

Year	Production	Export	Supply to the Local Petrochemical Plant	Export Ratio
2010-11	133,071	133,071	0	100%
2011-12	113,686	113,686	0	100%
2012-13	138,461	133,901	4,560	97%
2013-14	142,859	93,086	49,773	65%
2014-15	166,138	75,320	90,818	45%
2015-16	120,615	37,566	83,049	31%
2016-17	159,955	109,130	50,825	68%
2017-18	83,031	18,585	64,446	22%
2018-19	108,401	36,513	71,888	34%
2019-20	82,386	0	82,386	0%
2020-21	149,849	18,795	131,054	13%
Total	1,398,452	769,653	628,799	55%

Source: BPC

(5) Domestic Demand for Petroleum Products by Sector

Petroleum consumption in Bangladesh has expanded more than twofold between 2000 and 2020. From around 2010, consumption of petroleum products for power generation expanded fast to offset declining domestic gas production. However, as LNG import started in 2018, this quantity is decreasing. Among others, petroleum products are mainly used for transport and irrigation pumps.



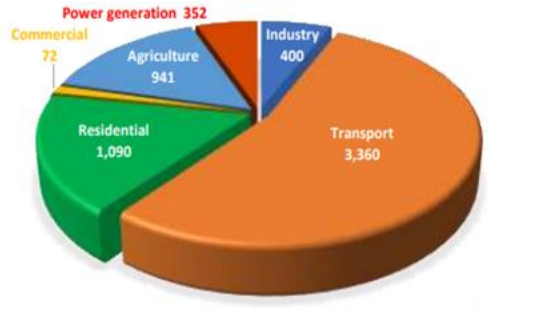
Source: IEA World Energy Balances 2022

Figure 2.2-3 Consumption of Petroleum Products in Bangladesh

In 2019-20, sales and consumption amount in Bangladesh (6,215 ktoe) were 5,228 ktoe of petroleum products by BPC, and 987 ktoe of LPG by private distributors and;

a. More than half of the total, 3,360 ktoe, was for the transportation sector (including road, rail, domestic air and domestic maritime transport).

b. The second largest consuming sector was residential (1,090 ktoe), of which LPG comprises more than 90%.
c. Over the past five years, LPG consumption in the household sector has been constantly growing at a rate higher than 40% per year, while kerosene for lighting and cooking is diminishing.
d. Petroleum products used in the agricultural sector (941 ktoe) was mostly diesel oil for irrigation pumps.



Source: SREDA

Figure 2.2-4 Petroleum Demand by Sector

2.3 Coal

The supply of coal in Bangladesh depends on the Barapukuria Coal Mine (BCMCL), the only domestic coal mine, and imported coal. Table 2.3-1 shows the supply of coal by year for the past five years in kt and ktoe[4]. The coal consumption is currently for brick factories, coal-fired power plants, and consumer use. Among these, the Payra coal-fired power plant (660 MW x 2), which uses import coal, was commissioned in May and December 2020, and imported 1.55 million tons of coal from September 2019 to December 2020. This means that 5.28 million tons of coal, the balance with the total import in 2019-20, was used for purposes other than thermal power plants[5].

Table 2.3-1 Supply of Coal in Past Years

Year	Domestic	Import	Total	Domestic	Import	Total
	BCMCL	Private		BCMCL	Private	
	ktons	ktons	ktons	ktoe	ktoe	ktoe
2015.7-2016.6	1,022	3,812	4,834	627	2,325	2,953
2016.7-2017.6	1,161	2,801	3,962	713	1,709	2,422
2017.7-2018.6	923	3,395	4,318	567	2,071	2,638
2018.7-2019.6	803	5,754	6,557	493	3,510	4,003
2019.7-2020.6	808	6,828	7,636	496	4,165	4,661
2020.7-2021.6	754	6,751	7,504	463	4,118	4,580

Source: Energy Scenario of Bangladesh 2019-20, 2020-21 Hydrocarbon Unit

[4] The coal conversion rate in ktoe is taken from SREDA's National Energy Balance 2019-20, 3.8 Calorific Value and Conversion (P14), where domestic coal is 0.614 toe/ton (BCMCL 25.68MJ/kg), Import coal is 0.610 toe/ton (DREDA estimate).
[5] BCMCL's production figures for 2018-19 and 2019-20 are different from the figures published on BCMCL's website, which will be discussed later, and are under investigation)

2.3.1 Current status and issues of coal demand

(1) Coal-fired Thermal Power Plants

Table 2.3-2 shows the coal-fired power plants in operation, under construction, or planned as of 2021. In this table, No. 1 to 11 are for imported coal, and No. 12 to 13 are for domestic coal. Therefore, if all the power plants shown in this table are put into operation, the total coal consumption in 10 years will increase to about 35 million tons.

Table 2.3-2 Coal-fired power plants for the next 10 years as of 2021

Name of the Power Plant	Installed Capacity (MW)	Ownership	Status
1. Payra, Potuakhali Coal Fired Power Plant (1st Phase)	1,320	BCPCL (NWPGCL)	Existing
2. Payra, Potuakhali Coal Fired Power Plant (2nd Phase)	1,320	BCPCL (NWPGCL)	Committed
3. Chittagong Coal Fired Power Project (S.Alam Group)	1,224	IPP	Committed
4. Borisal Coal Fired Power Plant	307	IPP	Committed
5. Rampal,Maitri Super Thermal Power Plant	1,320	BIFPCL	Committed
6. Patuakhali (Phase-1)	1,320	RNPL	Committed
7. Matarbari Power Plant (Phase 1: Unit 1&2)	1,200	CPGCBL	Committed
8. Dhaka Orion	635	IPP	Committed
9. Mirshorai Coal Fired Power Plant (Hangzhou Group)	1,240	IPP	Committed
10. Moheskhali Power Plant (ECA)	1,320	BPDB	Planning
11. Matarbari Power Plant (Phase 2: Unit 3&4)	1,200	CPGCBL	Planning
12. Barapukuria (1st & 2nd Unit)	250	BPDB	Existing
13. Barapukuria 275 MW (3rd Unit)	275	BPDB	Existing

Source: Compiled by the research team

The following is an overview of the coal-fired power plants currently in operation and the issues they face.

1) Barapukuria Power Plant

a. Overview

The Barapukuria Power Plant is located near Durgapur, Dinajpur, Bangladesh. It is a sub-critical (Sub-C) power plant with a total installed capacity of 525 MW, consisting of two 125 MW units that started operation in 2006 and one 275 MW unit that started operation in late December 2017, and is operated by the Bangladesh Power Development Board (BPDB). Coal is transported directly from the adjacent Barapukuria coal mine by belt conveyor.

The power plant was temporarily shut down in July 2018 due to a severe coal shortage and started generating power again in September 2018. Prior to the shutdown of the power plant,

it was supplying an average of about 380 MW of electricity to the national grid.

b. Issues

Coal supply is only from the Barapukuria coal mine, which remains in short supply, although its 525 MW installed capacity requires more than 1 million tons of coal per year; in 2018, the Barapukuria coal mine stopped selling coal to the private sector and now supplies all their coal to the power plant. Details of the Barapukuria coal mining plans to increase production will be discussed in Section 5.1.1(2), but the amount of power generated by the Barapukuria power plant is determined by the coal production of the Barapukuria coal mine. The supply to the Barapukuria power plant is shown in Table 2.3-4.

2) Payra Power Plant

a. Outline

The Payra Power Plant is an ultra-supercritical (USC) coal-fired power plant located in Dankari, Patuakhali District, Bangladesh. The plant was developed by Bangladesh China Power Company Limited (BCPCL), a 50:50 joint venture between China National Machinery Import and Export (CMC) and North West Power Company Limited (NWPGCL).

The 660 MW No.1 Unit was commissioned on May 15, 2020 and the 660 MW No.2 Unit on December 8, 2020, for a total of 1,320 MW in the 1st Phase. Coal is currently imported from PT Bayan Resources in Indonesia, with coal imports reaching 1.55 million tons between September 2019 and December 2020, requiring 4.12 million tons per year. Table 2.3-3 shows the operation status until December 2020. The 2nd Phase, 660 MW x 2 Units, is currently under construction.

Table 2.3-3 Payra Power Plant 1st Phase Operation Status as of December 2020

At a glance Payra 1320 MW Thermal Power Plant (1st Phase)

(as on 22 December 2020)

1st Unit Synchronization	13 January 2020
Initial Operation Date (IOD)	15 May 2020
2nd Unit Synchronization	26 August 2020
Commercial Operation Date (COD)	8 December 2020
Total Generation	3036091119 kWh
Total Coal Consumption	1308846 Tons
Total HSD Consumption	5152 Tons
Total Limestone Consumption	17428 Tons
Availability Factor	83.43%
Plant Factor	68.42%

Source: Annual Report 2020, Bangladesh-China Power Company (PVT.) Limited

b. Issues

The coal power plant faces the issue of unstable supply of coal due to the coal transportation route known as the "Rabnabad Waterway Draft". Several rivers originating in the Himalayas flow into the Bay of Bengal and wash away large amounts of soil in Bangladesh. Among those rivers, the Rabnabad channel serves as an outlet for the large amount of silt that flows through the Meghna, Tetulia and Kajal rivers. As a result, the siltation rate is very high in the Ravnabad channel, which poses a challenge to the Payra Thermal Power Plant located on the west bank of the Ravnabad channel. the length of the channel from BCPCL's jetty to the Payra Fairway is about 76 km. Due to the high sedimentation rate, the channel is blocked at several points and has to be dredged intermittently to maintain navigability. As a result, barge transportation from ocean-class vessels, called Lightering, is used when the vessel cannot enter.

(2) Industrial Consumption

In Bangladesh, industrial coal consumption is not very large compared with other countries, as general coal consuming industries such as cement and large-scale blast furnace steel production do not present broadly. This is mainly because carbonate rocks as feedstock for the cement industry is scarce and clinker is imported for production of final cement products. Instead, imported coal has been used for production of bricks as the major construction material in Bangladesh. In view of the environmental problems incurred by the industry, burnt bricks will be gradually replaced by non-burnt type stressed concrete blocks. Domestic steel production is not very large and only electric furnaces are used to reproduce scraps to steel. As such, industrial coal consumption will remain relatively small in the course of economic development.

2.3.2 Current status and issues of coal supply

(1) Indigenous coal

The coal resources of Bangladesh consist of Paleozoic to Mesozoic bituminous coal known as Gondwana coal and Tertiary sub-bituminous to lignite coal. According to the current exploration data, Bangladesh is divided into five coal fields, all of which are located in the northwestern part of the country between the Jamuna and Padoma rivers, with a total of 3,300 million tons of defined plus estimated coal reserves. In the Draft Coal Policy (June 2007), except for Jamalgonj, which is relatively deep, the definite amount of coal is 1,168 million tons, which is considered to be the amount of coal to be mined for the time being. This coal reserve is expected to increase further with the increase of exploration. Figure 2.3-1 shows the location of coal fields in red.

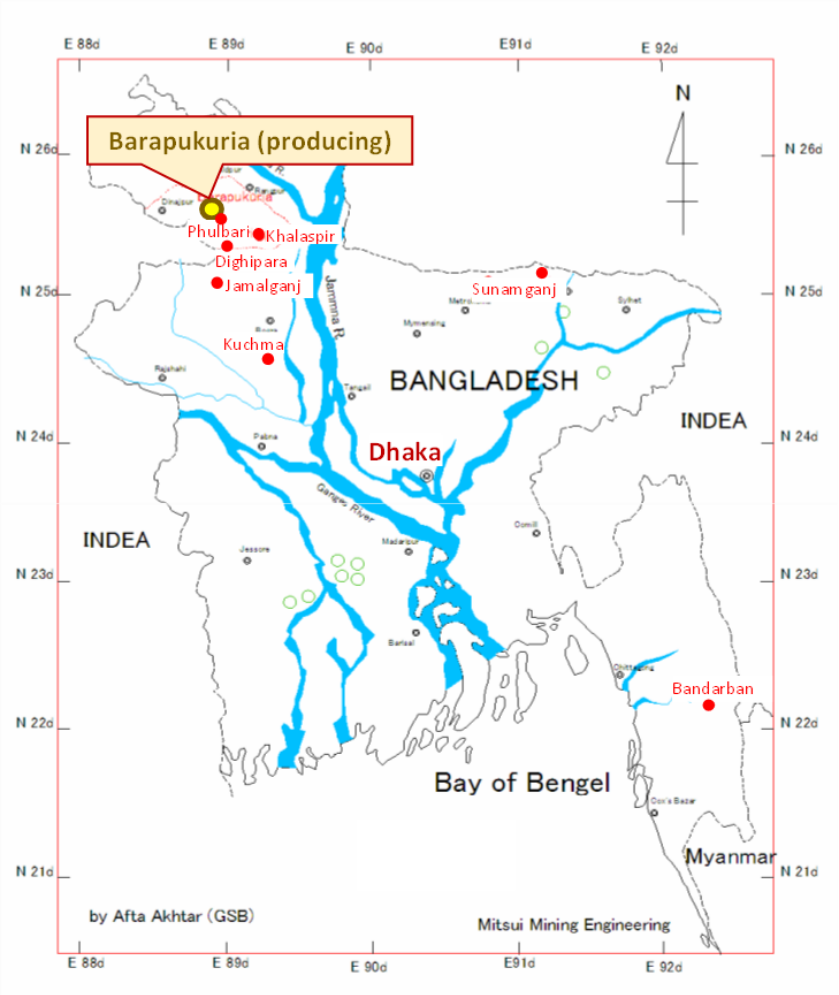
The characteristics of Bangladeshi coal are being high quality with low ash and low sulfur content, and some coal is classified as coking coal, which has high commercial value. Some F/S for future domestic coal development will be outlined in Section 7.1.1.(3).

1) Barapukuria Coal Mining Company Limited (BCMCL)

(a) Method of production:

BCMCL is the only coal mining company in the country.

In 1994, a Construction and Development Agreement (BCMP-77) was signed with CMC of China on a turnkey basis, and the development of shafts, mine bottoms and roads were completed. In 2005, the first Management and Production (M&P) contract for coal production was signed between BCMCL and a Chinese consortium (XMC-CMC), followed by a second contract called MPM&P, a Management, Production, Maintenance and Provisioning Services contract, and a third contract that ended in August 2021. Currently, the fourth contract has been signed and operations are continuing. As a result, the production cost has become expensive due to the coal mine management and production outsourcing fees.



Source: GSB

Figure 2.3-1 Location map of coal fields[6] in Bangladesh

[6] Red circles indicate coal fields. However, the exploration information of Sunamuganj and

(b) Geology

The Barapukuria coal basin has an area of 6.68 square kilometers. The coal reserves of this basin are about 390 million tons. The entire coalfield is covered by the Barind Clay Formation (Madhupur Clay). The Dupi Tila Formation lies beneath this layer. This formation is divided into two layers. The upper part is the water-bearing Upper Dupi Tila and the lower part is the thick clay layer (Lower Dupi Tila). Beneath the Dupi Tila is the Gondwana Formation, which contains coal. A total of six coal seams have been identified in the basin, and the average thickness of the coal seams is 36 meters.

(c) Coal quality

According to the classification of coal, Barapukuria coal is classified as the bituminous to sub-bituminous type. The major contents of the coal are 48.40% fixed carbon, 12.40% ash, 29.20% volatile matter, 10% total moisture, 0.53% Sulphur and calorific value of 25.68 MJ/kg (11,040 Btu/Ib).

(d) Production Status

It is the first underground coal mine in Bangladesh to use a mechanized longwall mining method and has achieved stable coal production. At the time of the first contract, the face length was 100-160 m, the working panel length was 300-600 m, and the mining height was 3 m. As of 2016, 15 faces had been mined. The problems in mining are thick layer mining, high temperature, high humidity, spontaneous combustion, and water runoff in the mine.

In the second contract with XMC-CMC, the LTCC (Longwall Top Coal Caving) facility, a thick layer mining technology was introduced and started operation in May 2013. The LTCC mining method involves cutting 3m mining height at the initial longwall face and simultaneously using a conveyor installed at the rear of the self-advancing support to convey about 2m of fallen coal above the frame. With this technology, more than 1 million tons of coal was produced in FY2015 and FY2016. After that, there will be no more than 1 million tons of coal produced until FY2020, but it is hoped that the thick layer mining technology will take root and production will increase.

All the equipment in the mine is made in China. The design capacity of the mine is about 1 million tons per year, but the company is aiming to increase production with the existing facilities due to the increased capacity of the Barapukuria thermal power plant. The company is also considering increasing the capacity of its facilities to accommodate a future increase of 1.5 million tons of coal output. The F/S for the expansion plan has been completed, and the F/S for the open pit mining is currently being proposed to EMRD. The details are described in 7.1.1.(3).

Bandarban is not disclosed.

(e) Production Volume

Table 2.3-4 shows the amount of coal produced and sold since the mine was opened. Coal is not sold to general industry from FY2018, but only to Barapukuria Power Plant (PDB is shown in the table). In addition, "to PDB by P.D. (Reference figure)" in Table 2.3-4 shows the figures from P.D.

Table 2.3-4 Coal production and sales

NO.	Financial Year	Coal Production (kt)		Coal Sale (kt)		
		Production	Remarks	to PDB	to local industries	to PDB by PD (Reference figures)
1.	2020.7-21.6	754		753	---	na
2.	2019.7-20.6	811		807	---	1,240
3.	2018.7-19.6	806		829	---	565
4.	2017.7-18.6	923	Stop coal sale to local in 2018	787	274	825
5.	2016.7-17.6	1,161		541	452	587
6.	2015.7-16.6	1,022		486	431	489
7.	2014.7-15.6	676		522	313	522
8.	2013.7-14.6	947		524	339	539
9.	2012.7-13.6	855	Introduction of LTCC, 2013.5	644	288	590
10.	2011.7-12.6	835		500	332	449
11.	2010.7-11.6	667		464	108	410
12.	2009.7-10.6	705		501	319	480
13.	2008.7-09.6	828		532	258	na
14.	2007.7-08.6	677		491	10	na
15.	2006.7-07.6	388		460	6	na
16.	2005.7-06.6	303		209	45	na
17.	2004.7-05.6	178	Construction	---	75	
	-2004.6			---	70	
	Total	12,535		6,662	3,320	

Source: Barapukuria Coal Mine Co. Ltd. [BCMCL], http://bcmcl.org.bd/home/ and Power Division in 8th Five Year Plan

(2) Imported Coal

Before start-up of the Payra power plant using imported coal, imported coal was mainly used as fuel at brick burning plants. The main source of imported coal was Indonesian coal, which has a high sulfur content and is inexpensive. Indian coal was also imported from the northern part of the country near the border with India, but this coal also had a high sulfur content. As a result, SO_2 air pollution has become a problem.

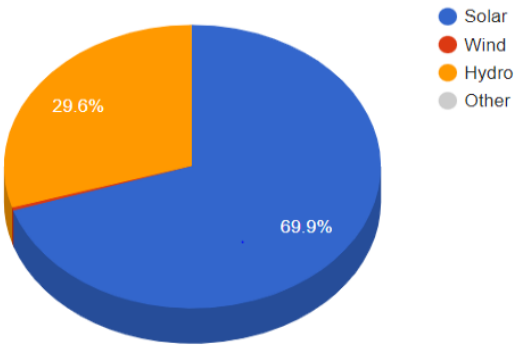
2.4 Renewable Energy

2.4.1 Current situation surrounding renewable energy in Bangladesh

Figure 2.4-1 shows a summary of the renewable energy installed capacity in Bangladesh. As of the end of December 2021, the renewable energy installed capacity (cumulative) was 777MW, out of which 543MW (about 70%) is Solar PV followed by Hydro (2.10MW, approx. 30%). This means that almost all the renewable energy capacity installed up to now is Solar PV and Hydro. The introduction of wind power is limited to about 3 MW: biogas power (0.69 MW) and biomass

power (0.4 MW) is also limited.

Techlology	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	347.43	196.01	543.44
Wind	2	0.9	2.9
Hydro	0	230	230
Biogas to Electricity	0.69	0	0.69
Biomass to Electricity	0.4	0	0.4
Total	**350.52**	**426.91**	**777.43**



(Source) SREDA, National Database of Renewable Energy

Figure 2.4-1 Renewable Energy Installed Capacity (December 2021)

Table 2.4-1 below shows a comparison between the renewable energy target in PSMP2016 and installed capacity as of the end of December 2021. Installed capacity (cumulative) of 777MW represents 31% of the original renewable target in PSMP2016. Similarly, the renewable energy ratio in total electricity generation is approx. 3.7% which is 37% progress of the PSMP2016 target.

Table 2.4-1 Renewable Energy Target

	Target in 2021 (PSMO2016)	Installed Capacity (December 2021)	Difference
Capacity(Cumulative)	2,470MW	777MW	▲1,693MW (▲69%)
Renewable Ratio	10%	3.7% (Note)	▲6.3% (▲63%)

Note: Calculated using total power generation capacity of Bangladesh (21GW) in 2021 by US State Department

(Source) Prepared by IEEJ referring to PSMP2016 and SREDA, National Database of Renewable Energy

As mentioned above, the installed capacity of renewable energy in Bangladesh is much lower than the target developed in PSMP2016. Progress of the renewable energy introduction is slower than the plan originally expected. Present status and issues are reviewed by renewable power generation technology as shown below.

2.4.2 Solar PV

Solar power is the renewable technology that the government of Bangladesh desires to expand most. A solar power potential study conducted under joint support of the United Nations Environment Programme (UNEP) and the Global Environment Facility estimated that the solar radiation in Bangladesh would be at least 2.4 x 10^{14} kWh, or 10,000 times the total electricity generated in 2007.

The government of Bangladesh sees great potential in grid-connected solar parks (promoted by

IPPs or state-owned power generation companies such as BPDB) and rooftop solar power, according to the Bangladesh Renewable Energy Expansion Program (SREP) released by SREDA with support from the World Bank. The potential of solar parks is estimated to be 1.4GW as of 2015, with an annual power generation of 20GWh. On the other hand, the installed capacity (cumulative) as of December 16, 2021 was 131 MW, and even if 110 MW were installed by the end of December 2021, the total capacity will be 241 MW, which is only 17% of the above potential. In addition, there are 430 MW of solar parks that were planned to be operational between 2016 and 2021, but they were postponed or rejected during the planning phase (Table 2.4-2).

Table 2.4-2 Summary of the installed capacity of Solar Park (December 2021)

Operation	Capacity(MW)	Finance	Status
2016～2021 (Original Schedule)	(430)	IPP/BPDB etc.	Delayed / Rejected during planning etc.
By the end of December 2021	131	IPP/Donor Support	Completed & Operating
By December 2022	110	IPP/BPDB	Under Construction
Total(*)	241		

Note: (*) 30MW, which were originally scheduled to commence operation during 2016～2021 but not yet operation due to delay or rejection during planning stage, is excluded
Source: Prepared by IEEJ referring to SREDA, National Database of Renewable Energy and the power generation development plan provided by BPDB

Table 2.4-3 summarizes the capacity of solar parks planned for installation in 2022-2030. Including those under feasibility study and land acquisition, the total capacity is about 2.0 GW. The successful implementation of these projects is the key to achieving NDC's GHG emission reduction target by 2030.

Table 2.4-3 Planned Capacity of Solar Park (2022～2030)

Operation	Capacity (MW)	Finance	Status
2022	480	IPP/BPDB	Construction/LOI etc.
202.1～2029	1,576	IPP/BPDB etc. /JV	Feasibility Study/Land Acquisition
Total	2,056		

(Source) Prepared by IEEJ referring to the power generation development plan provided by BPDB

The bottleneck in promoting solar parks is the difficulty in acquiring land. Bangladesh's land area is limited and it is the most densely populated country in the world. In addition, the Bangladeshi government restricts IPPs from acquiring land for agriculture in order to ensure food security in view of long-term population growth. In addition, in competitive bidding, IPPs are required to manage all the related risks related to land, but the complexity of the right of way makes it difficult for them to manage risks; this is the major barrier to entry, especially for foreign IPPs. In addition, IPP developers in areas adjacent to the river are required to carry out additional

work such as flood protection, which is a costly factor. The government is aware of this problem and is preparing land for Solar Parks by narrowing the river width through land reclamation. In recent years, the government has also begun to conduct competitive bidding under a scheme in which BPDP provides the land to IPP developers. However, the number of such bids has been small so far. Not limited to Solar Parks, the government of Bangladesh does not announce suitable candidate sites for Solar PV development and this is one of the factors preventing the spread of Solar PV. It is also important to take into account that Bangladesh has a unique climatic environment where about half of the year is rainy season (all day rainfall during the two months of monsoon).

The government of Bangladesh has an aspiration to promote Rooftop PV. The World Bank estimated the potential of Rooftop PV as 17GW nationwide. According to SREDA, the total number of projects is 1,620 with installed capacity of 75MW as of the end of December 2021, out of which 46% is grid-connected with net metering (NET) scheme while the remaining 54% is except NEM (Table 2.4-4). The government of Bangladesh has formulated Net Metering Guidelines in 2018 (NEM Guideline 2018). Considering the economics, NEM is an incentive for the adoption of Rooftop PV in the residential sector as households installing Rooftop PV can benefit from the difference between the generation cost of BDT 4/kWh and the electricity tariff of BDT 6-10/kWh from the public network. In addition, in September 2019, the Bangladesh government requested all government departments to install rooftop PV as per the current net metering guidelines. This is expected to result in installation of 300 MW of rooftop PVs across Bangladesh in four years. The government expects that industries including the Ready Made Garment (RMG), which is the backbone of the country's industry, will follow the guidelines. In addition, the government intends to focus on proactively installing rooftop PV in factories and commercial facilities located in SEZs. All the electricity generated by Rooftop PV are purchased by state-run distribution companies. They do not have concerns on the stability of the network with the currently low penetration ratio of rooftop PV so far. However, SREDA thinks it is necessary to manage the stability of the public network as the penetration ratio of the rooftop PV in the total electricity generation has been rising.

Table 2.4-4 Installed Capacity of Rooftop PV (as of the end of December 2021)

Category	Projects	Capacity(MW)	Grid	Purchaser
NEM	1,470	34	Connected	Distribution Co.
Except NEM	124	41	Connected/Non	Distribution Co.
Total	1,620	75		

Source: Prepared by IEEJ referring to SREDA, National Database of Renewable Energy

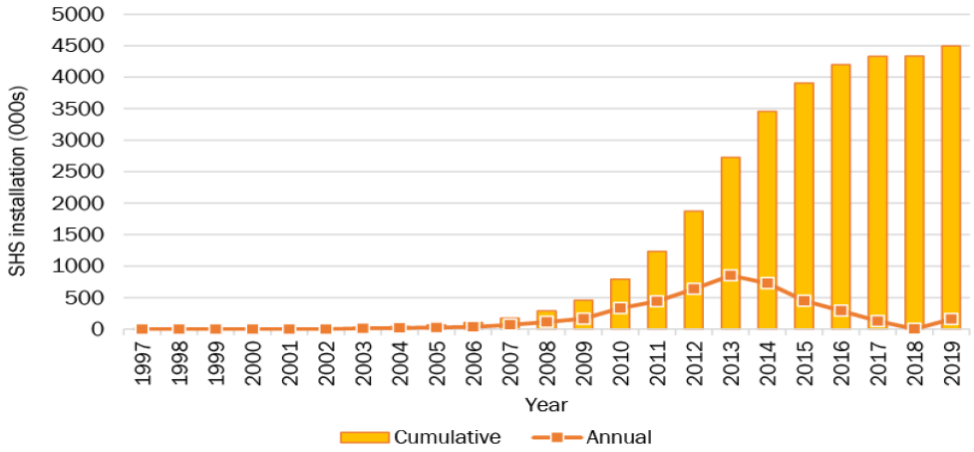
SHS (Solar Home System) is being promoted as an IDCOL program with funding from several donors. SHS is the driver of off-grid Solar PV in Bangladesh with 6 million projects implemented, of which 75% is coming from the IDCOL program as of the end of December 2021 (Table 2.4-5). However, as shown in Figure 2.4-2, the annual installation volume has already reached a

ceiling and thus, is not expected to increase significantly in the future.

Table 2.4-5 SHS Installation Capacity (as of the December 2021)

Program Sponsors	No. of Projects	Capacity(MW)
IDCOL	4,494,162	187.12
MoDMR	1,513,619	71.25
BREB	15,250	0.83
GIZ	400	0.2
RDCB	200	3.15
BRRI	1	0.003
Total	6,02.1,632	262.553

Source: Prepared by IEEJ referring to SREDA, National Database of Renewable Energy



Source: [DRAFT] National Solar Energy Roadmap 2021-41, Figure 3.3 (p.57)

Figure 2.4-2 SHS Installation Capacity (Yearly・Cumulative, 1997-2019)

2.4.3 Wind

The installed capacity of wind power generation at present is limited, about 3MW in total. On the contrary, installation of 375MW of wind power generation is expected from December 2021 to 2026 with the status of under construction or planning (Table 2.4-6).

Table 2.4-6 Wind Power Generation Capacity (Completed & Operating, Under Construction, Under Planning)

Operation	Capacity(MW)	Finance	Status
～ 2021 end	2.9	BPDB(self-funded)	Completion and Operating
2022～2026	357	BPDB(IPP)/CPGCBL	Under Construction(62MW) and Under Planning
Total	Approx.360		

(Source) Prepared by IEEJ referring to SREDA, National Database of Renewable Energy

High potential areas with good wind condition are limited to the coastal land or offshore in Bangladesh. An Indian company conducted wind power generation potential survey in 2005. However, the potential was limited as the survey only checked the potential for the wind turbine with a maximum height of 60m. Then after, during 2014 to 2018, USAID and NREL jointly conducted a potential survey for the wind turbine with maximum 120m heights. Currently, SREDA is conducting site specific survey for areas with good wind conditions. It is estimated that 245MW of wind power generation can be installed at 4 sites such as Cox's Bazar and Hatiya Island with good wind conditions. SREDA expects commencement of operation of those potential projects by 2021 through international tenders.

The installed capacity of wind power generation is limited due to insufficient capacity of SREDA to manage the tender process properly. Many companies including foreign investors have participated in the past tenders. However, they were disappointed with the scarce information and eventually dropped out since SREDA could not provide the requested information on logistics and the raw data necessary to obtain finance. SREDA is currently conducting a site survey so that they can improve its capacity to manage the tender process with provision of raw data. Upon completion, SREDA believes that they can provide raw data that would attract foreign investors. In parallel, SREDA has already started a feasibility study on offshore wind power generation.

2.4.4 Hydro

In Bangladesh, there is only 2.10MW Karnafuli hydro power generation located in Kaptai at Chattogram hill. Although the introduction of several pumped hydro power generations is planned in PSMP2016, no progress has been seen up until now. The Government of Bangladesh has the intention to import electricity by hydro power generation in Nepal and Bhutan through G &G agreements, where high potential is expected. However, it is necessary to provide economic merits to those neighboring countries if Bangladesh desires it. Also, it is necessary for Bangladesh to use the national electricity grid connected between Bangladesh and India or construct a dedicated transmission line when importing electricity from these countries. In 2012, a blackout occurred nationwide while electricity was imported from India through 500MW international grid connection between Bangladesh and India. Because of this accident, the state-run transmission company shows concerns on the plan for Bangladesh to import electricity of 8 GW in total via the international grid connection between Bangladesh and India. Hence, it is important for the government of Bangladesh to investigate the cause of the blackout that occurred in 2012 and establish reliable prevention measures against unforeseen accidents in the future.

2.4.5 Biomass, Biogas and Waste to Power

Table 2.4-7 shows a comparison of potential on biomass, biogas, and waste-to-power generation and the installed capacity as of the end of December 2021. The installed capacity is considerably lower than the potential in all categories.

Table 2.4-7 Biogas, Biomass and Waste Generation Potential and Installation Capacity (December 2021)

Category	Feedstock	Potential(MW)	Capacity(MW)	Diff(MW)
Biogas to Power	Rice husk	10	1	▲9
Biomass to Power	Animal waste	275	0.4	▲275
Waste to Power	City garbage	1	0	▲1
	Total	286	1.4	▲285

(Source) Prepared by IEEJ referring to SREP and SREDA, National Database of Renewable Energy

Adoption of biogas power generation is currently low compared to its potential. On the other hand, under the IDCOL program, 120,000 biogas plants are being promoted by public and social enterprises to produce cooking gas for residential use. However, it is estimated that only 30 to 35% of the installed biogas plants are currently in operation. This is due to the fact that farmers are selling their cattle and losing their biogas source as well as a lack of maintenance and repair.

The biomass power generation introduced to date is also limited at 0.4 MW. In Bangladesh, about 40% of biomass is used as primary energy such as cooking gas in households. In many cases, its use for power generation is below the commercial scale.

Of the 3Rs (Reduce, Reuse, Recycle), the Government of Bangladesh has high expectations for expanding waste-to-power generation, especially from the perspective of Recycling. In December 2021, a power purchase agreement was signed at a tariff of BDT18/kWh for the 42.5MW waste-to-energy power generation in northern part of Dhaka and the project is scheduled to start operation in 2021. The Government of Bangladesh has the intention to promote introduction of waste power generation not only in urban areas but also in suburban and rural areas.

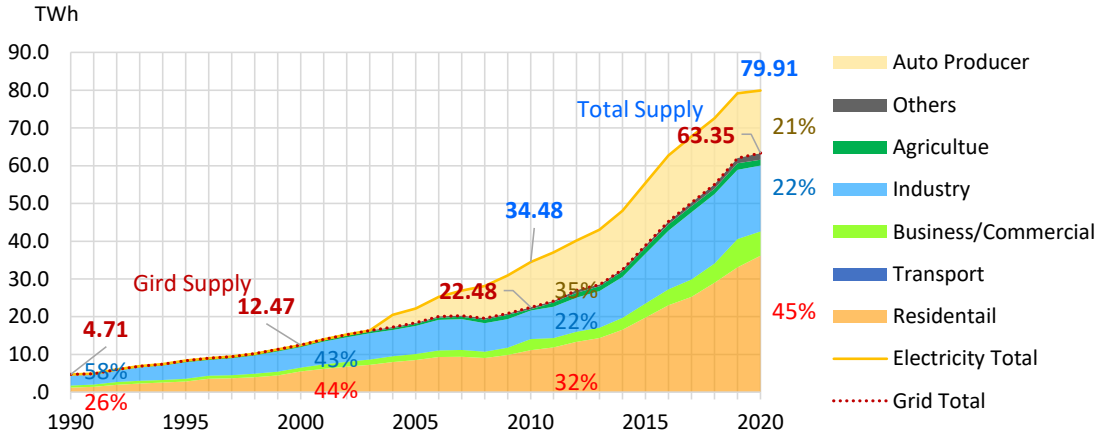
In summary, without resolving the issue of the access to land, it is assumed that additional installment of renewable power generation, save for those projects already under construction or in planning stage, would be difficult. Inviting international tenders, it is important for Bangladesh to introduce the best practice in benchmarking countries to prepare and manage an efficient tender process and provide reliable information for the participants so as to reduce the IPP tariff through high competition. Foreign investors are generally nervous about the complex permission process (more than 30 permits are required from different ministries and regulators). In order to improve the business environment for investors, it is important to improve transparency of the bidding process and also to simplify the licensing process with a centralized focal point. At the same time, it is also important to improve access to the financial market.

3. Electricity Supply

3.1 Electricity Demand

In Bangladesh, substantial efforts were made to develop an electricity supply system after the turn of the century. Electricity supply jumped 6.4-fold between 2000 and 2020. A 100% electrification was announced in 2021. Nevertheless, electricity consumption per capita was 560kWh in FY2020-21, merely 17.4% of the world average (3,212kWh in 2020), and comprising 23% of the country's energy consumption (as per Figure 1.1-1)[7]. More than 40% of electricity is used by the residential sector while more than 40% is used by the industry on grid and captive power generation at industries combined.

Electricity demand recorded a transitory jump in 2019, but swung downward in 2020 affected by the Covid-19 pandemic. In the long run, however, it is expected to grow steadily and will exceed 4-fold of the present level by 2041 according to the PSMP 2016. It is essential to develop power generation sources, efficient operation system of them, and transmission and distribution network under appropriate planning, accordingly.

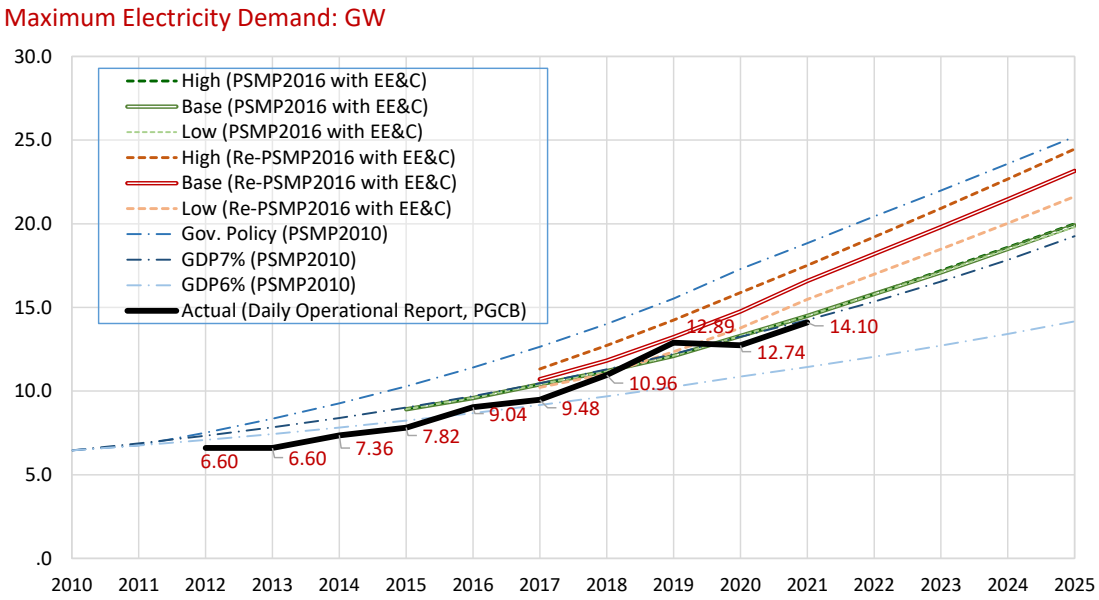


Source: IEA World Energy Balances 2022

Figure 3.1-1 Electricity Demand in Bangladesh

As shown in Figure 3.1-2, the maximum electricity demand (MW) has been increasing slightly below the projection in the PSMP 2016. Once the impact of the Covid-19 pandemic is no longer felt, it will return to the long-term growing trend. Since the electricity demand is expected to grow rapidly but is encountering various impacts from uncertain factors, it should be prudent to review it periodically and fine tune the development plans for power generation sources.

[7] Actual for Bangladesh is cited from Hydrocarbon Unit "Energy Scenario of Bangladesh 2020-21" and the world average from the IEA World Energy Balances 2022. Same sources for the per capita electricity consumption.

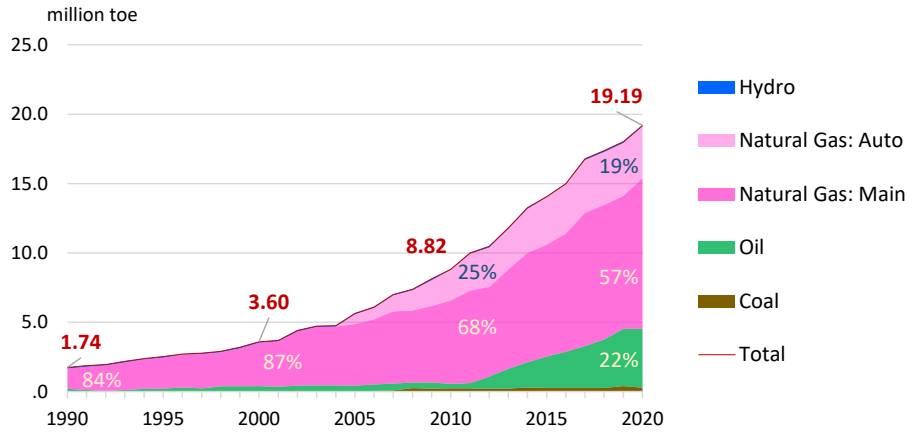


Source: PSMP 2016 and Power Division

Figure 3.1.2 Maximum Electricity Demand: Recent Years vs. Past Master Plan

3.2 Present Status and Issues on Power Supply and Development

In Bangladesh, most of the power sources have been driven by natural gas; it amounted to 76% in 2020 of the entire power supply including the grid and automotive generations combined. Small scale generators are run in rural areas with diesel oil, while coal fired power generation started in 2006 at a mine mouth plant. Hydro remains at a limited amount as the country is geologically located in the estuary of big rivers.



Source: IEA World Energy Balances 2022

3.2-1 Power Sources in Bangladesh by Energy Input

Indigenous natural gas supply has been stagnant in recent years and in turn is affecting

operation of gas-fired power stations. This has caused an increase of oil consumption for power. Thus, LNG import started in 2018. There are also difficulties in developing indigenous coal mines and thus the Payra coal-fired power plant was built, which uses imported coal, and started its operation of Phase-1 (660MWx2) in 2020. In addition, The Rooppur nuclear power plant (1,200MW x2) is being constructed 140km west of Dhaka, and will be put in operation in 2024 and 2025 consecutively.

Developing the power supply system to cope with the expected growth in demand, major issues are anticipated as follows:

(1) Gas-fired Power Generation

Bangladesh has so far been blessed with indigenous natural gas resources and has been able to supply electricity by gas-fired power generation at a unit cost considerably lower than the world standard price. However, with the start of LNG imports to cope with peaking of domestic natural gas production, fuel costs of gas-fired power generation will certainly rise and the country will be exposed to the risk of international fuel price fluctuations.

As mentioned above, systematic power development in Bangladesh is essential to meet the envisaged future demand, and full consideration should be given to securing alternative power sources to gas-fired power generation.

(2) Coal-fired power generation

Coal-fired power generation is currently the leading technically established method and it is a stable alternative to gas-fired power generation, but the coal-fired power plants currently planned are fueled almost entirely by imported coal, which, like LNG, exposes them to the risk of international fuel price fluctuations.

In addition, it is well known that there are many challenges in achieving a global low and decarbonized society. In June 2021, the Government of Bangladesh responded swiftly to this global situation by freezing the plans for the construction of the following 10 coal power plants.

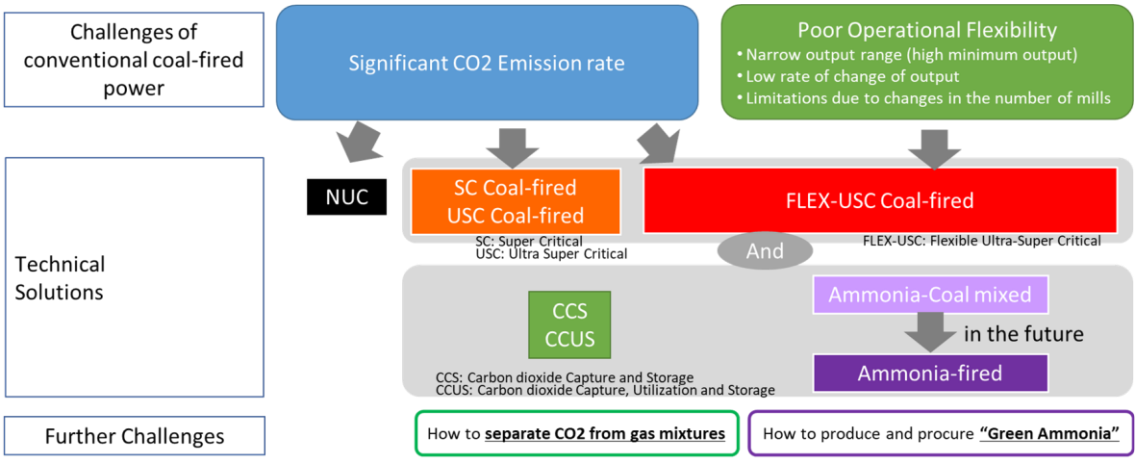
Electricity demand continues to increase steadily over the long term and fluctuates on a variety of time horizons - seasonal, monthly, weekly and daily. Until now, gas-fired thermal power has played a role as an adjustment power source to maintain balance between supply and demand. However, whether all of the role to supply stable power can be met by CO_2-free power sources poses major issues for the future.

Table 3.2-1 Freeze on coal-fired power project reported in Dhaka Tribune 2021.6.28

Name of Power Plant	Capacity (MW)	Fuel	Owner	Expected Commissioning	Status
Patualhali USCPP Phase 1 (660MWx2)	1,320	Im. Coal	ASPCL	December/2031	Plan
Uttarbongo Thermal	1,320	Dom. Coal	ASPCL	after 2030	Plan
Moheskhali USCPP (KEPCO)	1,320	Im. Coal	JV	after 2030	Plan
Matabari USCPP Phase-1 (JV of Symcorp & CPGCPL)	700	Im. Coal	JV CPGCBL	June/2030	Plan
CPGCBL-Sumitomo USC (600MWx2)	1,200	Im. Coal	JV CPGCBL	June/2028	Plan
Moheskhali Phase-2 USCPP (Bay of Bengal)	1,320	Im. Coal	JV BPDP	December/2029	Plan
522MW plant in Mawa	522				
282MW plant in Dhaka	282				
282MW plant in Chittagong	282				
565MW plant in Khulna	565				
Total	8,831				

Source: Compiled by Study Team

While it is important to apply the latest and most advanced technologies, it is also important to ensure a stable and affordable supply by combining power sources with proven technologies. It will be unavoidable to use fossil fuel power generation to a certain extent, such as gas-fired and coal-fired power generation, in order to secure low-cost and stable electricity supply through 2050, the target year of the IEPMP.



Source: JICA Study Team

Figure 3.2-2 Challenges and solutions for future development of coal-fired power

Figure 3.2-2 illustrates the current challenges of coal-fired power generation and the future technologies that will complement them.

The biggest technical challenge of conventional coal-fired power plants is the environmental impact of CO_2 emissions, which can be addressed by the established technology of high-efficiency power generation such as supercritical and ultra-supercritical power plants, as well as

technologies in the demonstration stage such as CCS/CCUS technologies or ammonia co-firing power generation. However, several technical challenges remain concerning these technologies, such as the method to separate CO_2 from the emitted gas mixture, CO_2 emissions during the ammonia production process, etc.

Another issue with coal-fired power is that it is difficult to use it as a regulating power due to its inflexibility in generating operation. There are three main reasons for this inflexibility.

- The variable range of generator output is narrow (minimum output is high);
- Even within the variable range, it is not possible to adjust it continuously (because it is necessary to switch the number of mills and burners according to the output values); and
- Slow speed of change in generator output (difficult to use as primary or secondary regulating power).

At present, technologies to overcome these difficulties, such as FLEX-USC technology, are being established in Japan, and it is one of the tasks of this IEPMP is to examine the possibility of their application. In addition, the lack of information and technical support for the Bangladeshis to evaluate these new technologies and make a decision on their introduction is an important issue to be addressed in this project.

(3) Nuclear Power Generation

Nuclear power is an excellent base-load power, but lacks flexibility. From the viewpoint of stability and safety of power plant operation, Japan does not use nuclear power for balancing electricity supply and demand (output adjustment according to instructions from dispatching control center such as NLDC).

If a similar operation is envisaged in Bangladesh, it is important to determine the base-load demand, taking into account the minimum annual electricity demand, because nuclear power can only be used as a pure base-load power.

It is also necessary to consider the impact on the power system in the event of a shutdown for any reason, since the rated capacity per unit of nuclear power generation is generally in the 1,000 MW class or more for economies of scale.

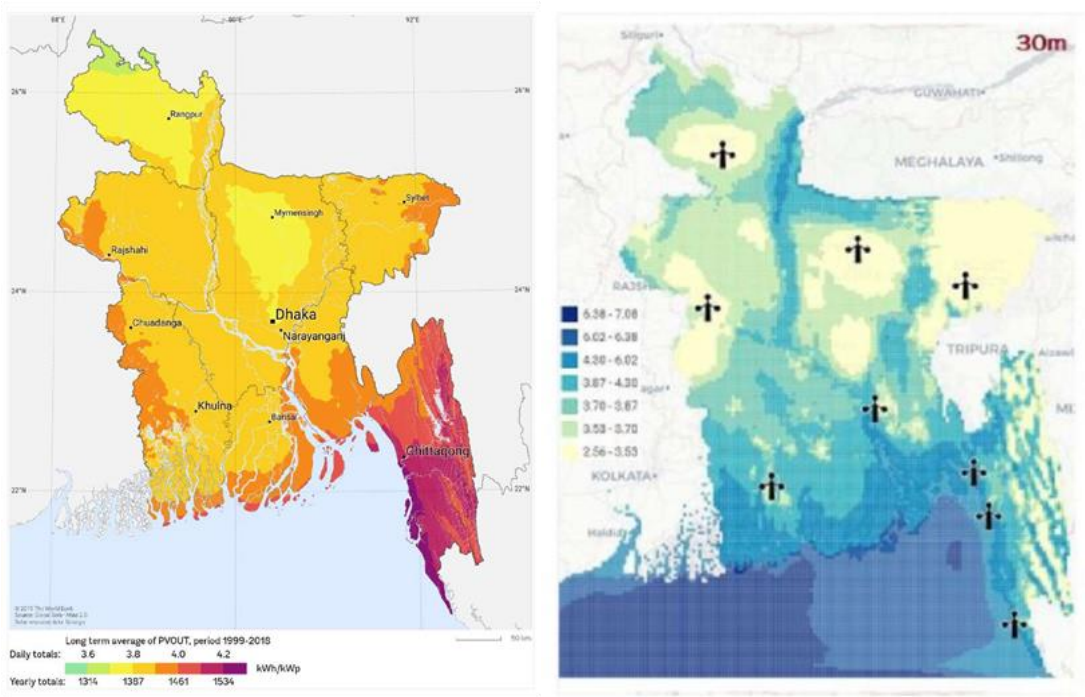
(4) Renewable Energy Generation

The potential for renewable energy in Bangladesh is limited by the fact that most of the country is located downstream of major rivers, which means that large-scale deployment of hydropower facilities is unlikely. One solution would be to stimulate cross-border electricity trade, and to strengthen international interconnection with India, where power sources have already been relatively diversified, and Nepal and Bhutan, who have plenty of hydropower resources.

According to the National Solar Energy Roadmap, 2021-2041 (Draft), suitable sites for wind power development are unevenly distributed along the coast in terms of wind conditions, which

means that introduction of large-scale on-shore wind power will be limited, while off-shore offshore wind power development may have potential. Therefore, it is necessary to determine the acceptability and future applicability of such new technologies in Bangladesh. It is also necessary to develop a stable network to transmit the generated electricity to Dhaka and other areas where the electricity demand is high, while right of way is an issue for construction of a high voltage transmission line additionally through a narrow corridor from Chattogram to Dhaka.

At present, solar power is the most promising for development. However, suitable sites are unevenly distributed and concentrated in the south-eastern coastal areas, including Chattogram. Therefore, the development of the network is a challenge, as is the case with wind power.



Source: National Solar Energy Roadmap, 2021-2041(Draft)

Figure 3.2-3 Potential of Solar Radiation (left) and Wind (right)

There is also the issue of how to estimate supply capacity of solar power itself, because it can only be expected to generate electricity during the daytime when there is solar radiation, and it is susceptible to weather effects. The long-term power development plan does not currently anticipate it as a source of supply capacity because the maximum power demand occurs during the lighting hours after sunset. However, as envisaged in the PSMP 2016 and Revisiting PSMP 2016, as industrialization of Bangladesh progresses, the time of maximum power demand is likely to shift to daytime, as observed in Japan and other developed countries. How to anticipate the supply capacity of VREs such as solar power will become an issue.

In Japan, the method of factoring in the supply capacity of run-of-river hydropower, which is

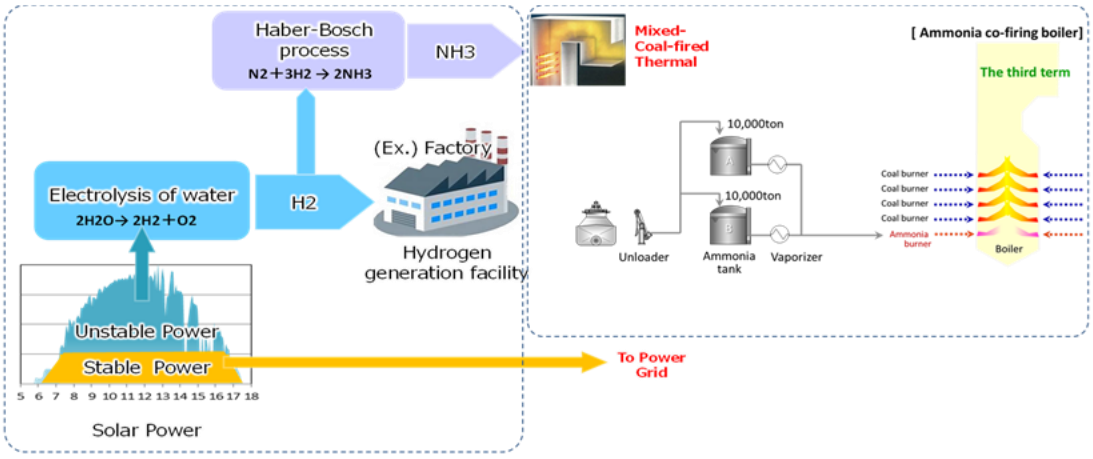
affected by changes in river flows, is well-established; a similar method could be applied in Bangladesh. One of challenges of this technology is the need of sufficient data accumulated over many years to establish accuracy of statistical analysis.

In addition, the spread of solar power generation is expected to expand mainly through self-generated-self-consumed power sources such as rooftop solar power and other distributed power sources. This will lead to changes in the electricity demand curve from the standpoint of utility and will make it difficult to estimate electricity demand. It is difficult to find a quick solution to this problem, and it will be necessary to accumulate data over many years to enable statistical analysis on demand movement.

Other issues for the power system as a whole include the steepening of demand change (duck-shaped demand curve phenomena), low inertia of the power system due to the increase in the number of power sources connected via inverters (increase in RoCoF), and the decline in synchronization power (out-of-step of synchronous generators). In addition, there are a number of local issues in the distribution system, such as the complexity of power flows, overloads, voltage deviations and other technical issues.

(5) Thermal Power with Ammonia and Hydrogen

Application of ammonia-fired power generation and hydrogen power generation, which are presently in a demonstration stage, still faces technical challenges, such as CO2 emissions during production of ammonia and hydrogen fuels, as mentioned in the section on coal-firing power generation. The production process shown in Figure 3.2-4 is a conceptual one.



Source: JICA Study Team

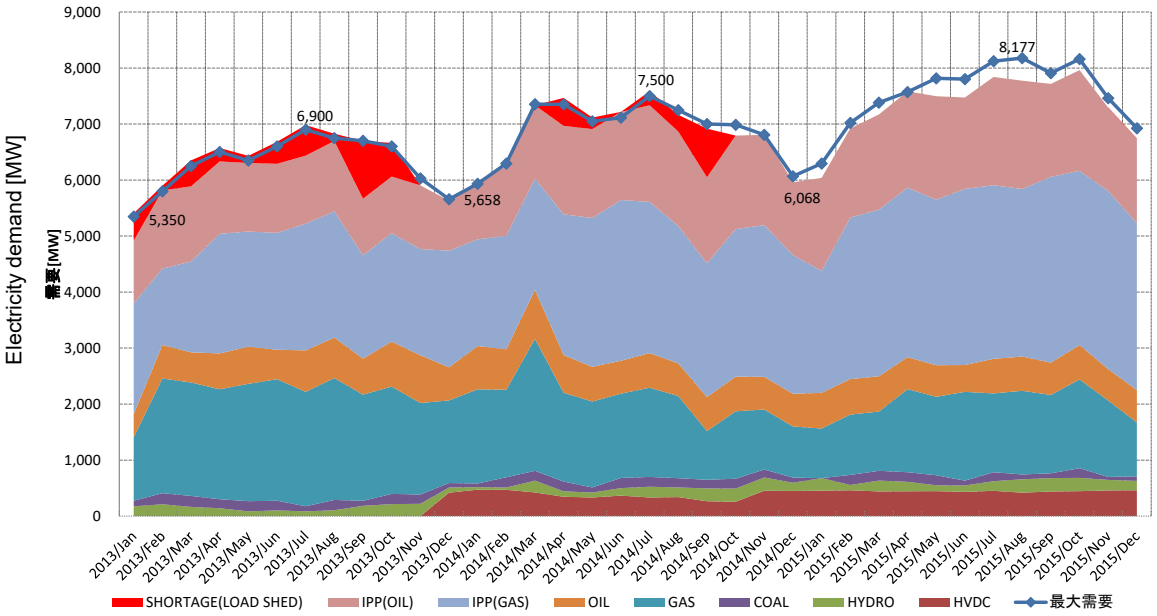
Figure 3.2-4 Conceptual diagram for production of green hydrogen and green ammonia

It is equally important that the Bangladesh power system is not used as a testing ground for the introduction of these new technologies, but should be provided with information and technical support for its own evaluation and decision-making.

3.3 Organizational and structural challenges in power plant O&M and power supply-demand balancing operation

During the survey to develop the PSMP 2016, investigation on generator operation on the day of maximum electricity demand occurrence from 2013 to 2015 (Figure 3.3-1) showed that measures to maintain the supply-demand balance by load shedding were frequently used. This was caused by a decrease in generator output and thermal efficiency, and equipment failure due to lack of regular maintenance on generation equipment. Among others, the NLDC, which was originally responsible for and had the authority to maintain the supply-demand balance, did not have sufficient authority to comprehensively manage and coordinate the generator operation plan (maintenance plan) as well as to instruct power stations in real time.

The general view of the power sector in Bangladesh is that there has been a significant improvement in maintaining the supply-demand balance in recent years, and that there is instead an excess of supply capacity over electricity demand. Figure 3.3-1 shows the maximum electricity demand and supply availability for each month since 2014 and the actual supply-demand balance by fuel type. In 2014 through 2016, load shedding schemes were taken mainly during periods of high electricity demand, but the reserve margin was around 40% of the actual maximum electricity demand in each year.



Source: JICA PSMP 2016 Final Report

Figure 3.3-1 Maximum monthly electricity demand and breakdown of supply capacity in Bangladesh (PSMP 2016)

Nevertheless, as the day of real time operation approaches, there were on average around 2,500 MW of generators that were either shut down or unable to operate at their rated capacity due to

breakdowns or fuel supply constraints. As a result, the declared available capacity to the NLDC during the evening peak demand period was much tighter than the electricity demand, and the reserve margin dropped to a few percent or less, which resulted in implementation of load shedding schemes.

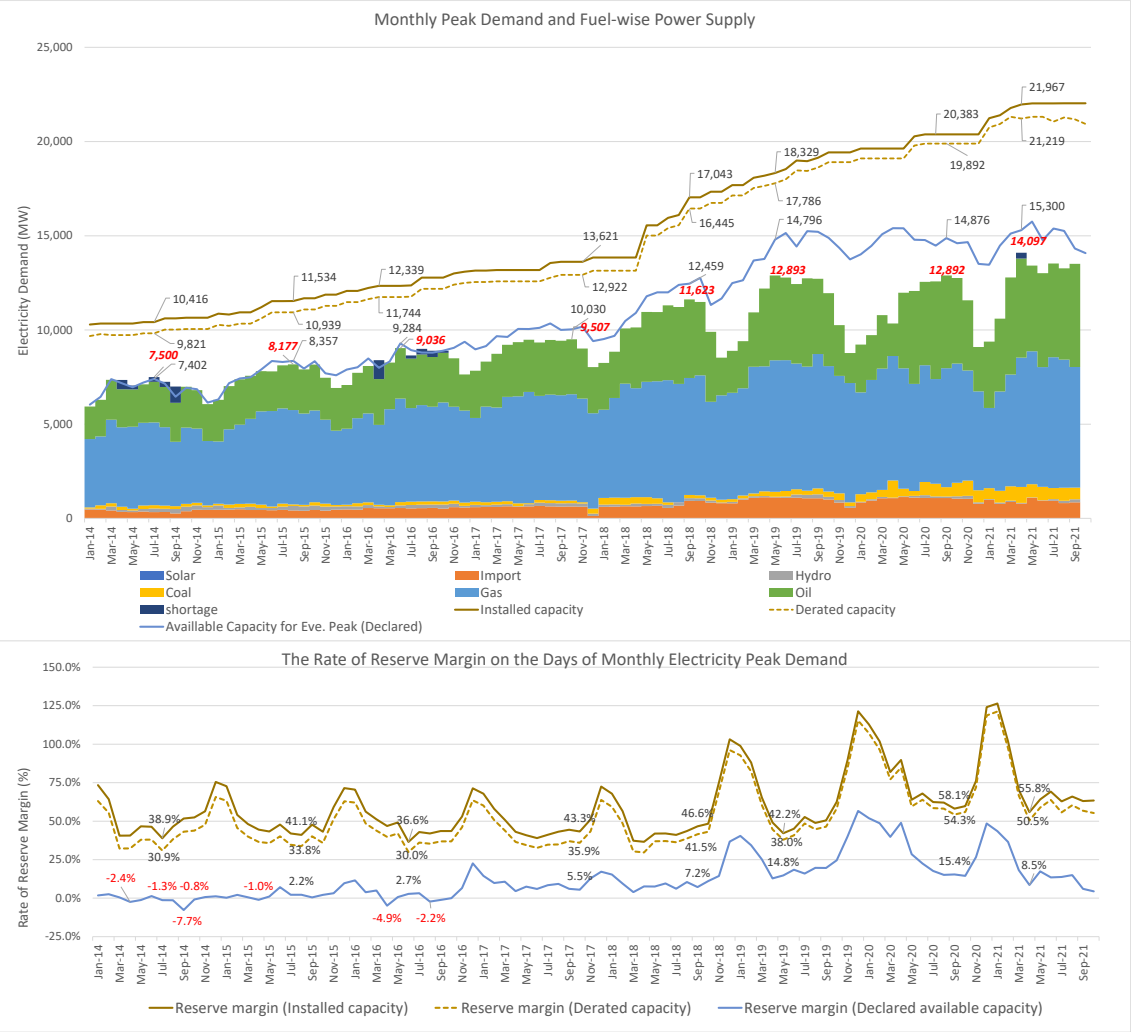


Figure 3.3-2 Maximum monthly electricity demand and supply capacity & reserve margin in Bangladesh (nearest survey)

Since then, the steady power development has resulted in sufficient supply capacity, including reserve margin. In particular, from 2019 onwards, due to a slowdown in electricity demand growth caused by the COVID-19 pandemic, the reserve margin ratio in 2020 and 2021 has increased to more than 50% of the actual maximum electricity demand.

However, there are still, on average, around 2,200 MW of generators shut down or operating below the rated output on the day of generation due to insufficient gas fuel supply, and on average more than 2,000 MW of generators fail or have reduced capacity, leading to similar shutdowns or reduced output. In addition, as Figure 3.3-2 shows, solar PV cannot function at the time of the

maximum demand in early evening when lighting demand increases. Combined with this, the day's declared available capacity is further reduced. Nevertheless, there is still at least 8% reserve margin available.

In 2021, however, the maximum electricity demand occurred in April, unseasonably, and load shedding occurred again. According to interviews with NLDC during the first visit to Dhaka (5 November ~ 3 December 2021), the causes of the load shedding were overloading of the distribution system due to increased household demand as a result of the COVID-19 pandemic and inability of the fuel supply to keep up with the recovery in economic activity. In addition, as is clear from Figure 3.3-2, the timing of maximum electricity demand is also not constant, and it is difficult to predict when it would occur during the six-month period from May to October, multiplying difficulties in securing supply capacity.

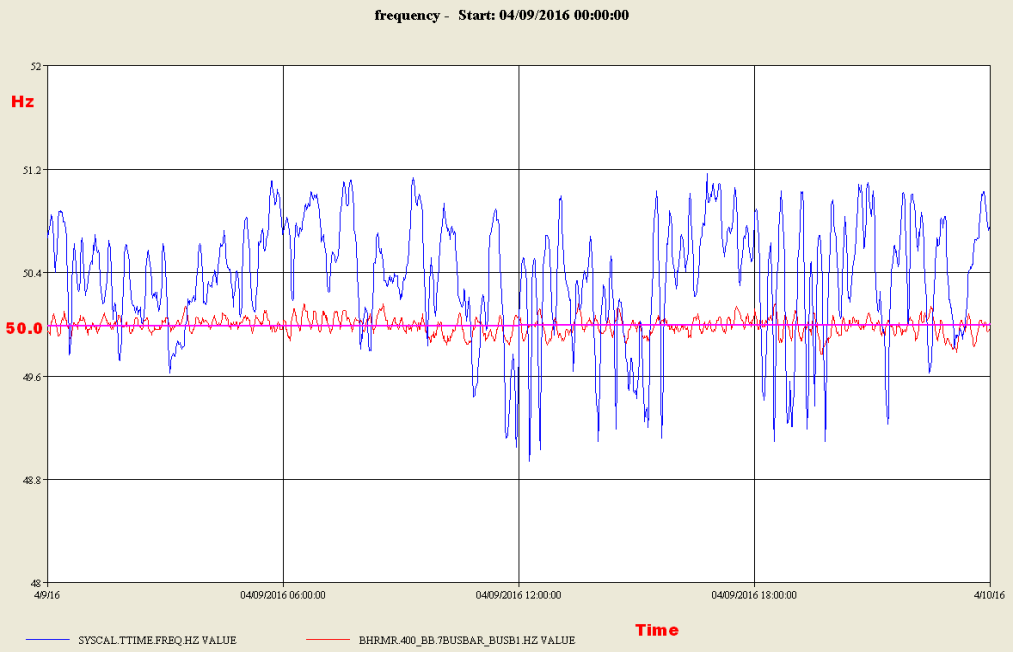
The total capacity of the power generation facilities is apparently more than enough, but the actual capacity available on the day of power generation is greatly diminished, and the situation continues to have some adverse effects on the stable supply of electricity. In addition, it is not desirable for operation of the electricity business to have an excess reserve margin, which means that the BPDB has to keep paying the fixed costs such as maintenance and depreciation of power plants while generating little electricity except during the peak demand periods.

As explained above, it is necessary to urgently improve the matters relating to O&M, such as replacement of aging generators with high-efficiency generators and rehabilitation of generators.

3.4 Challenges in securing reserves for frequency regulation

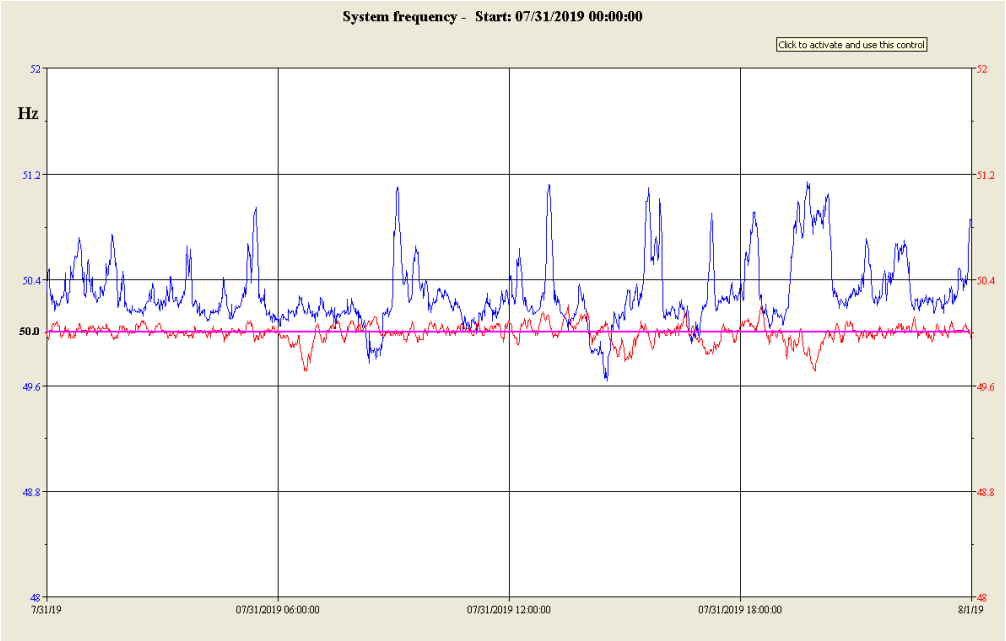
During the survey to formulate the PSMP 2016, it was observed that generators in Bangladesh did not have a sufficient automatic supply and demand adjustment functions (primary reserves such as governor free and secondary reserves such as AGC), and that all frequency adjustment instructions were carried out by telephone from NLDC to the power plants, resulting in fluctuations of 50 Hz ± 1.0 Hz or more. (See Figure 3.4-1)

As shown in Figure 3.4-1, generators implementing governor-free operation (primary reserves) have been steadily secured to some extent in recent years. Frequency fluctuation has been generally improved to around 50Hz±0.5Hz.



Source: NLDC presentation material, November 2021

Figure 3.4-1 System Frequency (09 April 2016)



Source: NLDC presentation material, November 2021

Figure 3.4-2 System Frequency (31 July 2019)

However, governor-free operation alone does not, in principle, have the ability to maintain the frequency at the target frequency (50 Hz). Therefore, when there are large deviations, the part that does not return to normal must be adjusted by other means.

Normally, the EMS at the load dispatching center and some generators need to be

interconnected online and controlled to maintain the frequency at the target level. This is called Load Frequency Control (LFC), and the extra reserves on the generator side to meet this adjustment function is called Secondary Reserves. At present, the EMS of NLDC of Bangladesh and the generators are still not linked online and are coordinated through telephone instructions.

Unless this problem is addressed, Bangladesh may not be able to cope with the substantial increase in the number of power sources such as solar and wind power, whose output fluctuates according to weather conditions, making it difficult to keep the balance of supply and demand. It may also have a negative impact on stable operation of the Rooppur nuclear power plant to start shortly and would significantly affect the scenario for development of CO_2-free power sources.

3.5 Challenges related to transmission system planning and operation

(1) Increase in power flows from south to north

As described in the past master plan, the present transmission system in Bangladesh can supply most of the electricity by allocating small-scale power plants using indigenous natural gas in a distributed manner according to the distribution of demand. Since there was little need for long-distance power transmission, it was possible to deal with by configuring it in a network with 210kV and 132kV power transmission lines and substations.

Since the latter half of the 2010s, indigenous natural gas alone has not been able to meet the electricity demand growth, and thus large-scale power plants to use imported coal and LNG have been constructed. As they are all located along the coast of the Bay of Bengal in the south, it is necessary to transmit a large amount of electricity from south to north toward Dhaka, the demand center, over a long distance. To meet this need, construction of 400kV transmission lines is underway, and construction of 765kV transmission lines is also being studied.

In the long run, various assumptions may change. It should be noted that the transmission system plan will be affected not only by the forecasted demand and total power sources but also by the change of regional balance. We should be careful not to construct excess transmission lines to be wasteful in the future. To solve issues with the transmission system, it is important not to solely rely on construction of new transmission lines but to take up appropriate temporary measures to maintain a stable supply of electricity even in the event of generator dropouts due to a single transmission line trip. To this end, it is important for the PGCB to establish a management system such as data preparation for in-depth grid analysis.

(2) Improving the reliability of power supply system to Dhaka

The transmission system that supplies the important demand-intensive area such as Dhaka generally constitutes an Extra High Voltage large-capacity transmission ring surround the area. This ring has the function of pooling a large amount of electric power from multiple directions and supplying it to the demand center. In Dhaka, a 400kV transmission ring is constructed; it is

planned to supply power from the substation in that ring to the demand center by 2.10kV and 132kV (partly 400kV) transmission lines.

On the inside power system of 400kV transmission ring, it is important to note the following points:

- Securing transmission routes to supply the growing electricity demand in the high-density areas,
- A system configuration that can recover from power outages in a short time in the event of an accident, and
- Avoiding an increase in fault current due to overcrowding of the transmission line.

In order to achieve these efficiently and in a well-balanced manner, it is important to have an easy-to-understand policy agreed upon among the parties involved in the development and formation according to the geographical situation of the high-density area. Close cooperation among related parties is required to respond promptly and appropriately to the growth of regional demand. From this point of view, in December 2021, a TWG2, TT-2 questionnaire was conducted to BPDB, PGCB, DPDC and DESCO. Unfortunately, the results could not confirm the policy regarding the formation of supply system equipment in the center of Dhaka and the existence of a system for each organization to communicate sufficiently.

Taking this IEPMP report as an opportunity, the JICA study team proposes establishment of a framework that those organizations will understand the specific points when planning a transmission system to supply power to the important demand-intensive areas and will fully coordinate each other to realize the plan.

(3) International Interconnection Lines

In Bangladesh, import of not only fuels such as natural gas and coal but also electricity generated by neighboring countries is planned. Unlike large-scale imported fuel power plants located on the coast of Bengal Bay in the south, imported electricity can be received inland across national borders, thus correcting the above-mentioned miss match incurring transmission of a large amount of power from the south to the north.

Recently, in "TRANSMISSION PLANNING AND PROJECTS PREPARATORY STUDIES FOR PGCB" compiled by PGCIL, an Indian consultant, it is noteworthy that the amount of electricity imported via the international interconnection line has remarkably increased, especially in the northern zone. This is because if the amount of electricity imported is not increased, the supply capacity in Bangladesh will be biased to the south, the transmission of electricity from the south to the north will increase, and the transmission stability of the power system will deteriorate. This issue is considered in in-depth study of the power system stability in this report.

When all of these planned interconnections are completed, there will be a total of 12 connection points with neighboring countries, and the capacity will exceed 10 GW accounting for 14% to

20% of the total demand of 50 to 70 GW in 2041. Considering the security aspect of covering this amount with imported electricity:

- Even regarding the disruption of imports due to accidents, it is possible to reduce the impact because it is dispersed in 12 locations, but on the other hand,
- Considering the security of the relationship between nations, for the example of an emergency, the supply capacity should be preserved more than the capacity of the economic aspect.

For the transmission system planning, it is important to establish a technology to closely simulate the dynamic characteristics of the generators, as this will have a braking effect on the instability of the system.

4. Long Term Policies Bearing on Energy

4.1 Social and Economic Policy

There are several social and economic policies in Bangladesh differently covering a medium to super-long period; the very long-term "Bangladesh Delta Plan 2100" (October 2018), the long-term "Perspective Plan of Bangladesh 2021-2041" (March 2020), and the short- to medium-term "8th Five Year Plan July 2020-June 2025" (May 2020). This section outlines Bangladesh's national visions on the future based on these socio-economic policies with particular attention to their impacts on the future energy supply and demand structure.

4.1.1 Bangladesh Delta Plan 2100

Bangladesh Delta Plan 2100[8] (herein after, BDP 2100) was developed by the Planning Commission in October 2018.

Key questions laid down behind this plan are how to control the risks associated with the delta region that geographically characterizes Bangladesh and, conversely, how to link this inherent characteristic to future growth. The delta provides fertile land as well as potential to develop marine resources such as fisheries, shipping, tourism, and energy. On the other hand, the delta and the many rivers that flow into it constrain land use in Bangladesh. Bangladesh is also rated 6th in the world in terms of vulnerability to natural disasters. BDP 2100 recognizes that without implementation of this strategy, the country will be vulnerable to climate change, natural disasters, accelerating urbanization, declining agricultural production, and the threat of climate change. Corresponding decrease in available land and rising prices are estimated to push down the GDP growth rate by 1.1% point annually.

Therefore, Bangladesh, known as one of the most densely populated countries in the world, needs to maintain the limited arable land through proper management of the water environment and thereby to secure land for its industries. With this background, BDP 2100 was formed to make the delta region a source of social development and economic growth rather than a risk factor of the country. Thus, it sets forth higher level goals as follows:

- Goal 1: Eliminate extreme poverty by 2030.
- Goal 2: Achieve upper middle-income status by 2030.
- Goal 3: Being a Prosperous Country beyond 2041.

Since the plan is literally for the very long term, until the end of the 21st century, the strategy is not fixed, but flexible, to be reviewed every five years, in light of the current situation of the time.

The strategy also touches on energy and indicates a policy of promoting development of

8 Planning Commission, accessed in March 2022, http://www.plancomm.gov.bd/site/files/fd6c54f6-dfab-4c71-b44a-e983ffd2bdee/-

renewable energy in terms of preserving the water environment, sustainable development, and mitigating the effects of climate change.

a. Develop long term renewable energy policy as well as strategies and formulate a master plan for at least 50 years to harness the potential of renewable energy resources in the country involving public and private sector investments.
b. Promote research on the development of technology in the field of renewable energy in universities and research institutions and build capacity for its application.
c. Enhance Green Growth through research and development of renewable technologies including clean development mechanism (CDM).
d. Devise innovative financing packages for grant funding and low interest financing to address affordability for both grid and off-grid renewable energy projects.
e. Target at least 30% energy production from renewable sources by 2041 in the context of being a prosperous country.

4.1.2 Perspective Plan of Bangladesh 2021-2041

The Perspective Plan of Bangladesh 2021-20419 (herein after, PP 2041) was developed by the Planning Commission in March 2020. The plan aims to realize Vision 2041, which sets the goal of becoming an Upper Middle-Income country by 2031 and a High-Income country by 2041. The pillars of the plan are (i) Becoming a High-income country in 2041 (GDP per capita over USD 12,500) and (ii) making poverty a thing of the past.

Table 4.1-1 Growth and poverty targets of PP2041

Indicator	Benchmark FY20	Target FY31	Target FY41
Real GDP Growth (%)	8.2	9.0	9.9
Poverty indicators			
Extreme Poverty (%)	9.4	2.3	<1.0
Poverty (%)	18.8	7.0	<3.0

The following 11 sectoral strategies for achieving these social and economic goals are presented.

1） Strengthen institutions
2） Macroeconomic management for accelerated inclusive growth
3） Zero Poverty Country
4） Human Capacity Development
5） Sustainable Agriculture to ensure Food Security and Nutrition
6） Accelerated growth with industrialization and trade
7） Sustainable Power and Energy
   a. Adopting a least-cost power generation expansion path

[9] Planning Commission, accessed in March 2022, http://www.plancomm.gov.bd/site/files/99b0fa7c-4fca-4154-ad7c-0bc00e35df8f/-

b. Promoting supply of low-cost primary energy;
c. Developing the required infrastructure for primary fuel
d. Ensuring investment balance between generation, transmission and distribution
e. Promoting efficient use of installed capacity
f. Promoting private investment in energy
g. Further expanding power trade
h. Ensuring proper energy pricing policy
i. Strengthening power and energy institutions.

8) Creating an Innovation Economy
9) Building Transport and Communications Infrastructure for sustained growth
10) Managing the Urban Transition
11) Managing Environment and Climate Change for sustainable growth
    a. integrating environmental costs into the macroeconomic framework
    b. implementing the Delta Plan to build resilience and reduce vulnerability to climate change
    c. reduce air and water pollution
    d. removal of fuel subsidies
    e. adoption of green tax on fossil fuel consumption
    f. taxation of emission from industrial units
    g. prevention of surface water pollution; and
    h. geo-spatial data analysis for evidence based decision making.

Particularly in the power sector, the strategy emphasizes (1) balanced development of power generation, transmission and distribution, (2) enhance private involvement, (3) broadening of electricity imports from all three neighboring countries, and (4) development of renewable energy.

4.1.3 8th Five Year Plan July 2020-June 2025

The 8th Five Year Plan July 2020-June 2025[10] (hereinafter, 8FYP) was developed by the Planning Commission in December 2020. The high-level policy of becoming a High-Income country by 2041 will be realized through a detailed plan that will be reviewed in five-year cycles. 8FYP is the first of these and covers the five-year period beginning July 2020. The plan defines six core themes, taking into account the impact of COVID-19.

1) Rapid recovery from COVID-19 to restore human health, confidence, employment, income and economic activities;
2) GDP growth acceleration, employment generation, productivity acceleration and rapid poverty reduction;
3) A broad-based strategy of inclusiveness with a view to empowering every citizen to participate fully and benefit from the development process and helping the poor and

[10] Planning Commission, accessed on March 2022, http://www.plancomm.gov.bd/site/files/8ec347dc-4926-4802-a839-7569897e1a7a/-

vulnerable with social protection- based income transfers;

4) A sustainable development pathway that is resilient to disaster and climate change; entails sustainable use of natural resources; and successfully manages the inevitable urbanization transition;
5) Development and improvement of critical institutions necessary to lead the economy to UMIC status;
6) Attaining SDG targets and coping up the impact of LDC graduation.

Below is an overview of the major development themes.

1) Accelerating Inclusive Growth

The first challenge will be how to get the economy, which was slowed by COVID-19, back on a growth trajectory to achieve its goals. Subsequent economic growth will be focused on labor-intensive and export-oriented manufacturing industry.

Table 4.1-2 GDP Growth Projections under the 8FYP

		FY20 (Actual)	FY21	FY22	FY23	FY24	FY25
Pre-COVID-19 GDP growth (as per pp2041)		8.19	8.23	8.29	8.32	8.37	8.51
GDP Growth with COVID-19		5.24	7.40	7.70	8.00	8.32	8.51
Polulation Growth		1.39	1.34	1.24	1.22	1.19	1.18
Per capita GDP Growth		3.85	6.06	6.46	6.78	7.13	7.33
	FY19 (Actual)	FY20 (Actual)	FY21	FY22	FY23	FY24	FY25
	Growth Rate (Percent)						
Agricultute	3.92	3.11	3.47	3.83	4.10	4.00	3.90
Ondustry	12.67	6.48	10.29	10.59	10.79	11.20	11.90
o/w Manufacturing	14.20	5.84	10.73	10.99	11.24	12.00	12.60
Services	6.78	5.32	6.74	6.95	7.25	7.30	7.35
GDP	8.15	5.24	7.40	7.70	8.00	8.32	8.51
	Share as % of GDP)Constant price)						
Agricultute	13.65	13.35	12.84	12.36	11.89	11.16	10.56
Ondustry	35.00	35.36	36.25	37.17	38.07	40.37	41.86
o/w Manufacturing	24.08	24.18	24.89	25.61	26.33	28.75	30.23
Services	51.35	51.30	50.91	50.47	50.04	48.47	47.58

Source: Planning Commission, 8th Five Year Plan July 2020-June 2025

Until now, the major engine of economic growth has been the ready-made garment (RMG) manufacturing industry. In the 8FYP, the policy is to diversify industry to non-RMG sectors and focus of development include processed food, leather and footwear, light engineering, and pharmaceuticals. In terms of industrial development, application of digital technology and automation, i.e., the 4th Industrial Revolution, will enhance the competitiveness of industry, while improving healthcare and education will foster and secure human resources, and the development of infrastructure such as roads, bridges, and power plants will attract private investment by both domestic and foreign players.

2) Strategy for Infrastructure Development

For electricity, the nation will continue to expand its electricity supply capacity and diversify its fuel supply, as successfully done in the Sixth and Seventh Five-Year Plans. In addition to reviewing the Power Sector Master Plan 2016, the nation will expand the use of renewable energy by rationalizing fuel oil prices (raising the price to a cost reflective level). Furthermore, secure funds by reviewing the energy tariff system, and improve energy efficiency by appropriate capital investment and price mechanisms.

In the transport sector, particular attention will be paid to construction of two ports, development of railroads connecting the East and West regions, and land transportation corridors linking South Asia and East Asia. Smoothing the flow of goods and services will lead to lower costs and enhanced competitiveness.

3) Digital Bangladesh and Information Communications Technology

Under the slogan "Digital Bangladesh" proposed by Prime Minister Sheikh Hasina in 2009, the government will promote expansion of the ICT infrastructure.

4) Managing the urban transition

Urbanization is expected to continue, and emphasis will be placed on strengthening and improving urban services such as water supply, drainage, sanitation and waste management.

4.2 Energy Policy

4.2.1 Energy mix

The Bangladesh Delta Plan 2100 (BDP 2100), Perspective Plan 2021-2041 (PP 2041), and 8th Five Year Plan July 2020-June 2025 (8FYP) commonly refer to expansion of renewable energy, though the degree of actual recommendations varies. In view of environmental sustainability, the country will promote development of renewable energy such as solar photovoltaic power generation. For instance, BDP 2100 indicates a quantitative target of renewable energy that at least 30% energy production comes from renewable sources by 2041. However, at the same time, they also point out the challenges of land use being restricted due to the fact that the delta area occupies most of the country, high population density, and the need to maintain food production. It also indicates a policy aimed at diversifying the primary energy supply structure which is currently centered on natural gas.

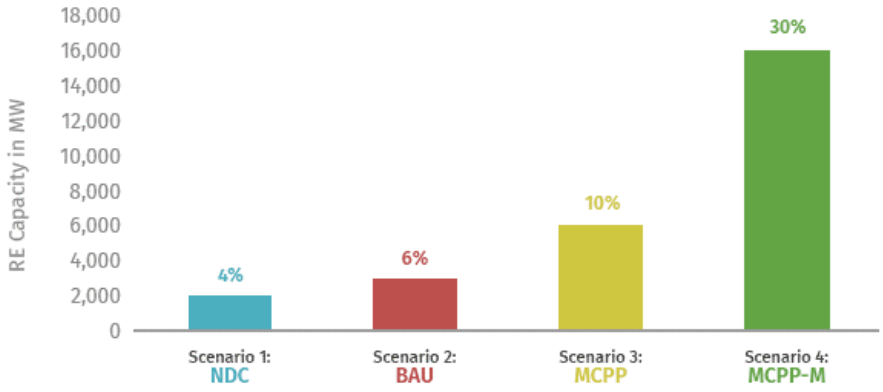
In the power supply, it shows the principle of emphasizing economic efficiency, choosing the least-cost option, while considering carbon emissions. In terms of economic efficiency, the country will reduce expensive oil power generation. Based on these principles, the policy is to use fossil fuel power generation in a well-balanced manner and expand renewable energy power generation. The Power Sector Master Plan 2016 (PSMP 2016) embodies these principles.

According to PSMP 2016, the share of natural gas power generation will be reduced to 35% in 2041 from 57% in 2019. Conversely, coal-fired power, which was only 6% in 2019, will be expanded to 35% in 2041. In addition to this, nuclear power generation, electricity imports, and supply from renewable energy will be added, and as a result, oil power generation is expected to decrease to 1% in 2041.

Table 4.2-1 Key Objectives and Targets for Power and Energy under PP2041

Objectives/Performance Indicators	Actual		Target		
	FY2019		FY2021	FY2031	FY2041
Make power sector viable	Losses amounting Tk.75 billion				
Total Grid based generation capacity of electricity	18,961 MW		21,369 MW	33,000 MW	56,734 MW
Maximum peak demand: PSMP 2016 base case	12,893 MW		14,500 MW	29,300 MW	51,000 MW
Increase efficiency of energy use as well as reducing the system loss (T&D loss)	11.96% (T&D loss)				T&D loss target: Single digit
Diversity fuel use in Power Generation Capacity to balance use of low-cost fuel with low-carbon content Note: Power generation by renewable energy is not listed in the generation mix in this table, being classified as power purchase.	Gas/LNG	57.4%	45%	29%	35%
	Coal	2.8%	27%	30%	35%
	Liquid Fuel	32.4%	17%	9%	1%
	Nuclear	-	-	14%	12%
	Hydro	1.2%	1%	1%	1%
	Renewables	0.2%	-	-	-
	Power Import	6.0%	9%	17%	16%
Increae private sector investments in electricity, gas, and other energy supply	50% including imports		50%	55%	60%
Encourage energy trade	1,160 MW		2,000 MW	5,000 MW	9,000 MW
Access to electricity	72%		100%	100%	100%
Installation of petroleum pipeline	0 km		451 km	1,077 km	1,177 km
Installed processing capacity of refinery	1.5 million tons		1.5 mil. tons	19.5 mil. tons	19.5 mil. tons

Source: Planning Commission, Perspective Plan 2041



NDC = national determined contribution, BAU = business as usual

MCPP = Mujib climate prosperity plan scenario, MCPP-M = Mujib climate prosperity plan scenario - maximal

Source: Planning Commission, Mujib Climate Prosperity Plan

Figure 4.2-1 RE Share in 2030 Energy Mix

However, the energy mix that these policy texts aim for is already outdated. At COP26 in November 2021, Prime Minister Sheikh Hasina confirmed that the country had canceled 10 coal-fired power projects and declared "We hope to have 40% of our energy from renewable sources

by 2041"[11]. As a result, the increase in coal-fired power generation predicted in PSMP 2016 cannot be expected, while the policy ambition indicates an increase of renewable energy far beyond the present plans. Since the country is vulnerable to climate change, it emphasizes more on the environmental sustainability, while taking into consideration the economic efficiency of energy supply. For instance, the Draft National Solar Energy Roadmap 2021-2041 (December 2020), developed by SREDA, targets 6 GW, 20 GW, and 30 GW of installed solar capacity in 2041 for the BAU, Medium, and High cases, respectively. In addition, Draft Mujib Climate Prosperity Plan (September 2021), which set the climate strategy up until 2030, emphasizes penetration of renewable energy in power generation, e.g., solar PV, wind turbine and green hydrogen.

It is also discussed[12] that "we should consider not only renewable energy but also various clean energy options such as nuclear power, hydrogen, and CCS." While Bangladesh is one of the most populous nations in the world, the available land area is limited. Therefore, it is conceivable that renewable energy with a low geographical density of energy production cannot supply a sufficient amount of energy. Given these circumstances, it is reasonable to consider options such as nuclear power, hydrogen, and CCS, which are also clean energies with high energy density.

A historically high energy price and resulting economic turmoil observed since early 2022 may also pose new awareness in terms of energy security; risks of depending energy supply on imports and imports from specific countries. Based on this, Bangladesh should first make the best use of indigenous energy such as natural gas and coal, and diversify the types of energy that must be imported. At the same time, electricity imports from neighboring countries that will pull up the power supply base must be based on mutual understanding and trust to avoid any security risk caused by political conflicts.

Bangladesh has a set of energy mix policies as above mentioned, while a part of them is becoming too outdated to correspond to the quickly changing domestic and international situations. It is time to flexibly review the policy based on the prevailing situation.

4.2.2 Energy efficiency

Energy efficiency policies in Bangladesh are centered around the policies planned in the Energy Efficiency and Conservation Master Plan 2016 (EECMP 2016). It sets out the energy conservation targets with a view to reduce the energy intensity (primary energy per GDP) by 15% by 2021 and 20% by 2030 compared to 2013.

In EECMP2016, energy efficiency policies are set for industrial, residential and commercial sectors, respectively, as shown below.

(1) Industrial sector

[11] UNFCCC, Bangladesh - High-level Segment Statement COP 26 (https://unfccc.int/documents/309520)
[12] Interview to the official of the government of Bangladesh

The industrial sector is promoting the introduction of an energy manager system, a regular reporting system, and a benchmark system for energy management in each company. The outline is shown below.

a. Large energy consuming entities (DCs: Designated large energy consumers) program
b. Energy manager and energy auditor program
c. Regular reporting system for energy consumption and energy efficiency efforts from DCs program
d. Sub-sector benchmark (Sub-sector energy intensity, production process energy intensity) program

Table 4.2-2 Energy consumption criteria and number of target entities of DC program

No.	Category	Criteria for DCs (Annual energy consumption toe)	Numbers of candidates for DCs
01	Chemical fertilizer factories	10,000	10
02	Paper and pulp industries	6,000	8
03	Textile industries: spinning, weaving, dyeing	3,000	15
04	Garments industries	3,000	7
05	Cement and linker grinding factories	10,000	14
06	Iron and steel (rerolling mills)	10,000	23
07	Chemical and pharmaceutical industries	6,000	9
08	Glass industries	6,000	5
09	Ceramic industries	6,000	9
10	Transportation terminals (including seaports, airport, stations)	3,000	2
11	Commercial and institution buildings (including office buildings, hotels, shopping malls, hospitals, educational facilities)	3,000	10
99	Other Industries and installations as published by government notifications	3,000	1
	Total		113

Sources: EECMP2016

a. Designation of large energy consuming entities

"Large energy consuming entities" (Designated Consumer: DC) is designated by the government. This program is to set the energy consumption criteria for each target sub-industry. The energy consumption and the number of target entities by sub-industry are shown below. When this program is operating smoothly, the number of target entities is

planned to increase by strengthening energy consumption criteria.

b. Energy manager, Energy auditor program

The energy management program required by DC includes the appointment of an "energy manager" who is educated and certified by the government, and the energy efficiency diagnosis by an energy auditor who has accumulated practical experience. DC is supposed to hire an energy manager and receive an energy efficiency diagnosis by the energy auditor once every three years.

1) Energy manager: Energy manager is hired in DC by the regulation. The energy manager leads the action of the energy efficiency in the entities and organize the periodical energy report.
2) Energy auditor: Energy auditor conducts energy efficiency diagnostics for DCs and recommend to energy managers.

c. Periodical report of Energy consumption and activities by large energy consuming entities program

Large energy consuming entities are obliged to submit to the government once a year the amount of energy consumption and the energy efficiency actions. The periodical report is prepared mainly by the energy manager.

d. Benchmarking program

The benchmark program is a system that sets target values for energy efficiency indicators (energy consumption per production at factories and energy consumption per building floor area) for the sub-industrial sector and encourages energy efficiency actions to achieve those targets. The energy efficiency of each sub-industry is analyzed, and the target value is set by referring to the regular reporting of energy consumption by DC. The first process will start by accumulating energy efficiency through the regular reporting.

(2) Residential and commercial sector

The residential and commercial sector is promoting introduction of energy efficiency standards for equipment such as home appliances, and the energy efficiency labeling program (S & L). Also, the energy efficiency standard and labeling program is applied to buildings.

a. Energy efficiency standards and labeling program
b. Bangladesh National Building Code, Green Building Guideline

(3) Energy standards and labeling program

For introduction of the energy efficiency standards and labeling program, common rules and technical issues relating to each home appliance (CFL, air conditioner, refrigerator, TV, fan, lighting ballast, motor) are mainly taken into consideration. The rules have been formulated and the program operation is being improved. At present, appliances for which energy labeling is obligatory are air conditioners, refrigerators, fans, and CFLs.

(4) Bangladesh National Building Code, Green Building Guideline

The Bangladesh National Building Code also sets out standards on energy efficiency. The main energy requirements are as follows. It is planned to gradually reduce the applicable areas covered by this code.

Table 4.2-3 Bangladesh National Building Code requirement

Category	Contents
Building envelope	■ Roof insulation and green roofing system ■ Window to wall ratio ■ Window opening ■ Shading
HVAC(Heating, Ventilation and Air-Conditioning)	■ HVAC system ■ Ceiling and wall mounted fans
Hot water supply	■ Solar hot water system
Lighting	■ Day lighting and supplementary lighting system ■ Lighting power density ■ Occupancy sensors
Lift and escalator	■ Energy efficiency of lift and escalator
Renewable energy	■ Solar Power ■ Other renewable energy
Others	■ Water management (Reuse of gray water, efficient fittings in toilets)

Sources: EECMP2016

The Green Building Guidelines are voluntary efforts aimed at overall reduction of the environmental impact in the life cycle (construction, use, removal) of buildings. As a guideline for designing and constructing buildings with a higher level of energy efficiency and low environmental impacts than the revised National Building Code, the following initiatives are being pursuit.

1) Organizing the seminars and workshops on energy efficiency
2) Information exchange of energy efficiency with industry sub-sectors
3) Implementation of public awareness by using media (Facebook, YouTube)
4) Public awareness initiative at educational institutions (energy conservation proposal competition at universities)
5) General public awareness initiative (energy efficiency cooking contest)

4.2.3 Electricity

The Perspective Plan of Bangladesh 2010-2021 (PP2021) (April 2012) and the Perspective Plan of Bangladesh 2021-2041 (PP2041) (March 2020), are the main pillars of the electricity policy in Bangladesh. PP2021 recognizes that the electricity and energy sector strategy has achieved significant

successes, particularly in the area of power generation, and has laid the foundations for further progress in PP2041, while leaving some challenges in terms of the energy mix, energy pricing and financing, and energy efficiency.

It also notes that, in 2041, with accelerated GDP growth and urbanization, demand for electricity and primary energy will surge and require further development of power and energy resources. At the same time, to cope with environmental concerns and climate change, it is necessary to reduce fossil fuel consumption and increase introduction of clean technologies and renewable energies.

(1) Challenges left by PP2021 and setting targets for PP2041

The basic policy of PP2021 is to ensure significant expansion of electricity supply with gas and coal as the main fuels, improve efficiency, induce private investment and diversify energy resources to promote GDP growth.

With promotion policies under PP2021, steady progress has been made in electricity supply, electrification rates, private investment in the electricity sector and energy efficiency. However, on the goal of diversifying energy resources, the report states that there are challenges, such as significant delays in development of domestic coal and introduction of renewable energy sources, and a heavy reliance on fossil fuel resources. From a financial perspective, the report praises the improvement in the bill collection rate of electricity charges and the Bangladesh Energy Regulatory Commission (BERC) for maintaining reasonable electricity tariffs. On the other hand, it cites rising generation costs due to gas shortages and increased reliance on liquid fuels, and the continued financial subsidies to the BPDB as a single buyer. Citing the continued financial subsidies, the report points out that the goal related to financial sustainability is yet to be met.

Reflecting the above, PP 2041 on the electricity and energy sector sets out the following objectives, as well as numerical targets as shown in Table 4.2-4.

(2) Main objectives of PP2041

a. Strategy of electricity and energy:

To meet the increase in electricity demand (annual 9.3%) reflecting the accelerated GDP growth (annual 9%), the following measures are required:

1） Reducing capital investment costs
2） Phasing out high-cost liquid fuel-based power stations and moving to lower-cost fuels
3） Moving away from over-reliance on fossil fuels:
4） A balanced mix of low-cost fuel-based power generation and renewable energy.
5） Use of imported hydropower and solar power from India, Nepal and Bhutan.

b. Strategy of finance:

To ensure financial sustainability of the power sector and a reasonable rate of return on assets

prevailing in upper-middle and high-income countries.

Table 4.2-4 Key Objectives and Targets for Power and Energy Under PP2041

Objectives/Performance Indicators	FY2019 (Actual)	FY2021 (Target)	FY2031 (Target)	FY2041 (Target)
Make power sector financially viable	Losses amounting Tk. 75 billion			
Total grid based generation capacity of electricity	18,961 MW	21,369 MW	33,000 MW	56,734 MW
Maximum Peak Demand Based on PSMP 2016 base case	12,893 MW	14,500 MW	29,300 MW	51,000 MW
Increase efficiency of energy use as well as reducing the system loss (T&D loss)	11.96% (T&D losses)			T&D loss target: Single digit
Diversify fuel use in power generation capacity to balance use of low-cost fuel with low carbon content of the fuel mix	57.4% gas; 32.4% liquid fuel; 2.8% coal; 6% power import; 1.2% hydro 0.2% renewables	45% gas; 27% coal; 17% liquid fuel; 9% power import; 1% hydro	29% gas; 30% coal; 14% nuclear; 9% liquid fuel, 17% power import 1% hydro	35% gas; 35% coal; 12% nuclear; 16% power import 1% liquid fuel; 1% hydro
Increase private sector investments in electricity, gas, and other energy supply	50% including imports	50%	55%	60%
Encourage energy trade	1,160 MW	2,000 MW	5,000 MW	9,000 MW
Access to electricity	72%	100%	100%	100%
Installation of petroleum pipeline	0 km	451 km	1077 km	1177 km
Installed processing capacity of refinery	1.5 million tons	1.5 million tons	19.5 million tons	19.5 million tons

Source: PERSPECTIVE PLAN OF BANGLADESH 2021-2041

(3) Specific policies on electricity and energy strategy

a. Expand power generation at minimum cost

PP2041 continues the strategy of expanding electricity supply at low cost by phasing out high cost rented power plants and adopting large-scale-low-cost fuel options in line with the PSMP 2016.

b. Promote low-cost primary energy supply

i. Natural Gas

Bangladesh is blessed with abundant reserves of natural gas, but the supply based on the known reserves is rapidly declining. Along with promotion policies to enhance exploration and development, improvement of pricing and demand side management policies for efficient use of natural gas, a program to increase LNG imports has been pursued under the long-term strategy for liquefied natural gas (LNG) imports developed in the PSMP 2016.

ii. Nuclear power

Nuclear power is envisaged to play a greater role in the power mix in the long term and the government has included the Rooppur nuclear power project in the fast-track project list to ensure rapid progress. An agreement is signed with the Russian Federation to set up a 2,400 MW nuclear power project and the government is already in talks with international nuclear regulatory and monitoring committees relating to safety and safe disposal of radioactive waste. In developing nuclear power options, PP2041 will carefully consider the experience of nuclear power generation to ensure an internationally acceptable level of operation and safety standards.

iii. Renewable energy

Considerable emphasis is placed on the development of renewable energy in PP2021 and that is continued in PP2041. Specifically, Bangladesh will amend its Renewable Energy Policy 2009, work to strengthen SREDA, and introduce incentive programs to encourage private investment in renewable energy, promote adoption of clean energy technologies in the residential sector, and promote use of renewable energy sources such as off-shore wind, tidal wave power and waste power.

c. Develop infrastructure needed for primary fuels

The Government will promote a strategy of major investment in infrastructure, including ports, storage facilities, railways and roads, to supply LNG and imported coal to power stations.

d. Ensuring a balance of investment in generation, transmission and distribution

In order to achieve the target of 100% electrification, it is important to strike an appropriate balance between investment in generation, transmission and distribution. PP2041 emphasizes the importance of eliminating transmission constraints at the local level in order to reduce idle generation capacity. There will also be an emphasis on further strengthening the rural electrification program.

e. Promoting the efficient use of installed capacity

The presently installed capacity significantly exceeds the maximum annual generation. Power utilities generally keep a surplus capacity of about 20% of its electricity demand while it is 33% in Bangladesh. This is mainly caused by inadequate fuel supply (especially gas), not well coordinated maintenance schedules, and other operational obstacles. PP2041 will address these issues by improving operational practices such as the timely availability of fuel, efficient maintenance and management, thereby lowering investment costs and electricity prices.

f. Encourage private investment in the energy sector

It is important to promote private investment in the construction of large-scale, highly efficient power plants. It is also appropriate to explore private participation in the electricity distribution sector to promote efficient operation and competition. To facilitate this, the Bangladesh Energy Regulatory Commission (BERC) has a key role to play in exploring how to regulate and price electricity and energy services. The solar housing scheme and solar irrigation supported by IDCOL are important examples of off-grid supply of renewable energy.

g. Further expansion of electricity imports and exports

PP2041 aims to significantly expand the options for importing electricity at competitive prices from neighboring countries such as India, Nepal and Bhutan, thereby extending the benefits to consumers. In particular, India (in the north-eastern states), Nepal and Bhutan have abundant hydropower potential, and importing electricity derived from these sources has the added benefit of reducing the carbon emissions associated with electricity generation.

h. Ensure an appropriate energy pricing policy

In order to maintain the sound and sustainable financial position of utilities, electricity prices are set so as to enable them to recover investment, O&M and fuel costs and to ensure a reasonable profit margin.

In addition, PP 2041 sets an appropriate price for all fossil fuels and removes subsidies to ensure consistency between power and energy development strategies and environmental protection. It also considers the introduction of carbon tax to reduce CO2 emissions from the use of fossil fuels and encourage investment.

i. Strengthening of the electricity and energy authorities

Under PP2021, the Government made significant progress in the power sector, including a significant reduction in transmission and distribution losses, significant improvements in meter reading, billing and collection, and improved consumer services.

To achieve further results, PP 2041 aims to deregulate and increase private sector participation, while ensuring the neutrality and strengthening of the main regulator, the BERC, to protect the public interest and promote sound competition. It also aims to strengthen SREDA to promote renewable energy and ensure energy efficiency.

(4) Specific policies on funding strategy

a. Private sector financing

Private sector financing of power plant construction has been quite successful in PP2021, and PP2041 is expected to increase the share of private sector financing. Further strengthening of ongoing support programs such as IDCOL and the Investment Finance

Facility for the Private Sector (IFFP) is also under consideration. The government will also gradually deregulate the electricity transmission & distribution and oil markets to encourage private investment in electricity, oil imports, oil refining and retail oil sales.

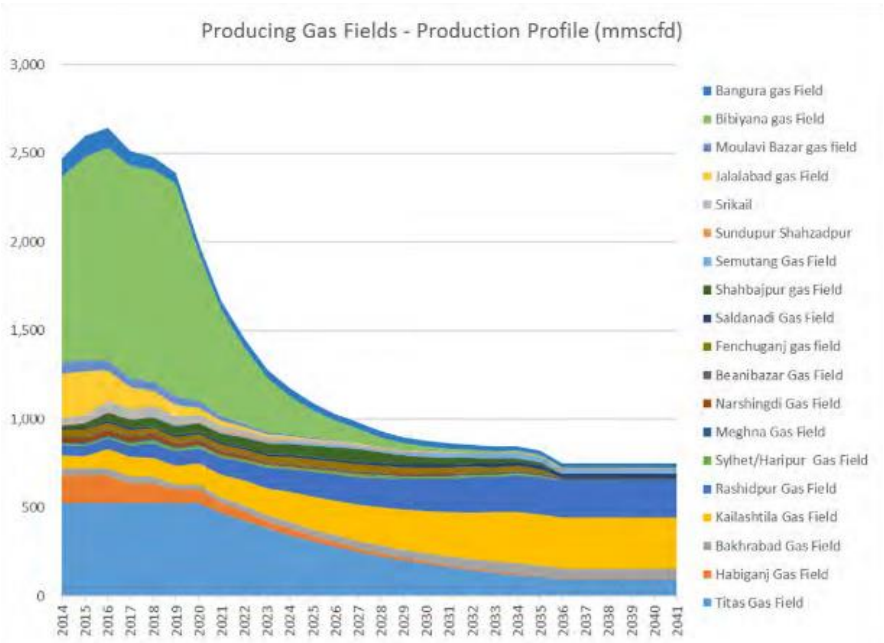
b. Financing through the national budget

For the time being, state budget financing will dominate, particularly for development of large-scale power stations, transmission and distribution networks and energy supply-related infrastructure. In the future, as private investment grows further and the finances of electricity and energy utilities improve, the share of total investment financing from the state budget is expected to decline, as seen in other high-income countries.

4.2.4 Natural Gas

(1) Power System Master Plan 2016 (PSMP2016)

In order to support Vision 2041, the PSMP 2010 was revised to the Power System Master Plan 2016 (PSPM 2016). It covers gas, oil, coal, and primary energy comprehensively. In particular, it numerically analyzes Bangladesh's future natural gas supply and demand, as well as its reserves. Figure 4.2-2 shows the production forecast of gas fields until 2041. In this analysis, gas production peaked in 2017 and is projected to decrease below 1,000 MMcfd after 2025.

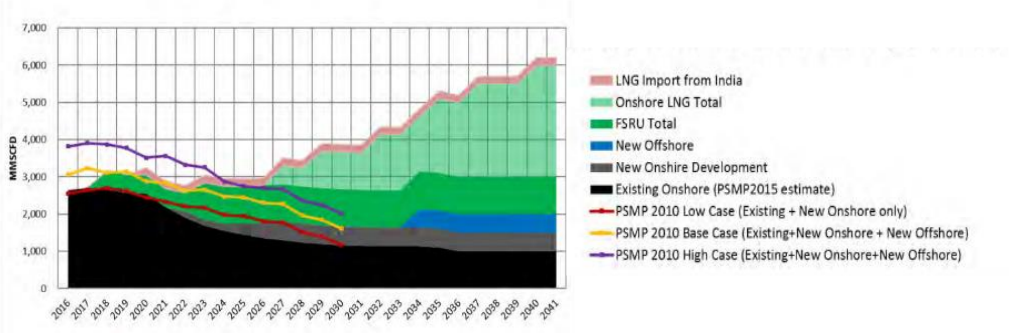


Source: PSMP2016

Figure 4.2-2 Gas Production Profile of Each Producing Gas Field

Figure 4.2-3 shows the scenario that LNG will be used to make up the shortfall in gas supply

caused by declining production from the existing gas fields. LNG terminals will be constructed onshore as well as offshore with FSRUs (Floating Storage and Regasification Unit), and RLNG (regasified LNG) will be supplied. Import of regasified LNG via pipeline from India is also considered good seaports are scarce in the western part of the country.



Source: PSMP2016

Figure 4.2-3 Supply Scenarios 2016-2041

The PSMP 2016 also estimated investment costs for an LNG receiving terminal at USD 865.1 million, including 3 x 180,000m3 LNG tanks, a jetty and vaporization facilities.

The report points out issues related to maintenance and management of gas pipelines and regional distribution networks. Specific issues are listed relating to installation of gas metering equipment and the computerization of pipelines, as well as management of the trunk pipeline network incorporating introduction of LNG, suggesting the need for urgent action.

Table 4.2-5 Total Investment Costs for Gas Development

	Item	Cost (million USD)
A. Domestic Gas Development Costs for the Remaining Reserves 2P		
A1	Field Explorations Costs	30
A2	Field Development Costs	
A2.1	Drilling costs	60
A2.2	Facility construction Costs	
1)	Facility construction costs for domestic gas which has already been discovered.	302.8
2)	Gas transmission pipelines from gas production facilites for domestic gas which has already been discovered	9.0
3)	Facility construction costs for domestic gas which has not been discovered.	90.0
4)	Gas distribution pipelines for fututе power plants	5.0
	Subtotal (A)	*496.8*
B. Import Gas Development Costs		
B1	Facility construction Costs	
1)	LNG Receiving Terminal	760
2)	LNG transmission pipeline	115.1
	Subtotal (B)	*875.1*
C. Contingency (=(A+B)x50%)		
	Subtotal (C)	*686*
	Total (A+B+C)	***2057.9***

Source: PSMP2016

(2) Gas Sector Master Plan Bangladesh 2017 (GSMP2017)[13]

The Gas Sector Master Plan Bangladesh 2017 (GSMP2017) was developed in February 2018, funded by the World Bank RERED-II, with Ramboll[14], a Danish company, as a consultant and EQMS[15], a local company, as a local consultant. The report covers gas demand forecast, least cost supply study, infrastructure planning for gas transportation, study of domestic gas network, LNG import planning, and gas supply forecast. It consists of a gas demand forecast, gas supply forecast, least-cost supply study, gas transportation infrastructure plan, domestic gas network study, LNG import plan, and legal system.

4.2.5 Oil

As a government statutory body under the Ministry of Electricity, Energy and Mineral Resources (MPEMR), Bangladesh Petroleum Corporation (BPC) was established in accordance with the Bangladesh Petroleum Corporation Ordinance and started its activities on January 1, 1977. It is mandated to oversee, coordinate, manage and handle all activities related to import, storage, sale and distribution of petroleum products in the country.

BPC's mission is to ensure the country's energy security through import, refining, distribution and development of fuel oil, with the vision of "ensuring a stable supply of environmentally friendly petroleum products to the whole country at reasonable prices." The following 12 main activities are in its control of petroleum-related areas in general covering from crude oil to chemicals.

1) Collection and import of crude oil and refined petroleum products
2) Processing of crude oil and manufacture of various petroleum products
3) Establishment of refineries and related facilities
4) Manufacture of lube base oil, necessary additives and other chemicals
5) Import and manufacture of lubricants
6) Establishment of a recycling plant for used lubricants
7) Establishment of the infrastructure and adoption of procedures necessary for treatment of refined residue products
8) Planning and implementation of petroleum product storage facilities
9) Arrangement and construction of inland oil tankers
10) Construction and expansion of facilities necessary for sale of petroleum products

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[13] Ministry of Power, Energy and Mineral Resources,「GAS SECTOR MASTER PLAN BANGLADESH 2017」
https://mpemr.gov.bd/assets/media/pdffiles/Bangladesh_GSMP_Final_Report.pdf

[14] Ramboll is a global engineering, architecture and consultancy company founded in Denmark in 1945. https://ramboll.com/

[15] Environmental Quality and Management System Consulting Limited (EQMS) established in 2002, is one of the leading sustainability consulting firms of Bangladesh.
http://www.eqmsbd.com/home/category/2/the-company

11) Acting as a managing agent for signing of agreements with firms or companies for import, storage, distribution and sale of oil in Bangladesh.
12) Monitoring and coordinating of the subsidiary companies of BPC and any other functions and responsibilities as directed by the government.

Among the above items, BPC delegates its function to the subsidiaries on petroleum product sales, petroleum refining, lubricating oil blending, and LPG bottling.

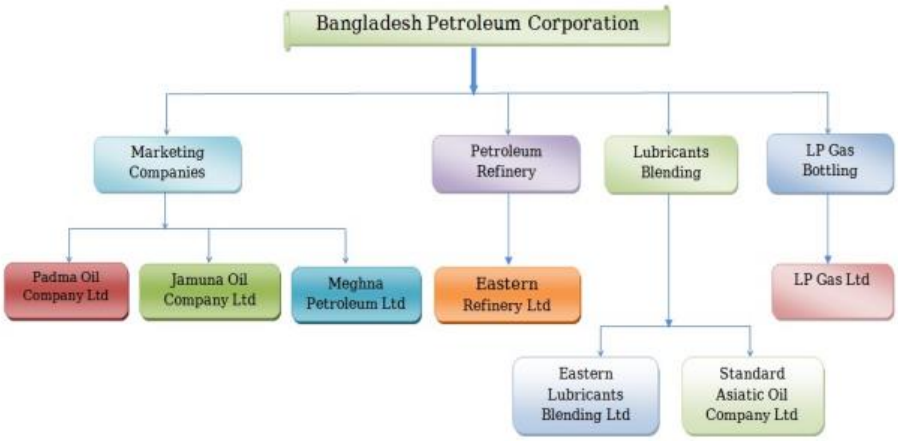


Figure 4.2-4 Diagram of BPC's subsidiaries

The functional sharing in the BPC is shown below, and the Commercial and Operation Division is responsible for importing crude oil and importing and exporting petroleum products.

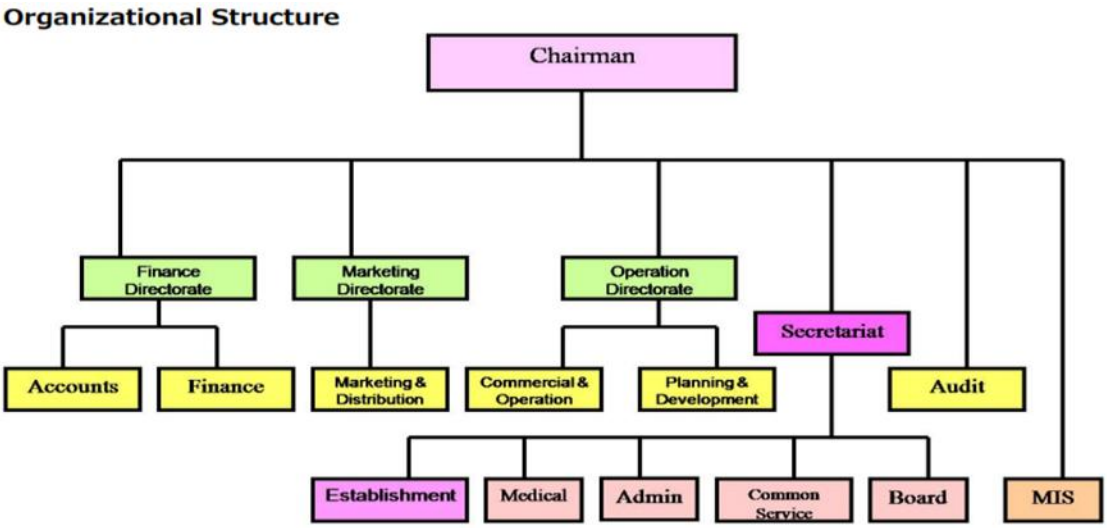


Figure 4.2-5 BPC Organization Chart

The role of Commercial and Operation division and main product import and export transactions are as follows (excerpted from BPC homepage):

Commercial and Operation Division

The main function of the Commercial and Operation Division is to build safe stock by importing Crude Oil & Refined Oil to ensure Energy security in the country and maintain an uninterrupted supply of Fuel Oil. This Division imports Crude Oil to ensure an uninterrupted supply of raw material to Eastern Refinery Limited (ERL) and supervises all types of operational activities of the organization. The Commercial and Operation Division ensures an uninterrupted supply of Fuel Oil by importing refined oil from different sources. This division imports 50% of its Fuel oil through the Open tendering method and the other 50% through G-2-G basis of the total country's demand according to the decision and the guidelines of the Energy & Mineral Resources Division. It exports Naphtha through Open tender and makes arrangements to supply the same to the local Petrochemical Plant considering the stock of Naphtha at ERL. It makes arrangements of taking approval for procuring different types of essential instruments, spare parts, chemicals for ERL and Hot-Rolled Mild Steel Plate, Cold Rolled Steel Sheet (CRSS) according to the demand. In the context of the approval of the Energy & Mineral Resources Division this division signs contracts, monitors and supervises import activities of High Sulphur Furnace Oil performed by the different private power plants in the country. Moreover, it makes arrangements of supplying surplus Naphtha from ERL to different petrochemical plants through signing contracts with them and procures different grades of petroleum products produced from the surplus Naphtha for the internal industry development and reduction of import dependency. This Division prepares foreign currency demand related with the fuel oil import, import expenditure estimation, export earnings and annual operational budget.

4.2.6 Coal

(1) Coal related issues in 8th Five Year Plan, July 2020 - June 2025

The 8th Five Year Plan (8FYP) states that "The supply of primary energy comprising oil, gas and coal is to help meet energy demand of the country by undertaking exploration, production, development and appraisal of oil, gas, and coal fields and subsequent energy reserve enhancement, and to meet energy shortfalls through imports. Having an adequate supply of low-cost energy is critical for all segments of society in general and in particular for having a competitive and sustainable industry and an efficient power generation system that can benefit from an optimal primary fuel mix. Another critical aim is to try and ensure energy security."

With regard to power generation fuel, it states, "As a part of our strategy to generate electricity at the lowest cost to achieve the goals of the Government's Energy Sector Strategy, we will continue to own high-efficiency, low-polluting coal power plants."

It also says "The development of coal-based generation lags behind", and "Both under the 6th and 7FYP there was a strategic decision to increase the share of coal in generation, but it continues

to lag behind, and its share fell from that level of FY2015. Implementation and completion of planned coal fired plants has otherwise been very slow, though there are some large sized coal fired power plants now at different stages of implementation. Coal mining has not proceeded due to the lack of a coal policy. The planned large-scale imports of coal have not moved fast enough due to infrastructure constraints, particularly port and related transport and handling infrastructures."

PP2041 highlights the need to extract more domestic coal for long-term energy security. There is an urgent need for a policy on primary fuels, especially a coal policy.

The Table 4.2-6 below, prepared by the Power Division, is attached regarding the cost of electricity generation by fuel. The comparison between imported coal and domestic coal is particularly informative. Since the price of each fuel fluctuates, this MP will discuss the updated cost of electricity generation in a separate section.

Table 4.2-6 Cost of Electricity Generation by Fuel by Power Division (Tk/kWh)

Fuel Type in Generation	Unit Cost (Tk./KWH)
Furnace Oil (FO)	17
HSD	26
LNG	13
Imported Coal	8.1
Domestic Coal	6
Domestic Gas	2.57
Hydro	1
Solar Power Plant	12
Imported Power	6.48

Source: Power Division

(2) Coal Policy

The Coal Policy draft was prepared in 2007, but the Final report has not been completed. The draft Coal Policy presented the government's position on domestic and imported coal, but currently, consumers are free to determine the import destination, import price, etc. for imported coal at their own discretion. At present, the government is facing problems on relocation of residents, environmental issues, and investment in development. Thus, development of new coal mines is slow. The Coal Policy needs to be established firmly to show the policy on domestic coal and import infrastructure construction.

4.2.7 Renewable Energy

Since 2008, many plans and guidelines were formulated in Bangladesh on promotion of renewable energy as shown in Table 4.2-7. The Government of Bangladesh set up the Bangladesh Renewable Energy Policy in 2008 as its first policy for renewable energy and has renewed the

target to more challenging ones as new policies were formulated. Many plans and guidelines were formulated since 2020 in line with the global trend toward achievement of carbon neutrality in 2050. At the same time, however, there is a possibility of confusion, as inconsistencies are found in several policies. This section will provide an overview of each policy and the renewable energy targets.

Table 4.2-7 Renewable Energy Policies in Bangladesh (2008-2021)

2008	Bangladesh Renewable Energy Policy
2013	Guideline for the Implementation for Solar Power Development Program
2015	Renewable Energy Development Target, 2015-2021
2016	Power System Master Plan 2016 (PSMP2016)
2018	Bangladesh Delta Plan 2100
2020	Perspective Plan of Bangladesh 2021-2041
	[DRAFT] National Solar Energy Roadmap 2021-41
	Eighth Five Year Plan July 2020-June 2025
2021	NDC

(Source) Prepared by IEEJ based on various information sources

(1) Bangladesh Renewable Energy Policy

The Bangladesh Renewable Energy Policy was formulated in 2008 as the first policy on renewable energy in Bangladesh. The Government of Bangladesh set a renewable target that 5% of the total electricity generation shall be sourced from renewable power generation by 2015 and 10% by 2020. At that time, the total electricity generation in 2020 was assumed to be 24 GW, and hence, 2.4 GW was targeted for renewable power generation in 2020.

(2) Guideline for Implementation of Solar Power Development Program

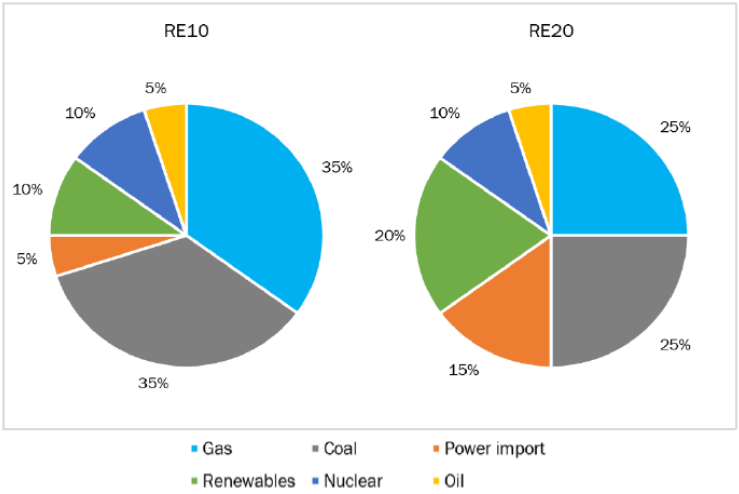
As it is important to install Solar PV as much as possible to achieve the target of 2.4GW renewable power generation in 2020, the guideline for implementation of the Solar Power Development Program was formulated in 2013. In particular, it aimed to set a clear guideline for development of grid-connected utility scale Solar PV (so called Solar Park).

(3) Renewable Energy Development Target 2015-2021

The Renewable Energy Development Target, 2015-2021 was formulated in 2015 as the first long term target for renewable power generation. In it, a new target was set at 3.1 GW (1.676 GW solar and 1.37 GW wind) for renewable energy generation. The government of Bangladesh hoped to promote solar parks and wind power generation in coastal areas where wind resources are abundant.

(4) Power System Master Plan 2016 (PSMP2016)

PSMP 2016 covers energy balancing, power balancing and tariff strategies, and outlines the targets and specific approaches needed in the energy and power sectors to realize Vision 2041. It proposes two scenarios: 10% renewable ratio (RE10) and 20% renewable ratio (RE20) as the best energy mixes in 2041. At the same time, target for installation of the renewable power generation (cumulative) were revised to 2.47GW by 2021 and 3.864GW by 2041.



(Source) [DRAFT] National Solar Energy Roadmap 2021-2041, Figure 4.7 (p.72)

Figure 4.2-6 Best Energy Mix in 2041 as proposed by the PSMP2016

Table 4.2-8 Renewable Energy Target in the PSMP2016

Generation Capacity (cumulative)	2.47GW (by 2021)、3.864GW (by 2041)
Domestic biogas production	790,000m3/day (including additional 600,000m3/day by 2031), 3 million m3/day (by 2041)
Cross-border Energy Imports	3.5～8.5GW (by 2031), 9.0GW (by 2041)
Cross-border Energy Imports rules and regulations	Set up mid to long term rules and regulations with capacity building in this area

(Source) Prepared by IEEJ referring to the PSMP2016

(5) Bangladesh Delta Plan 2100 (BDP2100)

BDP2100 was formulated in 2018 to indicate the vision for development of the Bangladesh delta area up until 2100 and to define mid and long term mitigation actions for climate change. In BDP2100, the renewable target was revised to 30% in the total electric power generation by 2041.

(6) Perspective Plan of Bangladesh 2021-2041 (PP2041)

PP2041 was formulated in January 2020 as the development vision, strategic explanation for target and purpose and the roadmap for its implementation to transform policies and programs designated in Vision2041 into strategies. In PP2041, it is mentioned that 35% of the total energy

mix will be supplied by renewable energy and cross-border energy import (assuming hydro power generation in neighboring counties) in 2041.

(7) [DRAFT] National Solar Energy Roadmap, 2021-41

[DRAFT] The National Solar Energy Roadmap, 2021-41 was formulated in December 2020 for the purpose of setting a long term vision or Solar PV development and a target for introduction of solar energy. It indicates 3 scenarios for introduction of Solar PV; 1) Business-As-Usual (BAU) Case (Solar PV shall be 10% in the total power generation capacity), 2) Medium Case (Solar PV shall be 33%) and 3) High Case (Solar PV shall be 33%), where installation capacities are estimated at maximum 6GW, 20GW and 30GW, respectively (the installation capacity will be affected by the regulation for land use for Solar PV, policies and incentives). As practical action plans, it proposes 1) setting of a new target for introduction of solar PV, 2) introduction of smart grid to manage intermittent renewable energy, and 3) introduction of utility scale batteries and a flexible grid system to achieve peak shift, load shift and smooth effect. This draft is yet to be finalized as it has induced many objections from experts, and thus it is currently under review by high level decision makers.

(8) 8th Five Year Plan July 2020-June 2025

The 8th Five Year Plan was formulated in December 2020 to show the commitment of the government of Bangladesh toward low-carbon sustainable energy and power generation technology. The renewable energy target was revised to 5% by 2025 in the total electricity power generation.

(9) NDC

NDC was submitted to UNFCC in August 2021 as an update of INDC submitted in September 2015. In the unconditional scenario, GHG emissions would be reduced by 27.56 million tons of CO2e (6.73%) below BAU in 2030 and in the conditional scenario which can be achieved only if there is external financial/technology support, GHG emissions would be reduced by 61.9 million tons of CO2e (15.12%) below BAU in 2030. GHG reduction in the Conditional scenario is additional to the proposed reduction in unconditional scenario. Hence, GHG emissions in Bangladesh would be reduced by 89.47 million tons of CO2e (21.85%) in total in 2030 from the BAU case. Of this, the energy sector is to reduce 85.98 million ton of CO2e which is 96% of the total GHG reduction in Bangladesh.

Table 4.2-9 GHG emission reduction scenarios

UNFCCC Sector	Sub-sector	GHG Emission Scenario		GHG Reduction by Mitigation (2030)							
		BAU 2030		Unconditional			Conditional			Combined	
		$MtCO_2e$	In %	$MtCO_2e$	Reduction $MtCO_2e$	In %	$MtCO_2e$	Reduction $MtCO_2e$	In %	Reduction $MtCO_2e$	In %
Energy	Power	95.14	23.24	87.13	8.01	29.06	51.4	35.73	57.72	43.74	48.9
	Transport	36.28	8.86	32.89	3.39	12.30	26.56	6.33	10.23	9.72	10.86
	Industry (energy)	101.99	24.91	95.33	6.66	24.17	94.31	1.02	1.65	7.68	8.58
	Other energy sub sectors:										
	Households	30.41	7.43	28.78	1.63	5.91	24.77	4.01	6.46	5.64	6.3
	Commercial	3.35	0.82	2.94	0.41	1.49	2.51	0.43	0.69	0.84	0.94
	Agriculture	10.16	2.48	9.37	0.79	2.87	10.13	0.03	0.05	0.82	0.92
	Brick Kilns	23.98	5.86	20.7	3.28	11.90	12.82	7.88	12.73	11.16	12.47
	Fugitive	8.31	2.03	8.31			4.03	4.28	6.91	4.28	4.78
	F Gases	2.92	0.71	0.78	2.14	7.76	0.03	0.75	1.21	2.89	3.23
Total Energy		312.54	76.34	286.23	26.31	95.46	226.56	59.71	96.46	85.98	96.1
IPPU	Cement and Fertilizer	10.97	2.68	10.97			10.97				
AFOLU	Agriculture and Livestock	54.64	13.35	54	0.64	2.32	53.6	0.4	0.65	1.04	1.16
	Forestry	0.37	0.09	0.37			0.37				
Total AFOLU		55.01	13.44	54.37	0.64	2.32	53.97	0.4	0.65	1.68	1.16
Waste	MSW and wastewater	30.89	7.55	30.28	0.61	2.21	28.44	1.84	2.97	2.45	2.74
Total Emission		**409.41**		**381.85**			**319.94**				
Total Reduction					**27.56**	**6.73**		**61.9**	**15.12**	**89.47**	**21.85**
Note: INDC (2015) proposed 12 $MtCO_2e$ (5%) reduction in unconditional and a further 24 $MtCO_2e$ (10%) reduction in conditional scenario											
Note: NDC (2020) proposed 27.56 $MtCO_2e$ (6.73%) reduction in unconditional and an additional 61.91 $MtCO_2e$ (15.12%) reduction in conditional scenario.											

(Source) Table 3, Mitigation Action, Nationally Determined Contributions (NDCs) 2021 Bangladesh

Table 4.2-10 Possible Mitigation Actions in NDC (Renewables)

Category	Unconditional	Conditional
Grid-connected Solar	581 MW	2,227MW
Wind	149 MW	597MW
Biomass	20 MW	50MW
Biogas	5 MW	5MW
New Hydro	100 MW	1,000MW
Solar Mini-grid	56.8 MW	56.8MW
Waste-to-Electricity	N.A.	128.5MW
Total	**911.8 MW**	**4,114.3MW**

(Source) Prepared by IEEJ referring to Table 4 & 5, Mitigation Action, Nationally Determined Contributions (NDCs) 2021 Bangladesh

Table 4.2-10 shows the target for the installation capacity of renewable power generation by 2030 in NDC. Also, Table 4.2-11 shows the investment cost estimation to achieve the aforementioned installation of the renewable power generation by 2030. Installation of Grid-connected Solar in the conditional scenario is 4 times bigger than the unconditional scenario and installation of New Hydro in the conditional scenario is 10 times bigger than the unconditional scenario. Also, installation of 128.5MW Waste-to-Electricity is expected in the conditional scenario.

Table 4.2-11 Investment Required for Key Possible Mitigation Measures (Renewables)

Mitigation Measures	Estimated investment required (Million USD, 2021-2030)	
	Unconditional	Conditional
Implementation of energy efficient coal power plant	9,905	13,204
Implementation of renewable energy projects		
Grid connected Solar	1,208	1,845
Wind	333	600
Biomass	35.4	71
Biogas	32.1	64
Hydro	204	2,166
Solar mini grid	260.5.	260.5

(Source) Prepared by IEEJ referring to Table 6,

Implementation Mechanism, Nationally Determined Contributions (NDCs) 2021 Bangladesh

4.3 Climate Policy

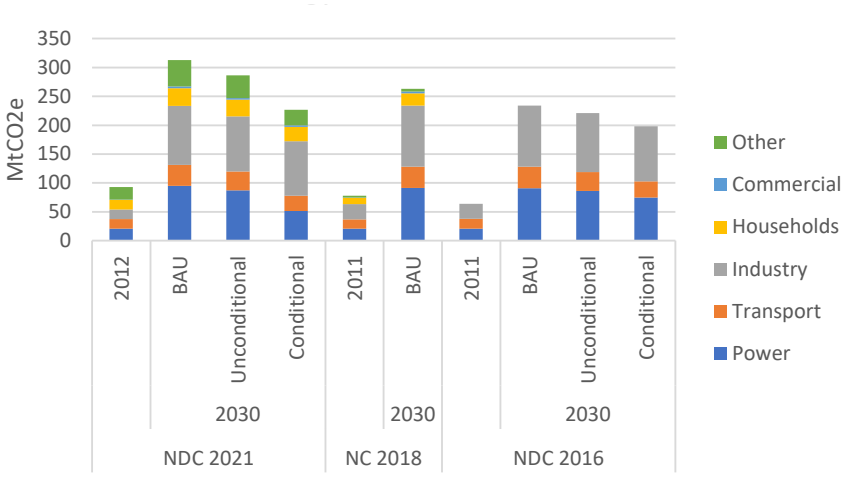
In response to rising concern on climate change, Bangladesh submitted its updated version of Nationally Determined Contribution (NDC) to the UNFCCC Secretariat on 26 August 2021. In line with this, the preliminary report of the Mujib Climate Prosperity Plan was released in September 2021.

4.3.1 Updated Nationally Determined Contribution

Bangladesh's NDC is presently:

1) In the unconditional scenario, GHG emissions would be reduced by 6.73% below BAU (409.4 MtCO2e) in 2030; and,
2) In the conditional scenario, GHG emissions would be reduced by 21.85% below BAU in 2030.

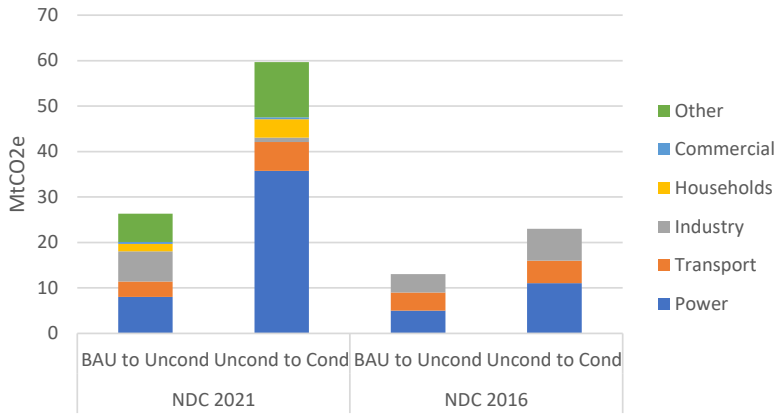
They were updated from a reduction of 5% and 15%, respectively, from BAU levels (234 MtCO2e) which covered only the power, transport and industry sectors. Energy-related emissions in NDC 2021 are compared with those of the national communication (NC) 2018, and NDC 2016 in Figure 4.3-1).



Source: NDC 2021, NC 2018 NDC 2016.

Figure 4.3-1 Comparison of energy-related emissions between scenarios in NDC 2021, NC 2018 and NDC 2016

Figure 4.3-2 shows emissions reductions from the BAU scenario to the unconditional contribution scenario, and from the unconditional scenario to the conditional scenario in NDC 2021 and NDC 2016. Power and 'other' are the two largest emission-reductions sectors in the scenario from conditional to unconditional in NDC 2021. 'Other' represents the fuels used by brick kilns (mainly coal) listed separately form the industrial energy consumption.



Source: NDC 2021, NDC 2016.

Figure 4.3-2 Emission reductions from BAU to unconditional, and from unconditional to conditional in NDC 2021 and NDC2016

A set of potential mitigation actions for unconditional and conditional contribution scenarios are summarized in Table 4.3-1. Note that 'other' includes the brick kilns sector.

Table 4.3-1 Possible mitigation actions

	Unconditional Contribution	Conditional Contribution
Power	● Implementation of renewable energy projects of **911.8 MW** ● Installation of new Combined Cycle Gas based power plant (**3,208 MW**) ● Efficiency improvement of Existing Gas Turbine power plant (570 MW) ● Installation of prepaid meter	● Implementation of renewable energy projects of 4114.3 MW ● Coal power plant with Ultra Super Critical technology-12,147 MW ● Installation of new Combined Cycle Gas Turbine based power plant (5,613 MW) ● Efficiency improvement of Existing Gas Turbine power plant (570 MW) ● Installation of prepaid meter ● Bring down total T&D loss to a single digit by 2030
Transport	● Improvement of road traffic congestion (5% improvement in fuel efficiency) ● Modal shift from road to rail (10% modal shift of passenger-km) through different Transport projects such as BRT, MRT in major cities, Multi-modal hub creation, Padma Bridge etc. ● Improved and enhanced Inland Water Transport (IWT) system (Improve navigation for regional, sub-regional, and local routes, improve maintenance of water vessel to enhance engine performance, introduce electric water vessel etc.)	● Improvement of road traffic congestion (**15%** improvement in fuel efficiency) ● Modal shift from road to rail (**25%** modal shift of passenger-km) through different Transport projects such as BRT, MRT in major cities, Multi-modal hub creation, new bridges, etc. ● Improved and enhanced Inland Water Transport (IWT) system (Improve navigation for regional, sub-regional, and local routes, improve maintenance of water vessel to enhance engine performance, introduce electric water vessel etc.)
Industry	● Achieve **10%** Energy efficiency in the industry sub-sector through measures according to the Energy Efficiency and Conservation Master Plan (EECMP)	● Achieve **20%** Energy efficiency in the industry sub-sector through measures according to the Energy Efficiency and Conservation Master Plan (EECMP) ● Promote green Industry ● Promote carbon financing
Residential and Commercial	● Use energy-efficient appliances in household and commercial buildings (achieve **5%** and **12%** reduction in emissions respectively)	● Use energy-efficient appliances in household and commercial buildings (achieve **19%** and **25%** reduction in emissions respectively)
Other	Brick Kilns ● **14%** emissions reduction through Banning Fixed Chimney kiln (FCK), encourage advanced technology and non-fired brick use	Brick Kilns ● **47%** emissions reduction through Banning Fixed Chimney kiln (FCK), encourage advanced technology and non-fired brick use

Source: NDC 2021.

4.3.2 Mujib Climate Prosperity Plan

The overview of the Mujib Climate Prosperity Plan is shown in Table 4.3-2.

Table 4.3-2 Overview of the Mujib Climate Prosperity Plan

<table>
<tr><th colspan="4">Key Initiative/measure</th></tr>
<tr><td colspan="4">Key Point 1: Accelerated adaptation</td></tr>
<tr><td colspan="4">Key Point 2: Just transition of Labor and Future Proofing Industry with Technology Transfer</td></tr>
<tr><td></td><td colspan="3">2B: Future Proof Bangladesh’s Position in the Global Supply Chain</td></tr>
<tr><td colspan="4">Key Point 3: Increasing Public Revenue to Spend on the Most Vulnerable</td></tr>
<tr><td></td><td>3B: An Established Carbon Financing Regime for Revenue Generation</td><td colspan="2">Target Milestones 2024: Implement carbon pricing or tax with dividends that disproportionately benefit low-income households.</td></tr>
<tr><td colspan="4">Key Point 4: Comprehensive Climate and Disaster Risk Financing and Management</td></tr>
<tr><td colspan="4">Key Point 5: Leveraging 21st Century Technologies for Well Being</td></tr>
<tr><td colspan="4">Key Point 6: Maximized Renewable Energy, Energy Efficiency and Power & Transportation Sector Resilience</td></tr>
<tr><td rowspan="4"></td><td rowspan="3">6A: Maximized Renewable Energy Wealth, Energy Efficiency and Energy Storage Infrastructure</td><td>Mujib Bongoposagor Independence Giga Array</td><td>4GW offshore wind with parallel planting of a greenbelt of mangroves.</td></tr>
<tr><td>Strategic Mujib Energy Hubs</td><td>Convert coal plants into green energy facilities such as hydrogen works.</td></tr>
<tr><td colspan="2">30% maximal variable renewable energy by 2030, lower energy intensity by 20% by 2030, subject to grid modernization, financing and investment, setting the trajectory for low carbon growth towards 40% renewable energy by 2041.</td></tr>
<tr><td colspan="3">6B: Modernization of the Grid and the Ancillary Market to Support Resilience</td></tr>
<tr><td></td><td colspan="3">6C: Transitioning to Transport Solution of the Future</td></tr>
</table>

Source: Mujib Climate Prosperity Plan, 2021.

The Mujib Climate Prosperity Plan incorporates four scenarios:

1） Business-As-Usual (BAU): Uses the reference scenario in Vision 2041;
2） Nationally Determined Contributions (NDC): Based on the first NDC submitted. It is important to note this will be continuously updated as NDC submissions;
3） Mujib Climate Prosperity Plan (MCPP): Realistic climate prosperity scenario based on current and expected prospective access to resources and support;
4） Mujib Climate Prosperity Plan Maximized (MCPP-M): Maximized climate prosperity scenario based on a significant increase in resources made available both from international support and private sector (domestic, regional, and international).

The renewable energy share in the energy mix and lower energy intensity in these scenarios is shown in Table 4.3-3.

Table 4.3-3 Renewable energy share in energy mix and lower energy intensity by scenario

	Scenario	2025	2030	2041
RE share in energy mix	BAU	3%	6%	
	MCPP	5%	10%	
	MCPP-M	7%	30%	40%
Lower energy intensity	MCPP-M		20%	

MCPP (Mujib Climate Prosperity Plan): Realistic climate prosperity scenario based on current and expected prospective access to resources and support.
MCPP-M (Mujib Climate Prosperity Plan Maximized): Maximized climate prosperity scenario based on a significant increase in resources made available both from international support and the private sector (domestic, regional, and international).
Source: Mujib Climate Prosperity Plan, 2021.

4.4 Environmental Policies

4.4.1 Overview of Environmental Policies, Laws and Regulations in Bangladesh

The first environmental law, the Environmental Conservation Act (ECA-95) was promulgated in 1995[16], followed by the Environmental Conservation Rules (ECR-97) of 1997[17]. ECA-95 provides for promotion of environmental conservation, development of environmental standards and control/mitigation of environmental pollution. ECR-97 lays down the process for obtaining clearances, including forms for obtaining clearance certificates and standards for pollution control.

The latest environmental policy developed by the government is the National Environmental Policy (2018) (NEP 2018) that provides a comprehensive framework for environmental action, together with a set of broad sectoral action guidelines.

4.4.2 Bangladesh Policies, Strategies, Plans and Actions Relevant to Environment

The government of Bangladesh has adopted a handful of policies addressing environment and development issues. Although these are not judicially enforceable according to the Constitution of Bangladesh, they provide the guidance, influencing the activities of the concerned Ministries and other governmental agencies as summarized below.

[16] ECA of 1995 has been subsequently amended in 2000, 2002 and 2010 respectively.
[17] ECR of 1997 has been subsequently amended in 2002, 2003, 2005, 2007, 2008, 2010, 2017 and 2020, respectively.

Table 4.4-1 Environmental Policies of Bangladesh

Name	Year issued	Description
National Environment Policy (NEP)	1992	● NEP of 1992 embraces policies related to agriculture, industry, health, energy, water, land, forest, fisheries, marine, transport, housing, population, education and science, facilitating long-term sustainable use of all natural resources and amending the existing laws, formulating new laws. It also assigns the Ministry of Environment and Forests (MoEF) to implement these policies, headed by a high level National Environmental Committee (NEC).
Forest Policy	1994	● Forest Policy is the amended and revised version of national forest policy of 1997, and formulated in light of National Forestry Master Plan. The policy provides afforestation programs, highlighting bio-diversity particularly for threatened flora and fauna through establishing National Parks, Wildlife Sanctuary and Game Reserves. Commitment also includes 10% increase of the reserved forest land by the year 2015 such as Chittagong, Barind tract, etc.
National Fishery Policy	1998	● National Fishery Policy aims at increasing fish production and create self-employment to improve the socio-economic condition of the fishermen. ● It calls for enhancing control of the wetlands, and facilitates protection of water bodies by managing the release of untreated effluents from the industries.
National Energy Policy	1995	● National Energy Policy provides for utilization of energy for sustainable economic growth, supply to different zones of the country, development of the indigenous energy sources and environmentally sound energy development programs. ● It highlights the importance of protecting environment by requiring Environmental Impact Assessment (EIA) for any new energy development project, introduction of economically viable and environment-friendly technology and putting a ban on the use of fuel-wood for brick burning and disposal of ash and reduction of environmental emission encouraged in coal-based power plants.
National Environment Management Action Plan (NEMAP)	1995	● NEMAP is a multi-faceted plan, which builds on and extends the statements set out in the NEP. NEMAP sets out the framework (1995-2005) which outlines 1) key environmental issues affecting Bangladesh, 2) actions necessary to halt or reduce the rate of environmental degradation, 3) conservation of habitats and biodiversity, 4) promotion of sustainable development, and 5) improvement in the quality of life of the people. ● The location-specific action focuses particularly on acute environmental problems at local levels that need to be addressed on a priority basis. One of the key issues in NEMAP regarding the energy sector is: “energy conservation awareness is generally low throughout the country”.
National Industrial Policy	1999	● The National Industry Policy of 1999 calls for environmentally sound industrial development along with its other goals of ensuring high rate of investment by the public and private sectors, strong productive sector, direct foreign investment, development of labor intensive industries, introduction of new appropriate technology, women’s participation, development of small and cottage industries, entrepreneurship development, high growth in export and infrastructure development.
National Water Policy	1998	● The National Water Policy of 1999 ensures efficient and equitable management of water resource, proper harnessing and development of surface and ground water, availability of water to all concerned and institutional capacity building for water resource management. ● It has also addressed issues like river basin management, water rights and

Name	Year issued	Description
		allocation, public and private investment, water supply and sanitation and water need for agriculture, industry, fisheries, wildlife, navigation, hydropower, recreation, environment, preservation of wetlands etc. People's participation in water development projects is also recognized as an essential part of project planning process.
National Agriculture Policy	1999	● The National Agriculture Policy of 1999 aims to ensure sustainable agricultural production, conservation of crop biodiversity, introduction of new technology, increased use of organic manure, integrated pest management system, efficient irrigation system, diversification of crops and establishment of agro processing and agro-based industries.
Renewable Energy Policy	2008	● The Renewable Energy Policy defines the necessity for the country to develop renewable energy technology, including solar, wind, biomass, hydro, geo-thermal, and tidal wave.
Bangladesh Climate Change Strategy and Action Plan (BCCSAP)	2009	● BCCSAP is a 10-year program (2009-2018) to build the capacity and resilience of the country to meet the challenge of climate change. ● The needs of the poor and vulnerable, including women and children are prioritized in activities to be implemented under the Action Plan, focusing on 1) food security, social protection and health, 2) comprehensive disaster management, 3) infrastructure, 4) research and knowledge management, 5) mitigation and low carbon development, 6) capacity building and institutional development.
National Adaptation Program of Action (NAPA)	2009	● NAPA aims at the development of a countrywide program that encompasses the immediate and urgent adaptation activities to address the current and anticipated adverse effects of climate change, including extreme events. ● The goal of the NAPA is provision of a framework to guide the coordination and implementation of adaptation initiatives in the country, through a participatory approach and building synergies with other relevant environmental and related programs.
Intended Nationally Determined Contribution (INDC)	2015	● The INDC includes both unconditional and conditional emissions reduction goals for the power, transport, and industry sectors, alongside mitigation actions in other sectors, which Bangladesh intends to carry out. ● The INDC of Bangladesh consists of the following elements: ● An unconditional contribution to reduce GHG emissions by 5% from Business as Usual (BAU) levels by 2030 in the power, transport and industry sectors, based on existing resources. ● A conditional 15% reduction in GHG emissions from BAU levels by 2030 in the power, transport, and industry sectors, subject to appropriate international support in the form of finance, investment, technology development and transfer, and capacity building.
National Environmental Policy (NEP)	2018	● NEP 2018 is an updated policy document, providing a comprehensive framework for environmental action, together with a set of broad sectoral action guidelines. The updated environmental policy includes total twenty-four sectors and areas.

Source: Accessed from different ministry and department websites, compiled by EQMS

4.4.3 The National Environmental Policy 2018

The NEP 2018 is the subsequent development of the NEP 1992. The main objective of the policy is to guide the actions of the people in such a way that contribute to the sustainable

development. The updated environmental policy includes total twenty-four sectors and areas as summarized below.

(1) Highlights of the NEP 2018

NEP 2018 addresses considerations of the cross cutting environmental issues related to development and guides national authorities and industries to consider mitigation measures. For assurance of such sector polices, the NEP 2018 takes a wider political step that ensures:

a. All laws related to environmental and resource conservation and pollution and degradation control should be amended as required and appropriate in consideration of the already amended the Bangladesh Environmental Protection Act and Environmental Court Act.
b. Ensure proper observance of all relevant laws and create wide public awareness in this regard.

(2) Institutional Set-up

a. All concerned Ministries and Departments will implement the NEP and the Ministry of Environment, Forests and Climate Change (MoEFCC) will coordinate the implementation of this policy.
b. The NEC, chaired by the Head of the Government, will provide comprehensive guidance on the implementation of this policy.
c. This policy will be reviewed by the MoEFCC every five years and at any time for special needs in view of the future environmental and socio-economic needs of the country.
d. The Department of Environment shall ensure proper, expeditious implementation and development of all laws, rules, policies, and government guidelines relating to the environment.
e. Concerned Ministries and Departments shall, where applicable, carry out Strategic Environmental Assessment (SEA) on the policy, plan, and program.

(3) Compliance of NEP

a. issue of conservation and development of environment and biodiversity has been adopted as a principle in the Constitution of the People's Republic of Bangladesh.
b. This policy will be considered an integrated policy for protection and development of the environment and will serve as a guideline for environmental activities enshrined in other national policies. All the concerned Ministries / Departments / Offices / Sangha shall abide by this policy.

Due to a wide variety of the sectoral considerations addressed in the NEP, this section provides a summary of the sector/area relevant to the environment, as underscored in the table below.

Table 4.4-2 Highlights of NEP 2018 Thematic Areas of Environmental Considerations

No.	Thematic Areas	Description
1	Land Resource Management	● Land use system compatible with different environments of the country should be introduced. ● Management strategies and action plans should be formulated and implemented to prevent the effects of land salinity. ● Land zoning based on ecosystem and environment shall be arranged and SEA shall be established. ● The banks of rivers and other reservoirs should be developed along with afforestation to prevent river erosion and landslides. ● Greening should be strengthened by native species of plants. ● Effective measures should be taken to prevent hill / hill cutting, and development activities should keep the hill environment intact. ● Ensuring access to ecosystem goods and services for the poor through conservation of environment and biodiversity. ● Protected forests cannot be used for any purpose other than forest management.
2	Water Resource Management	● Environmental use of all water resources of the country should be ensured and measures should be taken to conserve rainwater harvesting. ● The measures taken for water resource development, flood control, drainage and irrigation projects should be re-evaluated and made environmentally friendly as per the requirements after verifying whether the technical issues have already caused any adverse effects on the environment. ● Reservoirs and water resources of the country such as harbors, canals, rivers, floodplains, etc. should be kept pollution-free. ● Integrated water resource management policy should be adopted. Environmental use of water resources and conservation of biodiversity must be ensured through the participation of all stakeholders (especially local communities) in ensuring wetland conservation and rational use. ● Ecologically Critical Areas (ECA) and Protected Areas (PA) should be declared and restoration activities should be undertaken for the recovery and preservation of any fragile environment due to erosion. The ECA cannot be leased without permission of the ECA Management Authority. ● A catchment area map of all river and wetland water supply areas / basins should be prepared. All rivers, wetlands and flood flow zones must be protected by demarcating the boundaries. ● All roads and railways should be planned for free flow of water. ● Rules and regulations should be formulated by the government to identify new industrial zoning keeping in view the possibility of discharge of polluted water and waste from industry.
3	Air Pollution Control	● Environmental standards must be set and updated by identifying the areas necessary for air quality management, and air quality must be kept within environmental standards, and law enforcement must be strengthened to control the quality. ● In case of new industrial establishments and brick kilns, degraded air sheds should be avoided considering the level of air pollution. ● Necessary steps have to be taken to innovate and introduce alternative environmentally friendly brick making systems instead of the soil burning brick making method. ● The fuel quality standard used in motor vehicles and industrial establishments should be determined. Restrictions on imports of high-

No.	Thematic Areas	Description
		sulfur coal and other fuels should be imposed. ● Effective measures should be taken to control open ignition and odor. When pitch roads are constructed, open burning of pitch and open burning of agricultural residues should be avoided. Construction work must be done while avoiding dust pollution. Open lanes should be covered with grass or shrubs to control dust pollution. ● Effective air quality monitoring systems must be developed in the country and measures must be taken to determine air quality indicators, compliance, and air pollution control. ● To control in-land air pollution, an in-land air monitoring network should be established along with the neighboring countries and international negotiations should be carried out to control the pollutants.
6	Public Health and Health Services	● In all cases and in all development, activities that are harmful to public health as a result of environmental pollution or loss of environmental balance must be avoided. ● It is necessary to ensure a conducive environment in all the organizations providing health services and to make it mandatory for all these organizations to adopt appropriate management practices for all waste including medical waste.
9	Forest and Wildlife	● Alternative innovation and use of forest resources should be encouraged. ● The wetlands and migratory bird habitats of the country should be conserved and developed. ● Institutional structures should be strengthened, and special management activities should be undertaken for government supervision and law enforcement in ECAs and PAs. ● Appropriate measures must be taken to conserve endangered endemic species. ● Environmental management-based mangrove forests should be conserved and managed.
10	Biodiversity, Ecosystem Conservation and Biosafety	● To conserve and improve the quality of the overall environment and biodiversity, all concerned organizations take effective steps to preserve the species and ecosystem diversity existing in the environment. ● The country's wetlands must be conserved and developed; wetland filling must be stopped; effective steps to be taken for the conservation and development of migratory bird habitat including wetland biodiversity and livestock including restoration of already filled wetlands. ● In the case of the ECA, precautionary measures should be taken and conservation and proper management of environmentally sensitive areas must be ensured.
12	Fisheries and livestock	● Wetlands identified as a source of fisheries should be prevented from shrinking and conservation measures should be taken. ● Fisheries and livestock development measures must be taken to ensure that mangroves do not adversely affect the forest and other environments. ● Wetland leases should be discontinued in all protected areas, including coastal areas, and/or in environmentally critical areas, and participatory community-based management and co-management should be introduced. ● Wetland water quality must be maintained. Fisheries habitat should be conserved in wetlands.
13	Coastal and marine ecosystem	● Environmental conservation and development of the country's coastal and marine environment and resources must be ensured. ● Ecosystem based approach should be followed in extracting coastal and

No.	Thematic Areas	Description
		marine resources. ● The level of marine resource extraction in coastal and marine areas should be kept at a tolerable level, so that the regeneration capacity of the environment is maintained. ● Mangrove forest, coastal forest should be conserved and restored. ● Necessary action plans should be adopted for dealing with the intrusion of salinity and introduced saline and flood-free crop species. ● A Conservation Management Plan (CMP) must be formulated to ensure that ecotourism takes place in popular and environmentally friendly tourist areas. ● Coastal green belt, natural deforestation must be controlled and specific conservation policies must be adhered to in deforestation in social forestry.
15	Industrial Development	● Necessary steps to be taken by the industrial establishments to prevent environmental pollution. ● EIA should be conducted where applicable before setting up a new industry. ● To ensure waste prevention and sustainable use of raw materials in the industry and to implement waste management, waste management policies have to be implemented. ● The Internal Clean Development Mechanism method should be implemented in the country.
16	Energy and Mineral Resources	● The use of fuels that accelerate environmental pollution and climate change must be reduced and discouraged, and the use of environmentally friendly and less harmful fuels must be encouraged. ● The use of wood, agricultural waste and dung as fuel should be reduced and the use of environmentally friendly alternative fuels and fuel-efficient stoves should be increased. ● Research, production and use of environmentally friendly biogas, energy, wind, rain and wind energy and other renewable energy should be increased. ● EIA and mitigation measures should be taken before undertaking projects related to extraction of energy and mineral resources.
19	Climate Change Preparedness and Adaptation	● To address the adverse effects of climate change, Bangladesh has to formulate and implement the Climate Change Action Plan for implementation of the Climate Change Cell and Action Plan. ● Necessary adaptation/mitigation measures have to be adopted and, in this case, efforts will have to be made to increase international investment as well as to seek international cooperation for financial and technical assistance.
20	Disaster Management	● Disaster risk reduction should be included in all levels of the country's development plan. Therefore, while adopting the development plan, especially the infrastructural development plan, the risk should be identified and mitigation measures should be taken. ● Disaster mitigation and adaptation activities must be undertaken by identifying potential disasters caused by global warming.
22	Management of Chemical Substances	● All types of chemicals should be disposed of in an environmentally friendly manner. ● In the case of production and import of chemicals, proper usage of rules, stockpiling methods, assessment of harmful effects on the environment, pollution control, etc. should be conducted in line with applicable regulations.

No.	Thematic Areas	Description
		● Chemicals used in industry, pesticides and chemical fertilizers used in agriculture, chemicals used in households and chemicals used in public interest should be regulated in the light of pre-import regulations. In the light of inventory prepared at the stage of production, application and use after import, the movement of chemicals should be monitored in the light of the policy.
24	Environment Friendly Economic Development, Sustainable Production and Consumption	● Carbon emissions should be kept as low as possible in all development activities without disturbing the economic development and poverty alleviation of the country. ● The use of manpower should be increased in those sectors where carbon emissions are low. ● In order to expand or transform an eco-friendly economy, the domestic context, development plans and goals, as well as the policy of the country, must be followed. ● Emphasis should be placed on the use and dissemination of environmentally friendly technologies that are effective or cost effective in the domestic context for the expansion of eco-friendly economy.

Source: NEP 2018

Appendix B

Improving Energy Efficiency

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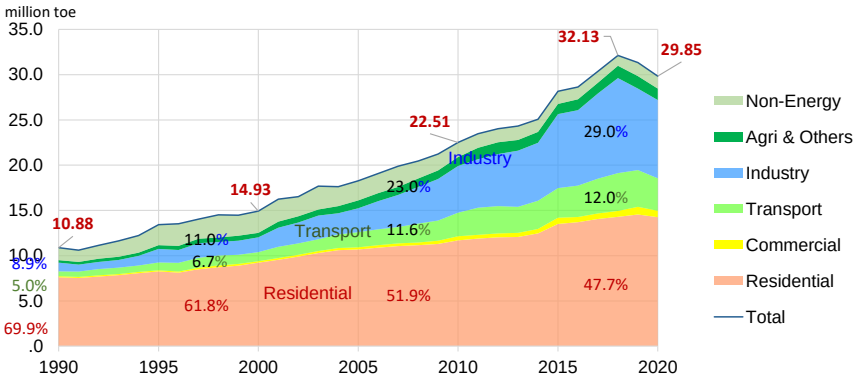
1. Overview of EECMP 2016

1.1 Final Energy Consumption and Energy Efficiency

In Bangladesh, final energy consumption increased 2.00-fold between 2000 and 2020 reflecting economic growth. During this period, GDP increased 3.30-fold. By sector, the industrial sector recorded a 5.27-fold increase, residential sector 1.54-fold, commercial and public services sector 4.10-fold, and transportation sector 3.61-fold. About half of the energy is consumed by the residential sector, while industrial use is increasing rapidly. To understand the current status on energy efficiency, an overview is shown on the energy efficiencies of the whole economy and each sector as below.



Note: As sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

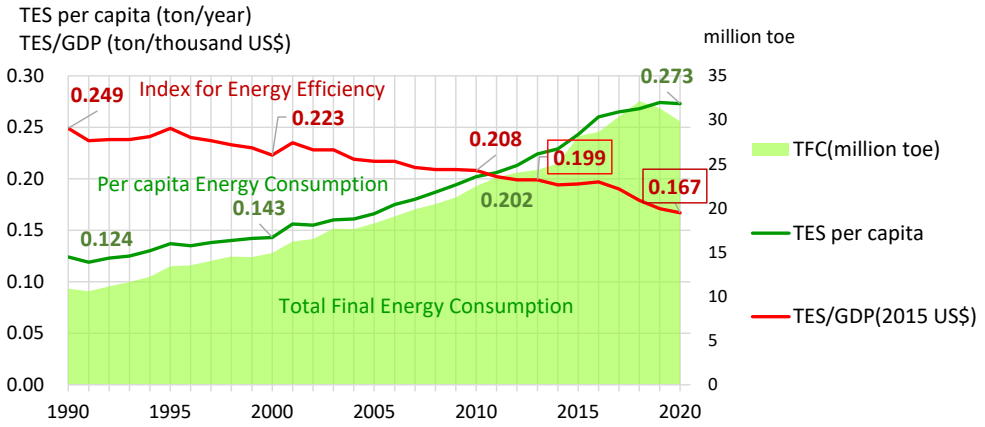
Sources: IEA World Energy Balances 2022

Figure 1-1 Final Energy Consumption by Sector

Promoting energy efficiency, it is important to adopt high efficiency technologies; that is, to enhance introduction of an energy efficient production process at factories and high efficiency appliances and equipment in residential and commercial sectors. In Bangladesh, the Energy Efficiency and Conservation Master Plan up to 2030 (hereinafter referred to as EECMP2016) was formulated in 2016, and energy conservation efforts are underway.

As an index of energy efficiency for the whole country, energy consumption per GDP (energy intensity: energy consumption/GDP) is usually used.

The evolution of energy intensity is shown in Figure 3.1-2. The Energy Efficiency and Conservation Master plan 2016 (EECMP 2016) schedules reduction of energy intensity by 15% by 2021 and 20% by 2030 from the base year of 2013 in primary energy base. We observed that energy intensity for 2013 was 0.199 (84.5% of that of 2013) and 0.167 (16.1%83.9%) in 2020.

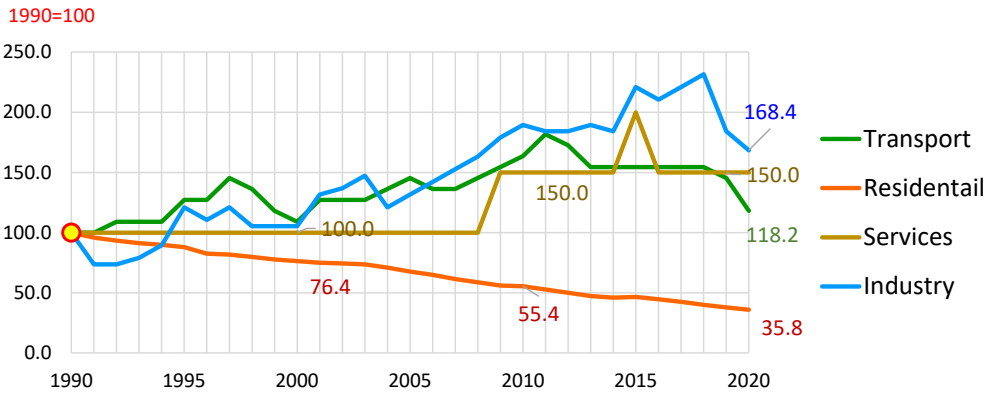


Note: As no sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

Source: IEA World Energy Balances 2022

Figure 1-2 Primary Energy Consumption per GDP: Bangladesh

The sectoral tendency analyzed as shown in Figure 1-3, which illustrates the sectoral energy consumption divided by GDP (2015 US$) and standardized as 1990=100. It should be noted that, during the period, industrial consumption continued vigorous growth and its sectoral composition increased from 8.9% in 1990 to 29.0% in 2020 while the residential sector energy consumption decreased its share from 62.2% in 1990 to 47.7% in 2020. These indices reflect such movements also. Service sector energy consumption was small comprising only 2.4% of the national total; IEA looks to estimate it using a conventional method.

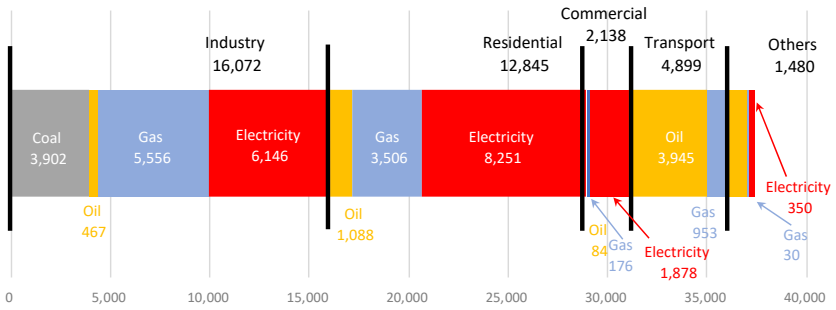


Note: As no sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

Source: IEA World Energy Balances 2022

Figure 1-3 Energy Consumption Indices by Sector

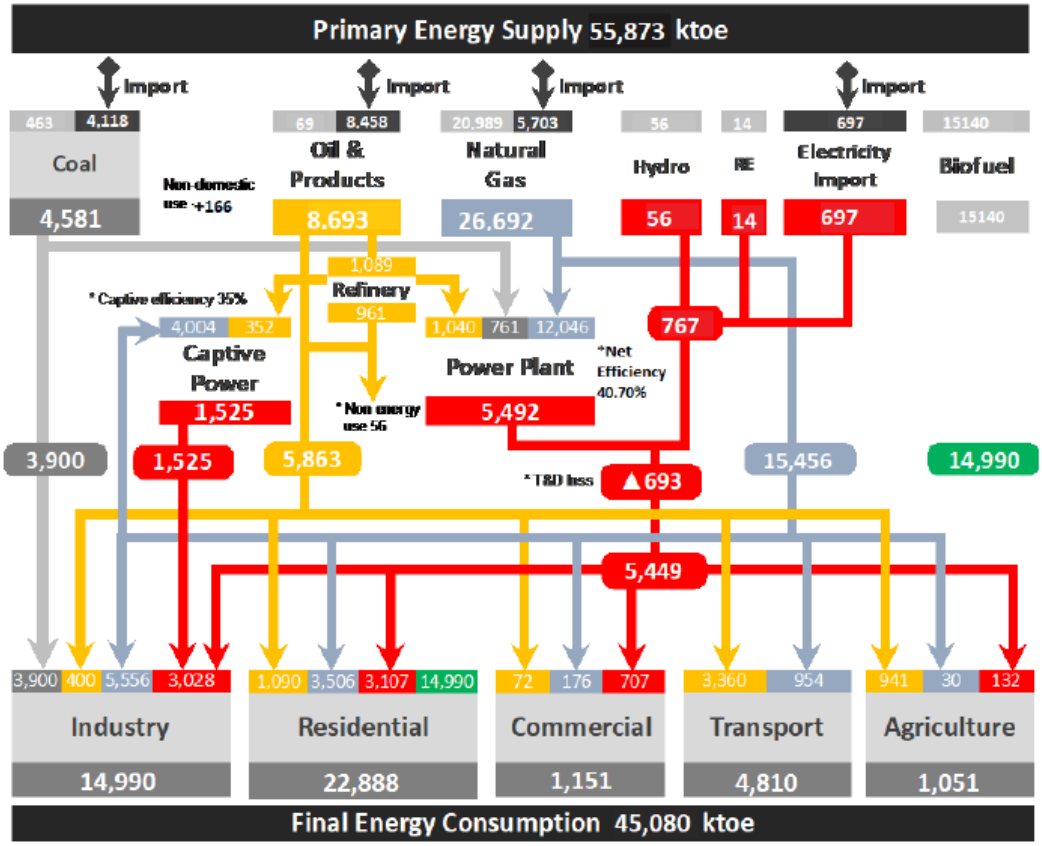
The following chart shows sector-specific data studied by SREDA. This data shows the primary equivalent of electricity consumption for each sector. This figure enables us to see the importance of improving electricity efficiency in the industrial, residential commercial and agricultural sectors.



- This is a sector-wise energy supply (primary energy basis) to show the fuel input to each sector.
- Electricity consumptions are converted to primary energy basis depending on their supply source.
- Energy saving potential on primary energy basis can be visually presented.

Unit: ktoe
Note: excludes biofuel.

Source: SREDA National Energy Balance 2020/21



Source: SREDA National Energy Balance Report 2020 - 2021

Figure 1-4 Energy Consumption by Sector in Primary Energy Data by SREDA National Energy Balance Report

1.2 EECMP 2016

As the supreme policy on energy efficiency and conservation, the Energy Efficiency and Conservation Master Plan 2016 (EECMP2016) was announced by the Sustainable and Renewable

Energy Development Authority (SREDA), Power Division, Ministry of Power, Energy and Mineral Resources, in May 2016. With a view to promoting energy saving activities among the general public, it sets the energy conservation target to reduce the energy intensity (primary energy per GDP) by 15% by 2021 and 20% by 2030 compared to 2013 as shown in Figure 1-4.

Source: EECMP 2016

Figure 1-5 EE&C Implementation Roadmap (2015-30) in EECMP2016

As shown in Table 1-1, major EE&C programs in action plan are:

a. Energy Management Program (EMP)
b. EE Labelling Program (EELP)
c. EE Building Program (EEBP)
d. EE&C Finance Incentive Program
e. Government's Own Initiatives
f. Energy consumption Data Collection
g. Global Warming countermeasures

The EECMP2016 focuses on industrial, residential and commercial sectors, while the transportation sector, are utilities (energy supply sector) are left to be addressed in the next version of EE&CMP. In this report, however, we look into EEC issues on transport and agriculture sectors as explained later (section3, 5). By sector, major key programs are as follows:

1) Key Industrial Sector Initiatives in the EECMP 2016

Major programs are designed on the introduction of an energy manager system, a regular reporting system, and a benchmark system for energy management as below:

a. Large energy consuming entities (DCs: Designated large energy consumers)) program
b. Energy manager and energy auditor program
c. Regular reporting system for energy consumption and energy efficiency efforts from DCs program
d. Sub-sector benchmark program on energy intensity and production process energy

intensity

Table 1-1 EE&C Programs in Action Plan (EECMP2016)

Program	Target	Methodology
Energy Management Program (EMP)	Large Industrial Energy Consumers	■ Large energy consumer designation ■ Energy Manager, Certified Energy Auditor and Accredited Energy Auditor certification with qualification and examination system ■ Energy audit (mandatory/voluntary) ■ Energy consumption reporting (mandatory) ■ Benchmarking
EE Labeling Program (EELP)	Residential Consumers	■ Label certification / Laboratory accreditation system ■ Standardization of EE measurement method and Star Label Rating criteria ■ Star Label Standardization (Unification) ■ Participation of manufactures, importers and retail shops (mandatory/voluntary) ■ MEPS (Minimum Energy Performance Standard)
EE Building Program (EEBP)	Buildings	■ New version of BNBC [Revised] Implementation ■ GBG development ■ Manual and assessment system introduction
EE&C Finance Incentive Program	Private Companies	■ Low-interest loan for EE&C investment ■ Preferential taxation on high efficiency equipment/appliances and/or EE&C investment ■ Subsidy for EE&C investment ■ Other incentive mechanisms
Government's Own Initiatives	Government	■ Green Purchase Program for Eco-friendly public procurement ■ Obtain ISO14001 and 50001 certification
Energy Consumption Data Collection	Government	■ Energy consumption data by fuel ■ Energy consumption data by sector and sub-sector ■ Energy intensity data
Global Warming Countermeasure	All	■ Formulation and quantification of national carbon market ■ Carbon abatement project as capacity development ■ Awareness raising

Source: SREDA, EECMP 2016

2) Key Initiatives of residential and commercial sector in the EECMP 2016

Programs are considered on energy efficiency standards for equipment such as home appliances and energy efficiency and labeling (S&L) including S&L program on buildings.

a. Energy efficiency standards and labeling program
b. Bangladesh National Building Code, Green Building Guideline

・Energy standards and labeling program

For introduction of S&L, common rules and technical issues on home appliances (CFL, air conditioner, refrigerator, TV, fan, lighting ballast, motor) are mainly taken into consideration. Rules have been formulated and program operation is being improved. At present, appliances for which energy labeling is obligatory are air conditioners, refrigerators, fans, and CFLs.

・Bangladesh National Building Code, Green Building Guideline

The Bangladesh National Building Code also sets out standards on energy efficiency. It is

planned to gradually reduce the applicable areas covered by this code.

In addition to collection of energy data every year on oil, gas, coal and electricity (renewable), indicators that express EE&C programs implementation and achievement will be collected as shown in Table 1-2. Except for the Energy Balance Report, data shortage challenges need to be solved.

Building up the monitoring system and tracking its progress with program-based data (e.g. DCs reporting data, etc.) are the challenges that need to be solved for further progress on future EECMP. Some part of programs or sectors should be implemented in a prioritized manner to make a success story out of the data monitoring system as flagship initiatives.

Table 1-2 Planned Monitoring for EE&C Programs Implementation

Program	Indicator	Data collection method	Interval
Energy Management Program	■ Number of designated energy consumers ■ Number of energy managers and auditors certification	DCs number, certification of EM, CEA and ACEA	Every year
EE Labeling Program	■ Penetration of EE label ■ Sales of labeled products ■ Energy efficiency	Market researches	Every 3 years
EE Building Program	■ Number, floor area and use of the buildings attending the building codes	Research by MOHPW	Every year
	■ Energy efficiency	Energy audits	Every 3 years
EE&C Finance Program	■ EE&C investment	Financial institutes	Every year

Source: EECMP 2016

On behalf of a lack of truck progress data, we found that enormous progress brought by EECMP 2016 activities through the discussions with SREDA. The summarized presents status of sectoral programs is as follows:

1) Industrial sector:
   a. JICA's finance functioned as a catalyst for the financial sector using the energy efficiency technology list which is shared by local finance institutions.
   b. 150 Large energy consuming entities（DCs: Designated large energy consumers) program: Submitted DCs list and are now waiting for final approval.
   c. Energy manager and energy auditor program: Examination on energy auditor was carried out and 18 persons passed.
   d. Regular reporting system for energy consumption and energy efficiency efforts from DCs program: Periodical report will be submitted.
   e. Sub-sector benchmark (Sub-sector energy intensity, production process energy intensity) program: Expert visiting surveys are planned to be implement in order to collect supplemental data for a survey of the Certified Energy Auditor.

2) Residential and commercial sector
   a. Energy efficiency standards and labeling program: Equipment for which energy efficiency labeling is obligatory includes air conditioners, refrigerators, fans, and LEDs
   b. Bangladesh National Building Code, Green Building Guideline: To reduce the regulated floor area year by year

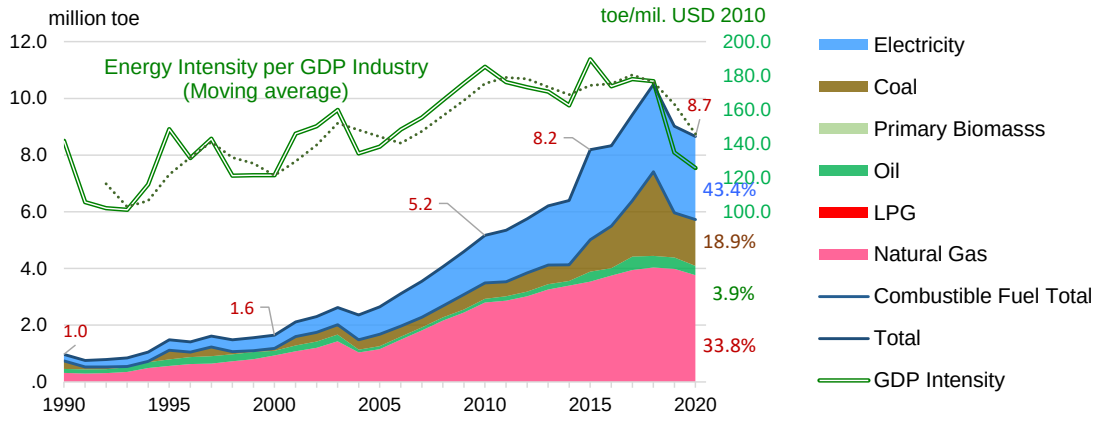
3) Energy efficiency related finance
   a. Low interest loan to be provided when introducing energy efficiency equipment
   b. JICA's finance functioned as a catalyst role for the financial sector using the energy efficiency technology list which is shared by local finance institutions (reiterated).
   c. Other financial support: Planning future implementation

In addition to the sectors covered by EECMP, current status and issues on energy efficiency are analyzed on transport and agricultural sectors in the following sections for further expansion of future EECMP.

2. Industry Sector

2.1 Energy Consumption Trend

Energy consumption of the industry sector expanded 5.3-fold between 2000 and 2020 according to IEA as shown in Figure 2-1. Fuel consumption expanded 4.8-fold in the same period while electricity 6.3-fold. Natural gas is the single largest energy source comprising 43.4%, while coal consumption has been increasing in recent years. Consumption of petroleum products in the industry sector remains nominal. Energy intensity (industrial energy consumption in toe per industrial sector GDP in million US$ 2010) has stayed on an upward trend until 2010 and then leveled off. It turned downward in 2019-2020, while it is uncertain at present whether this is a temporary phenomenon due to the COVID-19 pandemic or reflecting energy efficiency efforts under the EECMP 2016; maybe both. At any rate, as seen in the irregular fluctuation in the graph, the IEA data may include considerable ambiguity.



Note: As no sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

Source: IEA World Energy Balances 2022

Figure 2-1 Industry Sector Final Energy Consumption

According to IEA data, the electricity share was 43% in 2020 which shows 20% in SREDA data (38% expressed in primary energy base) shown in the SREDA National Energy Balance Report. Figure 2-1 shows trends toward electrification and a slow down in gasification since the late 2000s. Therefore, energy-saving measures for electricity are considered important.

2.2 Main Policies and Programs in EECMP 2016

Under the EECMP 2016, EEC programs for the industrial sector has started introduction of better energy management and adoption of better equipment as below.

1) Energy Management System

- 150 Designation of large energy Consumers (DC: Designated large energy consumer) which was expanded from 113 DCs.
- Nomination of energy manager and energy auditor. 18 Certified Energy Auditors are nominated.

2） Sub-sector benchmark (Sub-sector energy intensity, production process energy intensity)

3） Designation of large energy consuming entities

"Large energy consuming entities" (DC) is designated by the government. This program sets energy consumption criteria for each target sub-industry to nominate DCs among industry energy users. DCs must establish the Energy Management System (EMS), which includes the following actions:

- Setting up EE&C target and establishing energy management team (group)
- Appointment of full-time energy manager
- Implementation of EE&C activities according to EE&C promotion plan
- Conducting energy audits according to the provision of energy audit regulation
- Following the EE&C target and certain criteria including benchmarks, minimum energy efficiency
- Standards and specific technology requirements
- Conducting training on EE&C activities for management and employees
- Accreditation of ISO 50001 is welcome. It will be recognized as the establishment of EMS

The starting targets on energy consumption criteria and the number of target entities are shown by sub-industry in Table 2-1. Once the program turns out successful, the criteria for DCs will be expanded to the target entity coverage.

Table 2-1 Energy Management Program

No.	Category	Criteria for DCs (Annual energy consumption toe)	Numbers of candidates for DCs
01	Chemical fertilizer factories	10,000	10
02	Paper and pulp industries	6,000	8
03	Textile industries: spinning, weaving, dyeing	3,000	15
04	Garments industries	3,000	7
05	Cement and linker grinding factories	10,000	14
06	Iron and steel (rerolling mills)	10,000	23
07	Chemical and pharmaceutical industries	6,000	9
08	Glass industries	6,000	5
09	Ceramic industries	6,000	9
10	Transportation terminals (including seaports, airport, stations)	3,000	2
11	Commercial and institution buildings (including office buildings, hotels, shopping malls, hospitals, educational facilities)	3,000	10
99	Other Industries and installations as published by government notifications	3,000	1
	Total		113

Total number of DCs was successfully expanded to 150DCs as of December 2022

Source: SREDA, based on EECMP 2016

Note: Mentioned above DC number was expanded from 113 to 150, sector based DCs. Sub sector information which shows annual energy consumption levels are same as of December 2022.

4) Energy Reports and Audit

Energy consumers will implement energy audits for their facilities periodically. DCs must submit energy audit reports to the Government (SREDA)[1]. The energy audit will be conducted by Certified Energy Auditors or, in case of large DCs, by Accredited Energy Auditors.

DCs should prepare annual energy reports and submit them to SREDA for evaluation. The annual energy reports will contain the following:

- Total energy consumption (by source of energy, i.e., fuel, heat and electricity)
- Name, outline, operating condition and modification of energy intensive equipment
- Energy efficiency and productivity level (related to output measured through the production volume (t))
- Energy intensity trend for 5 years

[1] As of December 2022, there is no available energy audit report.

- Identification of appointed energy manager
- Annual EE&C plan including the measures and annual targets, in case of submitted improvement target to SREDA ware not met, implementation plan for consecutive 2 years
- Medium term (36 months) EE&C plan including the measures and targets as shown

2.3 Overview of the current status

The Sustainable and Renewable Energy Development Authority (SREDA), established in 2014 is now given a clear mandate to contribute to energy efficiency and conservation and the reduction of foreign fossil fuel imports. The following is a summary and confirmation of some of these advantages, focusing on its master plans.

1) Expansion of Designated Energy Companies and its capacity building

As shown in Table 2-1, 113 DCs (Designed Companies) are listed in EECMP2016. According to the hearing in December 2022, SREDA has now listed 150 DCs, completed the selection of candidates by industry, and is steadily expanding the number of DCs. In addition, DCs themselves are learning the importance of EEC through SREDA's educational programs. This effort will widen the coverage of energy users cognizing importance of EEC and create a firm platform to promote it.

2) Energy Audit

EECMP 2016 has developed a program implementation plan, which indicates targeted coverage of energy management programs by sub-industry. In 2018, the Ministry of Environment, Forest and Climate Change (MoEFCC) submitted Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), which addresses global warming issues based on the above energy management plan with some updating as shown in Table 2-2.[2] It assumes:

- The level of energy efficiency improvements possible in each industrial sub-sector by 2030 (both for existing plants and for new plants); and
- The proportion of the sub-sector that would take up the energy efficiency measures by 2030.

In the work for this report, in addition to the low-resolution case as shown in the table, calculation was made for medium and high scenarios though they are not shown in the report. These trials will help understanding the direction of the efforts to be exercised on energy saving.

[2] MoEFCC “Third National Communication of Bangladesh to the UNFCC”

https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

Table 2-2 Target Coverage Ratio of Energy Management: Industry Sector

Sector	Average efficiency improvement from BAU (%)		% of sector undergoing energy audit by 2030	% of audited sector undertaking energy efficiency improvements by 2030			% of sector with new plants installed by 2030	
	Existing plant (following energy audit)	New plant		Low ambition scenario	Medium ambition scenario	High ambition scenario	BAU Scenario	Abatement scenarios
Cement	20	30	50	30	50	70	20	30
Fertilizer	7.5	15	50	30	50	70	20	30
Garments	8	12.5	30	20	30	50	20	30
Textiles	10	15	50	30	50	70	20	30
Steel	30	60	70	50	70	90	20	30
Pulp and paper	10	20	50	30	50	70	20	30
Tiles	15	30	30	20	30	50	20	30
Bricks	0	12	10	Not modeled because EE potential is 0	Ditto	Ditto	0	Low: 5 Medium: 10 High: 20
Frozen food	10	17.5	50	30	50	70	20	30
Chemicals	5	10	70	50	70	90	20	30
Jute	15	0	50	30	50	70	0	0
Other industries	10	10	50	30	50	70	20	30

Source: MoEFCC, The Third National Communication to UNFCCC

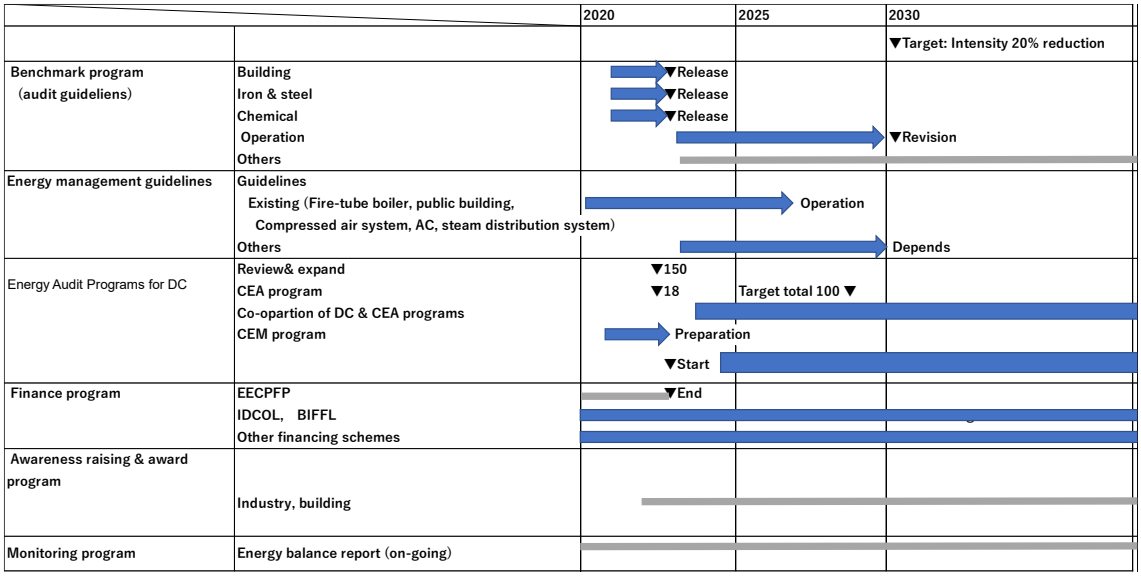
3) Benchmarking program

In General, the benchmark program is a system that sets target values for the large energy consuming sub-sectors with specific processes, such as steelmaking, cement, paper & pulp, soda chemical, etc., described in kgoe / tonoe of production (t) or floor area (m^2). Periodical energy consumption and production data may be reported to SREDA in an annual energy report. Factories which attained remarkable progress in energy efficiency improvement will be awarded by SREDA. The above mentioned benchmark and relevant technical information will be provided “Sector Based Guidance for implementation of energy audit by Certified Energy Audit”. Currently expert visiting programs are planned to be conducted.

4) Other energy saving actions

The textile industry of Bangladesh has developed its export competitiveness among the world market, and hence has achieved an advanced international certification scheme on EEC mentioned in the later part which is a good example from the private sector, including the textile sector.

In addition, the utility and chemical companies sub-sector that has significant EEC potential needs to attend EEC programs. The catalyst and leverage function of public finance are working effectively. Public and private financial institutions are making use of the energy conservation technology list. As of December 2022, 43 companies are awarded the loan, amounting to BDT 21 billion. The borrowers range from textile, cement, glass, electronics, and other sectors which contribute to EEC activities.



Source: SREDA

Figure 2-2 Target Realization Rate by Program

2.4 Case study on textile industry

Lack of indicators is a challenge for EECMP as well as to understand progress of sectoral implementation. Learning the practices experienced by the textile industry, which has become internationally competitive now, may help find solutions to overcome several challenges.

1) Current status of energy consumption

USAID (2018))[3] pointed out that the textile industry has the greatest potential for energy savings through the use of natural gas (process use) and electricity (grid and captive power generated). The textile industry could save almost 1.7 million tons by 2020.

There are likely to be around 45 factories, including planned plants until 2030 (Government of Bangladesh 2019, above). Of these, the energy management target aims to have about half of the DCs implement energy management.

Table 2-3 Energy consumption statistics in the textile industry

	Natural Gas		Electricity		Oil & Coal		Combined	
Sub-Sector	TOE	Share	TOE	Share	TOE	Share	TOE	Share
Garment	1,844	22.7%	221	6.3%	42	2.0%	2,107	15.4%
Textile	1,586	19.5%	92	2.6%	17	0.9%	1,695	12.4%

Source: Energy efficiency and conservation master plan 2016

[3] US AID (2018) promoting Energy Efficiency in Bangladesh

2) Implementation of Energy Saving Projects

a. Projects of Bangladesh Garment Manufacturers and Exporters Association (BGMEA)

According to the Bangladesh Garment Manufacturers and Exporters Association (BGMEA), a garment exporters association, in collaboration with IFC, schemes such as the Green Factory is introduced there[4]. In 2019, the Bangladesh RMG industry had 120 green buildings while more than 500 factories were in the pipeline to become a green status factory. They were: Platinum 29, Gold 79, Silver 11 and Certified 4. This is an excellent example of an advanced certification scheme.

b. Case Study of Toyota Energy Saving Loom[5]

The project involves introduction of air jet looms in weaving factories, which can simultaneously reduce energy consumption and increase production efficiency. At present, many rapier looms are prevalent in Bangladesh, and most of them are second-hand machines. The air-jet looms to be introduced are 15% more energy-efficient and about 1.8 times more productive than rapier looms, and can save about 53% of energy per weaving area.

c. Importance of focusing on dyeing boilers and the possibility of horizontal expansion to other industries (unconfirmed quotation)

Through interviews, it was found that some businesses in the textile industry include a "dyeing" process, which uses a higher proportion of heat than sewing only companies. In general, it was observed that the heating temperature of the boilers was excessive in some cases. The exact energy savings in Bangladesh have not been confirmed, but "to date we have achieved energy savings of 10-15%" according to the model cases[6].

It is also possible to manage the boilers remotely. This will potentially compensate for the lack of human resources for energy efficiency auditors. These boiler technologies can also be applied to other industries, and it is hoped that they will spread across industry boundaries.

2.5 Expectations on EEC policy in the industrial sector

Presently implementation of track progress of energy management, an indicator index shown in EECMP (table 1-2), is not publicly available. As a result, the proportion of energy management practices (as a percentage of energy consumption in table 2-4.) in the industrial sector is likely to be unknown.

4 BGMEA (2020) "BGMEA report SUSTAINABILITY REPORT 2020"
https://www.bgmea.com.bd/page/BGMEA_publishes_its_first_Sustainability_Report

5 Toyota Tsusho Corporation "Installation of High Efficiency Loom at Weaving Factory"
http://gec.jp/jcm/jp/projects/15pro_ban_01/

6 https://www.jase-w.eccj.or.jp/technologies-j/pdf/factory/F-36.pdf

1) Expectations for expansion of energy audits

In short of registered auditors who are essential for implementation of the Energy Management Program, an intensive capacity development program may be needed. It will enhance improved implementation with increased experts and specialists both in public and private sectors.

The above programs and action plans are progressively implemented as summarized below:

a. Large energy consumer designation

The listing of 150 companies is now successfully completed. SREDA plans to create certified private-sector Energy Managers with 3 days of compulsory training. In the first stage, it aims to satisfy the requirement for energy managers for 150 DCs also understanding the importance of implementation energy efficiency activity with monitoring data.

b. Energy Manager, Certified Energy Auditor and Accredited Energy Auditor

To date, there are 18 certified energy auditors (including SREDA member) who have passed the qualification. The problem of insufficient human resources should be solved with provision of additional training and registration of excellent staff (including foreign engineers) who engaged in actual energy management activities.

c. Energy audit (mandatory/voluntary)

Energy audits were implemented as a voluntary program in 2017 and a compulsory program in 2018, respectively. There is no information shared on implementation of detailed practices.

d. Energy consumption/Monitoring reporting (mandatory)

On reporting of energy consumption data (mentioned as mandatory MP2016), there is no publicly available information on based on DCs reporting and subsectors energy data consumption data other than “SREDA, Energy Efficiency Master Plan up to 2030”. Once the hurdle disappears, it would be easy to promote energy efficiency improvement, continuously.

Based on these efforts, energy efficiency indicators can be developed in combination with relevant indicators on sectoral activity data production, which will contribute to enhancing industrial power improvement.

e. Benchmarking

It is implemented as a survey/ preparation phase. In addition, EECMP mentions application of the minimum efficiency standards (MEPs standards) for energy saving, which may be applied to industrial facilities in energy intensive industries.

2) Other specific targets

a. Energy management for government related institutions

Currently, information on implementation is unknown.

b. Selection of energy managers and auditors.

Information on the implementation is unknown.

2.6 Next Step

1) Energy Management System

The system has started successfully, which needs to be monitored continuously through energy management systems in DCs base.

At present, there are 18 personnel including SREDA members holding Certified Energy Auditor. It was observed that seeds for energy efficiency and conservation are certainly growing, especially among experts.

National Energy Balance Reporting provides information on economy-wide progress on EECMP. DCs data collecting activity also contribute to monitoring the truck progress, which improves future EECMP activities.

2) Sector based solutions and expansion of energy-intensive factories and processes

The textile industry, which is the world's leading factory for textiles, has adopted an advanced certification program conducted by BGMEA, and it is hoped that other industries may follow suit, using this as a flagship project.

Project examples are available on the website, but those sharing information has future potential. There is a need to expand EECs and DCs for industries with high energy load with the energy conversion process such as electricity and gas utilities, and chemicals.

3) Human Resources

It is important, in addition to Certified Energy Auditors, to encourage activities of excellent staff through an expert registration system. An award system for excellent staff by sector would honor and encourage improving energy efficiency activities; it can also be used as a knowledge sharing platform. Furthermore, it is important to implement diagnosis projects by certified energy assessors and excellent staff (including foreign engineers) to (1) build up a monitoring database and (2) accumulate technical know-how.

4) Awareness and Involvement, catalyst role of finance

For wider awareness and promotion, it will be helpful to create a list of technologies that contribute to energy efficiency and conservation (Best Available Technologies) together with

information on available finance.

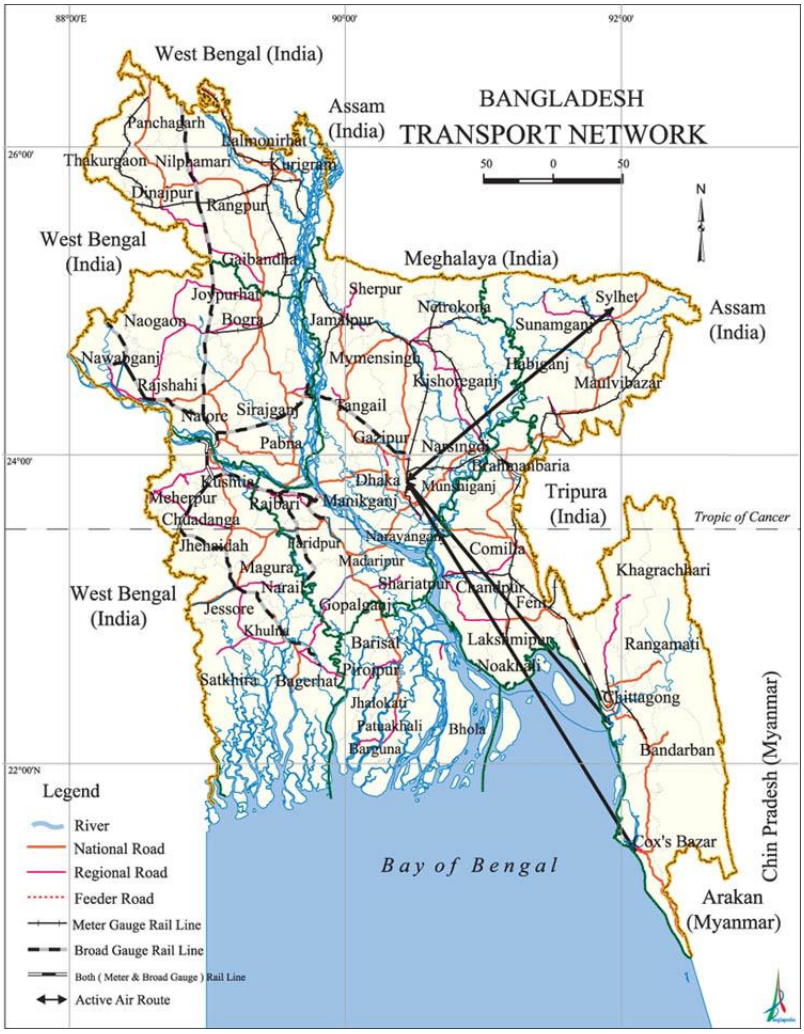
SREDA may disseminate this information to other relevant ministries, energy experts and auditors of energy intensive sectors and other stakeholders with financial institutions.

Based on these efforts, energy efficiency improvement can contribute to enhance industrial power improvement in future.

3. Transportation Sector

3.1 Transportation Sector Overview

Due to its flat land and abundant rivers, Bangladesh has historically developed with water transport as the primary mode of transportation, with the total distance of water transport being 13,000 km (700 rivers). With construction of bridges and roads along with economic development, there has been a shift to land transportation going on since the 1990s. In terms of railroads, the total track length expanded to 2,892 km, and the number of railway stations reached 517 by 1985. However, the abundance of canals hindered construction and maintenance of the rail infrastructure. In the 1980s, several lines were discontinued, and the total track distance was 2,855 km in 2011 and 440 stations in 2007. On the other hand, since the 1990s, road construction has been actively carried out, and road transport services have expanded greatly, with a total road length of 375,353km in 2020 and registered vehicles of 4.3 million units as of 2019.



(Source) National Encyclopedia of Bangladesh

Figure 3-1 Bangladesh Transport Network Overview

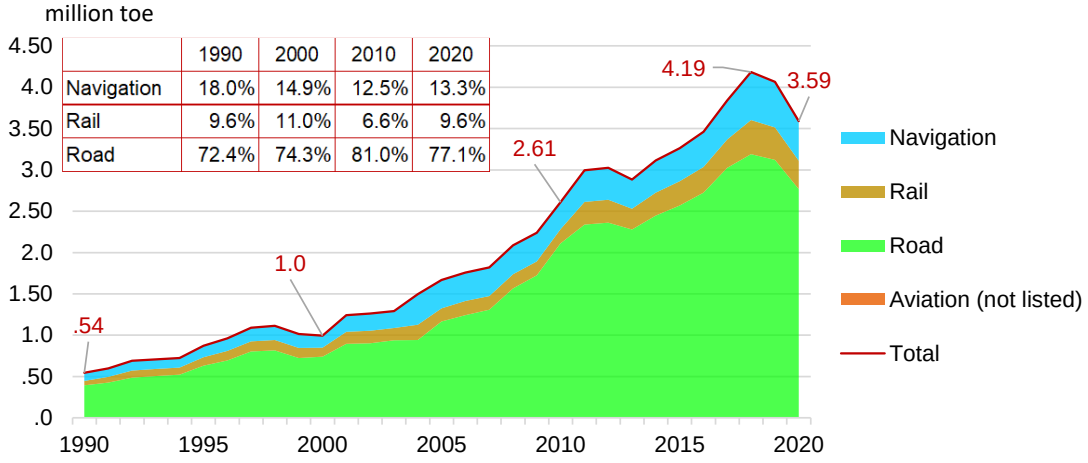
3.2 Energy consumption in transport sector

As shown in Figure 1-1 (Chapter 1), energy consumption for transport is relatively small in Bangladesh. It was only 5.0 % of the total final energy consumption in 1990. It has increased to 12.0% in 2020 but is lower than the composition of the industry sector that increased from 8.9% to 29.0% in the same period.

Figure 3-1 shows the energy consumption by energy sector. Road transportation dominates among sectors having been around 75-80% in recent years. With abundant river transport, fuel consumption for navigation has increased steadily. This is partly because the number of bridges crossing large rivers is limited, while river transport is cheaper and convenient. In view of the significance of the road sector with multiple types of vehicles, higher priority may be given in consideration of energy conservation. On the other hand, it should be noted that energy efficiency will be mostly fixed at the time of constructing infrastructure such as railways and port facilities.

Aviation fuel consumption is not recorded in the IEA statistics.

According to development economics theory, demand for automobiles generally increases with economic growth. Moreover, in view of the significance of the road sector with mixture of multiple types of vehicles, higher priority may be given in consideration of energy conservation. In summary, as the country becomes more affluent, the number of automobiles owned is expected to increase. For this reason, this chapter focuses on energy conservation especially for automobiles, which requires urgent measures.



	1990	2000	2010	2020
Navigation	18.0%	14.9%	12.5%	13.3%
Rail	9.6%	11.0%	6.6%	9.6%
Road	72.4%	74.3%	81.0%	77.1%

Note: As no sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

Source: IEA, World Energy Balances 2022

Figure 3-2 Transportation Sector Energy Consumption

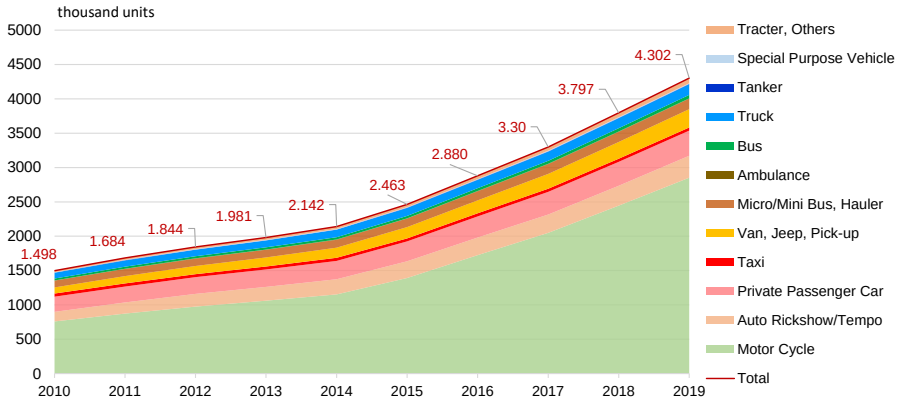
3.3 Road sector energy consumption

The number of road transport vehicles in Bangladesh increased 2.9-fold from 1.5 million units

in 2010 to 4.3 million units in 2019 at an average annual rate of 12.4% as shown in Table 3-1 and Figure 3-3. Being easy mobility, motorcycles have increased 3.8-fold in the same period. Together with rickshaws, the share of small vehicles exceeds 70%. On the contrary, the number of light duty vehicles such as passenger cars, taxis and vans is still low at 676,488 units in 2019. The number of heavy-duty vehicles such as buses and trucks was 380,443 units. Vehicle ownership was 26.4 units per 1,000 people in 2019, but it was 6.9 units if motorcycle and rickshaws are not included. Presently most motor vehicles are imported.

Table 3-1 Number of Registered Vehicles by Types in Bangladesh

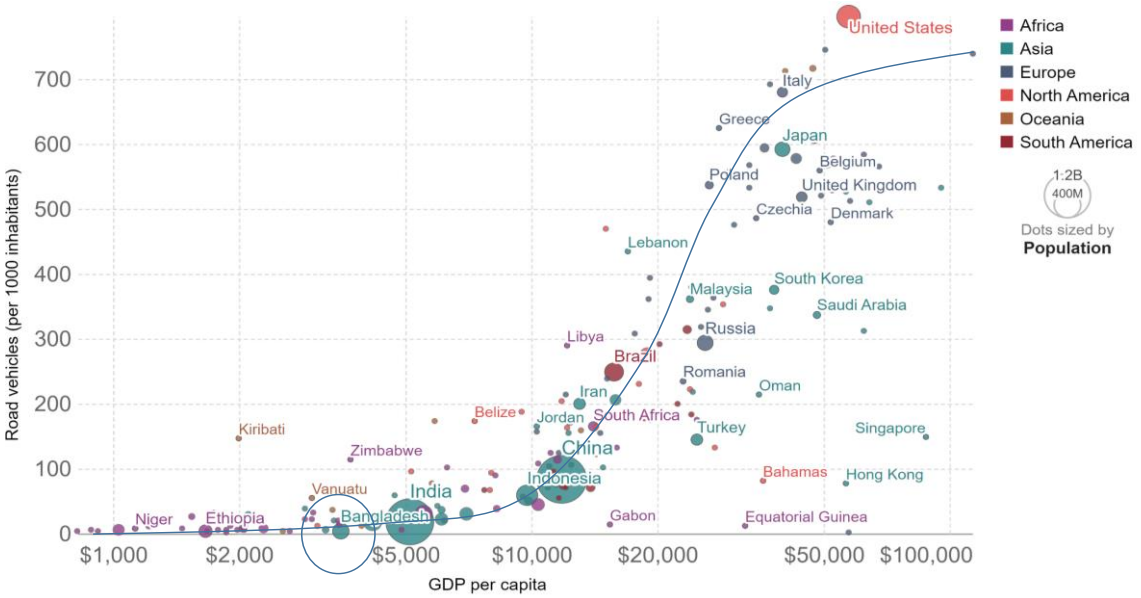
	Number of Vehicles			Composition			2010 to 2019
	2010	2015	2019	2010	2015	2019	
Motor Cycle	759,257	1,392,312	2,852,468	50.7%	56.5%	66.3%	15.8%
Auto Rickshow	141,029	243,382	320,119	9.4%	9.9%	7.4%	9.5%
Car/Taxi/Van	354,979	498,384	676,488	23.7%	20.2%	15.7%	7.4%
Bus/Truck/SPV	221,062	288,747	380,443	14.8%	11.7%	8.8%	6.2%
Tractor, Others	21,917	40,473	72,078	1.5%	1.6%	1.7%	14.1%
Total	1,498,244	2,463,298	4,301,596	100.0%	100.0%	100.0%	12.4%
Per 1000 people	10.2	15.8	26.4				11.2%



Source: Bangladesh Bureau of Statistics (BBS), "Statistical Yearbook Bangladesh 2020", May 2021

Figure 3-3 Number of Registered Motor Vehicles

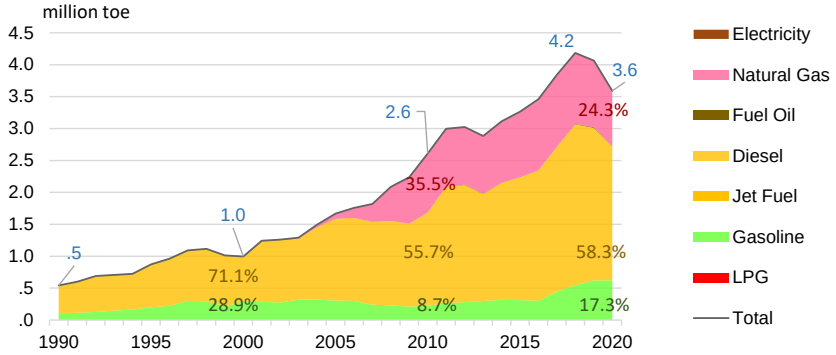
As shown in Figure 3-4, Bangladesh is still in an early stage of motorization with motor vehicle ownership of 26 units per 1,000 people in 2019. People start to spend more on mobility as their income increases. According to world history, many countries have experienced steep increases in motor vehicles when the per capita GDP exceeds US$ 10,000 except for Singapore and Hong Kong where extremely strict regulations were set because of their limited land space. Bangladesh would not be an exception and must establish an appropriate plan to cope with this trend.



Source: Chart created by the Study Team form Our World in Data

Figure 3-4 Road Vehicles per 1000 Inhabitants vs GDP per capita, 2014

Figure 3-5 shows the energy sources of road transportation. CNG was introduced around 2005 and its use rapidly spread among light duty vehicles such as passenger cars, taxis and rickshaws. Because of this, gasoline demand growth has been kept minimal, but started to increase around 2017 due to a shortage of natural gas supply. At present, consumption of diesel for buses and trucks dominates in the road sector.



Note: As no sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

Source: IEA, World Energy Balances 2022

Figure 3-5 Energy Consumption in the Road Transport by Fuel Type

3.4 Energy Efficiency Improvement Plan for Road Transport

As shown in Figure 3-4, rapid conversion of oil-based vehicles to compressed natural gas

(CNG) was implemented in the late 2010s, especially in Dhaka. Bangladesh's air quality strategy[7] also points out that the most harmful outdoor pollutants of concern are fine particulates and PM2.5 precursors such as SO_2 (from high sulfur diesel). Wadut et al (2012)[8] states that while the major air pollutants in Dhaka are under the national ambient Air Quality Standards (AQS), PM2.5 is significantly above the standards. For example, the annual average concentrations of PM2.5 and PM10 in Dhaka are about 80.4134 μ g/m3and 134 μ g/m3, respectively. In addition, the annual ambient AQS for these two pollutants are about 15 μ g/m3and 50 μ g/m3, respectively. Air pollution is even worse during the dry winter months when significant seasonal sources of pollution become active; many brick kilns around Dhaka and elsewhere in the country operate only during the winter months. The report points out that the primary source of particulates in Dhaka's air is automobiles, followed by emissions from brick kilns in the winter months. This serious air pollution situation has led to a policy shifting to natural gas vehicles.

On the other hand, recent trends show that conversion to electric driving is expected to become a significant industry in Bangladesh as well as to natural gas vehicles. According to the "Automotive Industry Development Plan 2020[9]" of the Bangladesh Ministry of Industry, Bangladesh aims to become a regional market hub for energy-efficient vehicles (EEVs) through strategic investments and introduction of high-performance vehicles and to introduce high technology to the domestic market in Bangladesh by 2030.

EEVs are defined here as fuel-efficient internal combustion engine (ICE) vehicles, hybrid vehicles (HV), electric vehicles, and alternative fuel vehicles (CNG, LPG, biodiesel, ethanol, hydrogen, fuel cells, and the others) that meet certain specifications in terms of carbon emissions and fuel consumption. Table 3-2 shows the fuel efficiency classified as EEV.

Under the plan, the government will introduce more attractive tax incentives and exemptions for investors who assemble EEVs, regardless of whether they have factories outside the Economic Zone (EZ). In addition, it will introduce import duty and VAT relief measures to encourage local assembly of EEVs by issuing individual notices (SROs). It will also introduce a tax rebate scheme for assemblers and parts/components producers on expenditures for R&D activities (in-house or outsourced), including acquisition of new technologies for EEVs, as well as new technologies related to high-efficiency batteries, charging stations, low emission and fuel-efficient (electric vehicles). The government will establish a "Technology Acquisition Fund" to promote investment in R&D and acquisition of commercially viable technologies such as batteries, charging stations, and electric vehicle development.

[7] Wadud, Z.; Ali, A. *Air pollution Reduction Strategy for Bangladesh*; Final Report to the Department of Environment, Bangladesh University of Engineering and Technology: Dhaka, 2012.

[8] Zia Wadud and Tanzila, *"Khan Air Quality and Climate Impacts Due to CNG Conversion of Motor Vehicles in Dhaka, Bangladesh,* "Environ. Sci. Technol. 2013, 47, 24, 13907-13916, November 6, 2013

[9] Ministry of Industries Government of the People's Republic of Bangladesh "Automobile Industry Development Policy, Ministry of Industries Government of People's Republic of Bangladesh

Table 3-2 EEVs Fuel Efficiency Standards

a) For Passenger and Commercial Vehicles

Segment	Description	Kerb Weight (Kg)	Fuel Consumption (L/100km)
A	Micro Car	< 800	4.5
	City Car	801 – 1,000	5.0
B	Super Mini Car	1,001 – 1,250	6.0
C	Small Family Car	1,251 – 1,400	6.5
D	Large Family Car	1,401 – 1,550	7.0
	Compact Executive Car		
E	Executive Car	1,550 – 1,800	9.5
F	Luxury Car	1,801 – 2,050	11.0
J	Large 4x4	2,051 – 2,350	11.5
Others	Others	2,351 – 2,500	12.0

b) For Three Wheelers

ENGINE SIZE (cc)	Fuel Consumption (L/100KM)
151 – 250	2.5-3.0
251 -400	3.0- 4.0

From the perspective of the country's overall economic development, the transportation sector has become one of the most important objectives in PP Vision 2021 (Bangladesh Vision 2021)[10]. The transportation infrastructure, including roads and bridges, has been substantially improved since then. For example, private sector participation in air transportation has expanded significantly, and most major cities are now connected by air. In addition, Bangladesh's first elevated railroad, MRT Line 6, is currently under construction. Three more MRT lines (Line-1, Line-5 North, and Line-5 South) are also planned for construction.

Along with these developments, the government has been promoting private sector participation in construction of transportation service infrastructure and sustaining transportation system through introduction of user fees and charges. The Vision emphasizes coordinating of multimodal transportation, developing national roads, improving inter-city and inter-regional connections, reducing cost of trade logistics, and improving asset maintenance of the transportation network. This was relayed to its successor, PP Vision 2041 (Making Vision 2041 a Reality: PERSPECTIVE PLAN OF BANGLADESH 2021-2041)[11] developed in 2020. PP Vision 2041 emphasizes prioritization of roads to accelerate economic growth, and in the 8th Five-Year Plan (2020-2025), construction of two-lane rural roads totaling 16,000 km of is planned as climate resilient roads. In addition, the urban transport development strategy of PP 2041 as shown in Table

[10] http://cpd.org.bd/wp-content/uploads/2007/08/Bangladesh-Vision-2021-English.pdf
[11] http://oldweb.lged.gov.bd/uploadeddocument/unitpublication/1/1049/vision%202021-2041.pdf

3-3 aims at improving convenience, safety, and economic efficiency of the people and have the synergistic effect of contributing to energy efficiency improvement.

Table 3-3 Strategies for Urban Transport Development in PP Vision 2041

The main objective of urban transport strategy will be to support sustainable urban development. The strategy for urban transport would aim at improving transport and traffic infrastructure so as to meet existing and potential demands, and developing an integrated and balanced system in which all modes (motorized and non-motorized) can perform efficiently and each mode can fulfil its appropriate role in the system. The main elements of an urban transport strategy are:
● Provision of mass rapid transit (MRT/Metro Rail), both elevated and underground rail, initially in Dhaka City and adjoining areas and eventually extended to all metropolises.
● Provision of Bus Rapid Transit (BRT) that is characterized by dedicated lanes for rapid movement of buses for all divisional cities.
● Creating special lanes for pedestrians and cyclists.
● Promoting high efficiency and alternative fuel vehicles.
● Introduce Intelligent Transportation Systems (ITS) initially in Dhaka and then extend to other metropolises. The major application areas of ITS technology include electronic road pricing, traffic management, integrated ticketing systems for different public transport modes, and traveller information. By 2031, all the major cities and the national highway networks of Bangladesh should be brought under Intelligent Transportation Systems.
● Strengthening linkages with cities and towns around Metropolitan Areas through bus rapid transit (BRT) and mass rapid transit (MRT/Metro Rail). The emphasis would be placed on coordinated development of land use and transportation planning in order to facilitate access to such basic necessities as workplaces and socio-economic facilities
● Commercial parking facilities will be encouraged through private investment. All parking regulations will be strictly enforced with penalties for non-compliance.
● Time of day use restrictions will be introduced in heavily congested roads. Consideration will be given to introduce entry fee during peak hours for heavily travelled roads.
● The emphasis would be given on the introduction of pedestrian roads in Dhaka City and then extend to other Metropolises.

(Source) Making Vision 2041 a Reality: PERSPECTIVE PLAN OF BANGLADESH 2021-2041

3.5 Future Direction

Under the PP2041, Bangladesh plans to promote transportation sector infrastructure development and safe transportation toward 2041, which will simultaneously contribute to efficient energy consumption in the transportation sector. From the viewpoint of an energy conservation policy, another priority area is improvement of the energy efficiency of automotive vehicles, which are expected to increase rapidly as the economy develops.

With ample domestic natural gas production, use of cleaner natural gas vehicles was promoted proactively in the 2000s to cope with air pollution. In the coming decades, the number of automotive vehicles will increase rapidly along with economic development; simultaneously

people may shift from two-wheeled motorcycles to four-wheeled vehicles. On the other hand, Bangladesh is facing a decline in domestic natural gas production, which peaked in 2015, while experiencing gas demand growth in other sectors. Against this backdrop, Bangladesh intends to challenge the improvement of vehicle fuel efficiency and expansion of EEV to a broader scope as explained in Section 3.3. At the same time, CNG as motor fuel will no more be recommended proactively as additional fuel needs to be sourced from imported LNG. Electric Vehicles (EVs) will be promoted, instead.

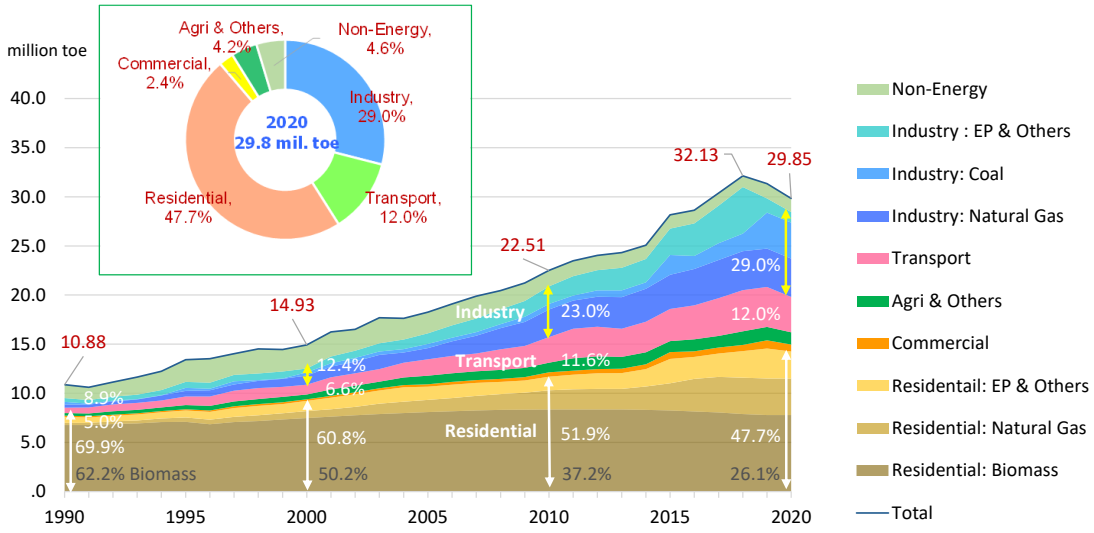
As mentioned above, Bangladesh has a plan to grant preferential treatment of technologies for high-efficiency vehicles and construction of recharging stations as a part of its industrial strategy. Policies to disseminate these technologies are also important to push the program forward. In particular, shifting from low-efficiency vehicles to high-efficiency ones should be effectively achieved mobilizing financial incentives to owners, such as subsidies and preferential vehicle registration taxes. Setting regulations on automobile fuel efficiency standards and making them visible to consumers through a labeling program will also contribute to penetration of energy efficient vehicles.

In view of the historical precedence in foregoing developing countries, an increase in the number of motor vehicles will be inevitable as the Bangladesh economy grows. Although present car ownership ratio is low, it will expand at an explosive pace. These efforts will keep the increase of motor fuel demand as reasonably low as possible.

4. Residential and Commercial Sector

4.1 Energy Consumption Trends

According to the IEA statistics, residential sector energy consumption dominates in Bangladesh, though its share reduced below 50% in 2020 as shown in Figure 4-1. On the other hand, the share of commercial sector energy consumption was only 2.4% in 2020. As discussed below, estimation of the commercial sector energy consumption is unstable and dubious. Biomass consumption of mainly firewood is listed only for the residential sector. Its share in the total demand has declined from 50.2% in 2000 to 26.1% in 2020 with the penetration of modern energy such as natural gas for cooking and electricity for lighting and appliances.



Source: IEA World Energy Balances 2022

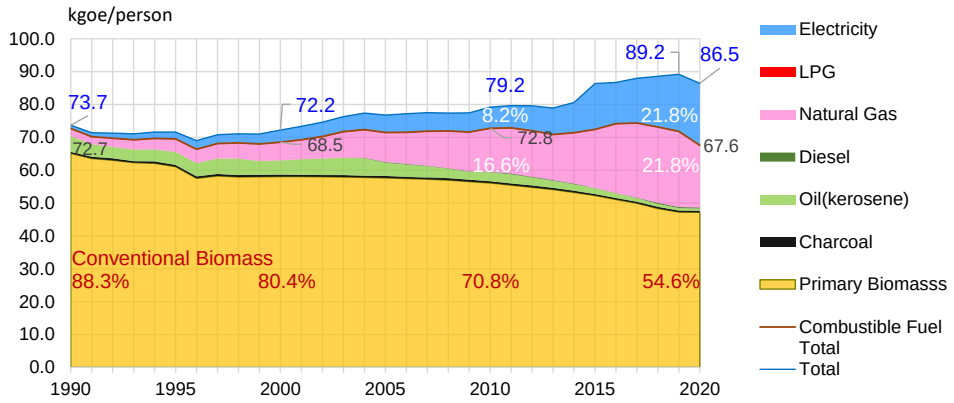
Figure 4-1 Trends of Final Energy Consumption by Sector

1) Residential Sector

In the residential sector, energy is generally used in units of families. Since reliable statistics on the number of family members is not available, per capita energy consumption is adopted as shown Figure 4-2. In recent years, share of traditional biomass such as firewood has been declining while consumption of city gas and electricity is increasing.

Nevertheless, biomass consumption in 2020 comprised 54.6% of the total energy consumption and 69.8% of the fuel consumption in the residential sector. There is still a big room to be replaced with modern fuels. Charcoal consumption, which generally increases the urbanization process of developing countries, is very limited in Bangladesh as the city gas system in the urban areas was developed in the 2000s utilizing domestic natural gas. However, as discussed in the natural gas supply sector, its management system is obsolete and problematic. LPG has started to penetrate but still remains at a small quantity. Electricity consumption is still low compared to the global average, but is expected to grow rapidly accelerated by the introduction of electric appliances.

As firewood for cooking and hot water is switched to modern energies such as gas and electricity, substantial improvement will occur in energy efficiency. It is always difficult to estimate biomass consumption in developing countries, but reduction in biomass consumption with traditional stoves and increase in electricity demand will become the main trend in the residential energy consumption in Bangladesh. This will keep growth of the overall energy consumption relatively low.



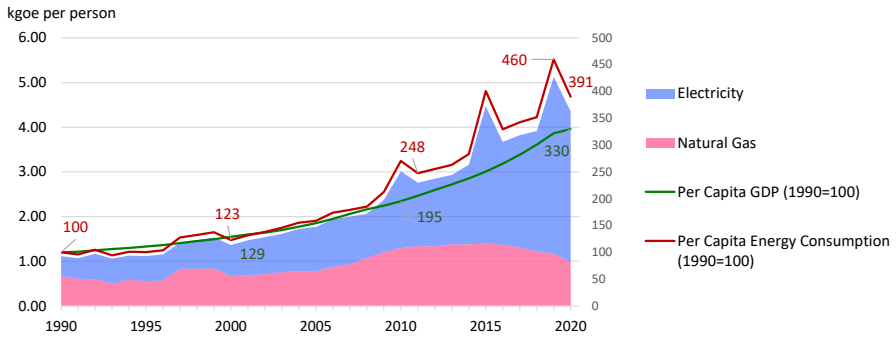
Note: As no sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

Source: IEA World Energy Balances 2022

Figure 4-2 Residential Sector Energy Consumption per Capita

2) Commercial Sector

As an index of energy efficiency for the commercial and public services sector, energy consumption per floor space is generally used. However, due to constraints on available statistics, sector's energy consumption per capita is illustrated in Figure 4-3. The IEA statistics says that the commercial sector energy consumption is only 2.4% of the total final consumption, where only natural gas and electricity were listed neglecting charcoal, LPG and diesel. These may have been estimated by some conventional method as explained in Section 1.1. Along with economic development, electricity consumption is expected to grow robustly as observed in foregoing emerging countries.



Note: As no sectoral time-series national data is available, this MP including Appendix uses the IEA data instead.

Source: IEA World Energy Balances 2022

Figure 4-3 Commercial Sector Energy Consumption Per Capita

4.2 Overview of EEC policies

The EEC programs for the residential and commercial sectors under the EECMP2016 mainly comprises adoption of high efficiency appliances and buildings as summarized in Table 4-1. As shown in Figure 1-4 in Chapter 1, it plans for the residential sector to introduce high efficiency appliances by 2020 and changes the target to introduce the highest efficient appliances by 2030. It also plans for buildings to achieve global best energy intensity by 2025.

With an assumption that all the existing home appliances will be replaced by higher efficiency products, it estimates that EEC potential is 28.8% in the total energy consumption in the residential sector and 10% EE&C potential for buildings. The EEC potential for buildings is relatively low compared to the residential sector because of it's EEC measures that are not easy to introduce with new equipment in existing buildings. To achieve these EEC targets, EECMP2016 has set the EE Labeling Program for the residential sector and EE Building Program for buildings.

Table 4-1 EE&C Programs for residential and commercial sector in EECMP2016

Program	Target	Action Plan
EE Labeling Program (EELP)	Residential Consumers	■ Label certification / Laboratory accreditation system ■ Standardization of EE measurement method and Star Label Rating criteria ■ Star Label Standardization (Unification) ■ Participation of manufactures, importers and retail shops (mandatory/voluntary) ■ MEPS (Minimum Energy Performance Standard)
EE Building Program (EEBP)	Buildings	■ New version of BNBC [Revised] Implementation ■ GBG development ■ Manual and assessment system introduction

Source: Energy Efficiency and Conservation Master Plan 2016

4.3 EEC Policies for Residential Sector

To enhance energy efficiencies in the residential sector, Energy Efficiency Standards and Labelling (EES&L) programs are the most popular policies to achieve the target by promoting sales of high efficiency products in the market. EES&L programs for appliances and equipment are now adopted in more than 120 countries around the world[12]. IEA (2022) estimated annual reduction in electricity consumption from standards and labelling programs analyzing nine countries such as the United States (US), the European Union and China for which data were available. It is estimated to deliver annual reductions of around 15% of the present electricity consumption. It is expected that this percentage increases each year as more of the older, less-efficient stock is replaced with equipment that meets new higher efficiency standards.

Table 4-2 Current Status of EES&L Implementation

Sl. No.		EE standard	2021	2022	2023	2024	2025	2026	2027	2028
1	Room Air Conditioner	enter into force			Voluntary			Mandatory		
2	Refrigerator, Freezer	enter into force			Voluntary			Mandatory		
3	Electric Fan	enter into force			Voluntary			Mandatory		
4	Electric Lamp/Light	enter into force			Voluntary			Mandatory		
5	Three-Phase Induction Motor	enter into force				Voluntary		Mandatory		
6	Electric Water Heater	enter into force				Voluntary		Mandatory		
7	Television Set	enter into force				Voluntary		Mandatory		
8	Microwave Oven	under development					Voluntary		Mandatory	
9	Water Pump	under development					Voluntary		Mandatory	
10	Induction Cooker	under development					Voluntary		Mandatory	
11	Inverter	under development					Voluntary		Mandatory	
12	Rice Cooker	under development						Voluntary		
13	Blenders/ Mixture	under development						Voluntary		
14	Washing Machine	under development						Voluntary		
15	All kinds of Water Pump (More than 2 Horsepower)	under development						Voluntary		
16	Transformer	under development						Voluntary		
17	Iron Machine	under development						Voluntary		

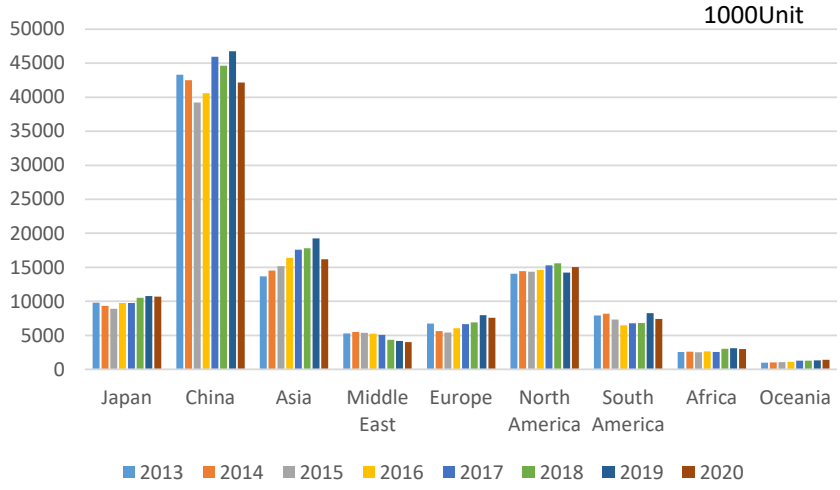
Source: SREDA

The overall structure and program design of EES&L program is prepared by SREDA as the

[12] IEA (2022) Achievements of Energy Efficiency Appliance and Equipment Standards and Labelling Programmes https://iea.blob.core.windows.net/assets/996ea40e-e010-48c3-ab53-9b4f72ddc815/AchievementsofEnergyEfficiencyApplianceandEquipmentStandardsandLabellingProgrammes.pdf

current status is summarized in Table 4-2. The Bangladesh EES&L policy is featured to introduce a voluntary system first and then convert it to a mandatory system. The voluntary labeling program is scheduled to be implemented for four items such as lighting (LED), refrigerators, air conditioners, and ceiling fans starting in 2023, with plans to expand the number of items covered by the labeling program in stages thereafter.

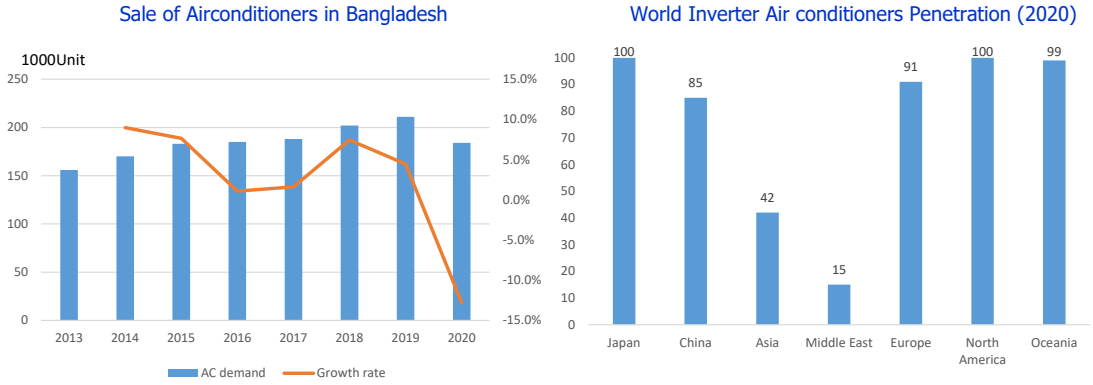
It is necessary to accelerate introduction of EES&L program and/or shift to mandatory scheme soonest possible, focusing on home appliances with large power consumption such as lighting, TVs, refrigerators and air conditioners. In Bangladesh, free CFL distribution programs were carried out to demonstrate the benefits on energy and cost saving. Consumers are now encouraged to use further energy efficient lights like LEDs, though LED promotion policy has not yet been implemented.



Source: JRAIA (The Japan Refrigeration and Air Conditioning Industry Association) data

Figure 4-4 Global demand for air conditioners from 2013 to 2020

Figure 4-4 shows the global demand for air conditioners from 2013 to 2020. The world demand for air conditioners in 2020 is estimated to reach 107.45 million units. The largest market is China, whose demand reached 42.14 million units. The second largest market is Asia, whose demand reached 16.20 million units. Bangladesh's 2020 air conditioners demand was 1.84 million units. Although the air conditioners market in Bangladesh is still small compared to neighboring Asian countries, the demand is growing steadily. Penetration of inverter (variable speed) air conditioners is about 15-30%, which are more energy efficient than non-inverter (fixed speed) air conditioners, while it is 42% in the Asian market.



Source: ibid.

Figure 4-5 Air Conditioner Penetration in Bangladesh and World

Actions to accelerate policy implementation

Table 4-3 summarizes the actions that should be taken as soon as possible according to the EES&L implementation procedures.

In order to ensure reliability of the EES&L program, it is essential to develop testing laboratories that can accurately test the energy-saving performance of equipment. If it takes time to develop such laboratories domestically, international third-party testing laboratories can be utilized through bilateral or multilateral Mutual Recognition Arrangement (MRA) schemes. Also, it is important to create a database of energy efficiency information on equipment provided by manufacturers/importers participating in the program; these data are valuable information for the next revision of the EES&L. Data can be collected efficiently, for example, providing a website for program participants to register themselves. Compliance tests such as periodic market buy-up tests should be conducted to ensure the credibility of the system, while such testing should be conducted by third-party laboratories.

Table 4-3 Actions to Accelerate EES&L Policy Implementation

	Program Operation Procedure	Actions for Implementation
1)	Manufacturers/importers get EE test on their products at accredited laboratories.	EE test laboratories should be ready and also accredited by BAB.
2)	Accredited laboratories should have been accredited by BAB through ISO17025, etc.	
3)	Manugfacturers/importers which have in-house laboratories can get EE test at their laboratories, provided laboratories are accredited by BAB.	
4)	Label certification body evaluates the EE test report and issue lable cetificates on the product with star rating, and delivers it to the manufacturer/importer.	Implementing agency/Label certification body collect necessary EE data.
5)	Manufacturers/importers affix the label on the products or their packages, and deliver them to the markets.	
6)	Label certification body carry out EE check test for the products sold in the market collecting samples at random, in order to maintain labels reliability.	Check test should be done by third party EE test laboratories.
7)	Anybody can claim challenge test to the label certification body, provided the test cost is backed by him/her.	

Source: SREDA

Introduction of EES&L in Bangladesh is delayed due to a lack of the manpower at the implementing agency, SREDA, etc., as well as a lack of necessary market data. As it has been pointed out, development of testing laboratories is essential for speedy implementation of the system and its effectiveness. The importance of this policy should be reaffirmed at the government level leading to provision of necessary supports.

4.4 EEC Policies for Commercial Sector

Major EEC policies applied to the commercial sector are as follows.

1) The Dhaka Mahanagar Imarat Nirman Bidhimala (2008)

The Dhaka Mahanagar Imarat Nirman Bidhimala -2008 mainly refers to the building set back, floor area ratio, maximum ground coverage, and mandatory open space. They are mostly passive approaches to reduce energy use in buildings. Buildings are not regulated or inspected for any active energy or water saving measures to reduce consumption.

2) Bangladesh National Building Code (BNBC)

The Bangladesh National Building Code (BNBC) is mandatory and the legal document for building construction firms and owners, architects, engineers, etc. It provides regulation and/or minimum requirement on building type (office, residence, commercial building, etc.), size (height, floor area), structure strength, indoor condition, construction material, etc. The BNBC was first published in 1993 to regulate construction of buildings and maintain and uphold them to certain standards. It remained unchanged for many years. Recently BNBC 2017 was amended (1) for the introduction of new materials, methods, and technologies in both design and construction of buildings and (2) to cope with increasing cases of safety hazards such as fires resulting from negligence in construction and flagrant violation of the code in some cases. The updated version of BNBC published in 2020 is proposed with the addition of energy efficiency requirements on buildings. It is expected to have a massive impact on construction practices. However proper enforcement and compliance check of the code is key to successful implementation.

3) Leadership in Energy and Environment design (LEED) Certification

USGBC LEED is a widely accepted rating system and is popular in Bangladesh. It is becoming a popular rating system for high-end commercial buildings and compliance textile factories. More than 100 buildings are already registered under the USGBC LEED certification. Bangladesh Bank is promoting energy efficiency in buildings with soft loan facilities under their refinancing scheme. Single digit loan (maximum 9%) facilities are available for LEED certified factories.

4) The Building Energy Efficiency & Environment Rating (BEEER)

Presently there is no designated green building rating system for Bangladesh. In line with EECMP2016, SREDA has developed Building Energy Efficiency & Environmental Rating

program (BEEER). The first draft was issued in November 2017. After the stakeholder consultation meeting of January 2018, the second revised draft was prepared. It is based on certain baselines and calculation procedures in order to evaluate their impacts and to compare them. The rating system is designed as a holistic approach to green buildings taking account of the entire environmental footprint of buildings (e.g., water, waste, resources). SREDA is preparing for implementation by conducting evaluations of the 11 selected buildings and plans to begin implementation in 2023.

With an aim of achieving net-zero annual primary energy consumption of non-residential buildings, net Zero Energy Building (ZEB) initiatives are being developed. ZEB uses a combination of energy efficiency and renewable energy. BEEER and ZEB are the main tools for energy savings in commercial buildings, and their integration into one scheme needs to be considered toward 2030. To further promote energy saving efforts, a multifaceted approach is needed to enable the benefits to be reaped. Various collaborative actions such as promotion, raising awareness on pay-back periods, creating technical expertise and easing access to affordable finance need to be reflected in the forthcoming regulations. In the past few years, many initiatives have been proposed by policymakers and financial organisations. The biggest challenge, however, is that implementation of these policies is slow.

5. Agricultural Sector

According to SREDA, the final energy consumption of the agricultural sector of Bangladesh was 1,103 ktoe in FY 2019-2020[13], which was 4.1%of the total energy consumption. Among them, diesel comprised 85.3%, followed by electricity at 12.0% and natural gas at 2.7%. The power consumption of irrigation pumps is mainly responsible for power peaks during irrigation season.

Table 5-1 Final Energy Consumption by Sector (FY2019-2020)

	Gas	Petroleum Products	Coal	Electricity	Total	
	ktoe	ktoe	ktoe	ktoe	ktoe	
Agriculture	30	941	0	132	1,103	4.1%
Commercial	176	72	0	707	955	3.5%
Residentail	3,506	1,090	0	3,107	7,703	28.4%
Transport	954	3,360	0	0	4,314	15.9%
Industry	5,556	400	3,900	3,208	13,064	48.1%
Total	10,222	5,863	3,900	7,154	27,139	100.0%
Composition						
Agriculture	2.7%	85.3%	0.0%	12.0%	100.0%	
Commercial	18.4%	7.5%	0.0%	74.0%	100.0%	
Residentail	45.5%	14.2%	0.0%	40.3%	100.0%	
Transport	22.1%	77.9%	0.0%	0.0%	100.0%	
Industry	42.5%	3.1%	29.9%	24.6%	100.0%	
Total	37.7%	21.6%	14.4%	26.4%	100.0%	

Note: Excludes biofuels and waste

Source: SREDA

Energy is mainly used for irrigation pumps and agricultural machinery such as tractors. Diesel and electricity are the main energy sources.

In FY 2018-19, there were 1,243,507 units of diesel driven pumps and 338,847 units of electric pumps applied for deep tube wells (DTW), shallow tube wells (STW) and low lift pumps (LLP); 79% of them were diesel driven. In order to reduce diesel consumption, Bangladesh is promoting the use of PV driven pumps.

As a short-term measure to promote energy conservation in the agricultural sector, introduction of energy efficiency standards and labeling will be beneficial. SREDA is planning a labeling program on pumps to start a voluntary system in 2023 and compulsory regulation from 2025. It expects that the replacement of old pumps with high efficiency pumps will progress. At the same time, switching from diesel to electricity is important. It will also be effective to introduce independent PV systems

[13] National Energy Balance 2019-20
(http://sreda.portal.gov.bd/sites/default/files/files/sreda.portal.gov.bd/page/7290ddb4_a205_41a9_a6a0_1436a56b7329/2022-01-10-08-19-2494fb13f3052bc231716a54e36fdaae.pdf)

into irrigation pumping to cut down the daytime peak demand for the grid.

In the middle to long run, a comprehensive irrigation plan may be considered with introduction of high efficiency pumps, optimization of pump distribution with appropriate capacity and optimal operation of them. Eventually, construction of a nationwide irrigation network system may be considered to establish safe and efficient use of water resources with low-carbon clean energy.

Introduction of an energy standard and labeling on tractors and agricultural machineries should also be considered to promote energy efficiency in the long run.

Program	Machine	2025	2030
Labeling	Irrigation pump		Preparation

Figure 5-1 Roadmap of Labeling program for Irrigation pump

6. Updated Action plan and Roadmap

The energy efficiency programs in Bangladesh in principle aim to achieve the EECMP 2016 plan. As discussed above, some of these programs are progressing, while others are underway. The transportation and agricultural sector should be included in the updated Action Plan and Roadmap. Then, the following challenges should be considered.

1) Securing human resources for energy efficiency
2) Securing financial resources for energy efficiency implementation
3) Coordination with related policies and institutions

1) Securing human resources for energy efficiency

According to EECMP2016, many programs are required to be formulated. However, the number of implementing personnel in charge of energy efficiency and conservation is very low, and the human resources are not sufficient to implement all the programs.

2) Securing financial resources for energy efficiency programs

In addition to securing human resources, securing budget for implementation of energy efficiency is key for the above review of the schedule. It is also important to implement pilot projects regarding the introduction of new and unproven technologies. With insufficient budget for introduction of an IT system for the energy management program, energy efficiency would not progress as scheduled.

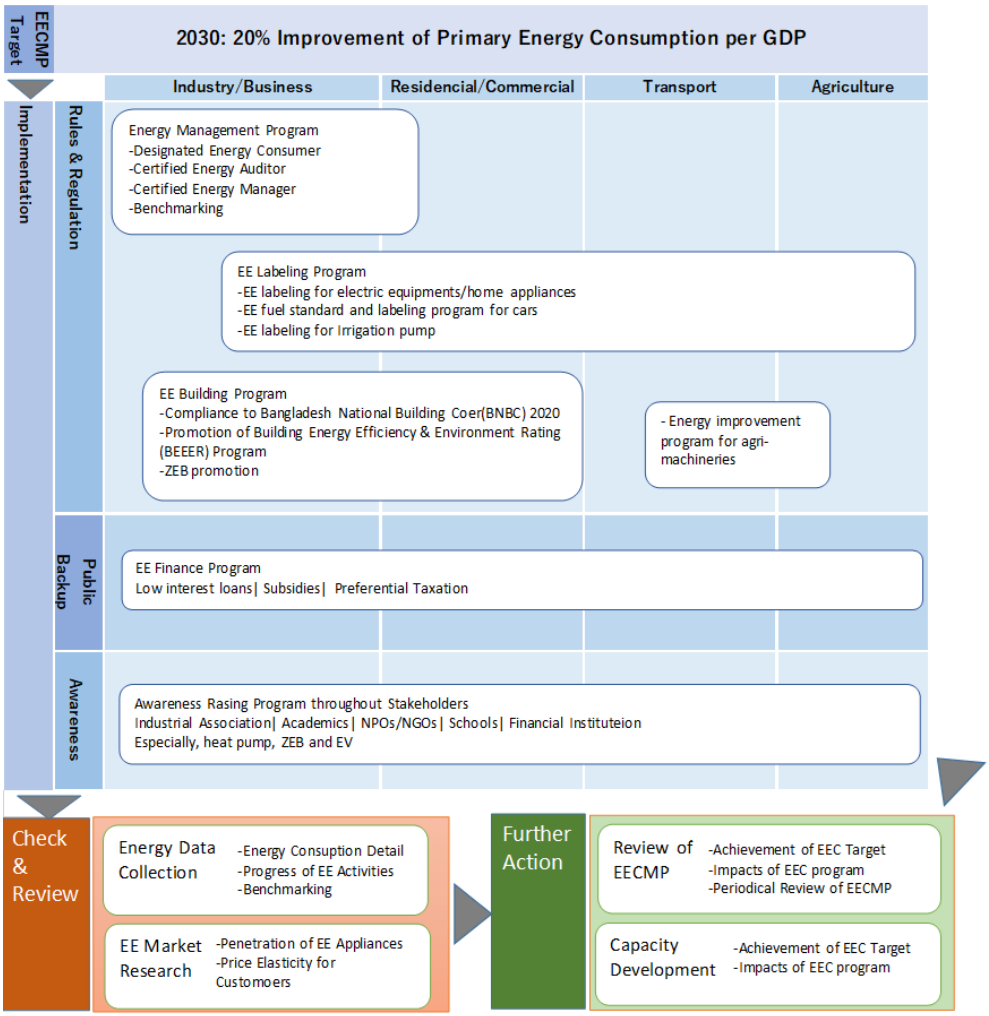
3) Coordination among related policies and institutions

In implementing energy efficiency programs, cooperation with other policies (for example, building code, urban policy (transportation sector)) is indispensable. Then, consistency with other policies and coordination of schedules will also be necessary. Thus, reviewing the program implementation schedule, it is important to consider the schedule of related policies and institutions as well.

In EECMP2016, roadmaps are shown for individual programs including plans for introduction of various initiatives. At present, they are progressing at different paces. The action plan and roadmaps should be updated to be realistic and be accelerated.

The updated Action plan and Roadmap are shown below. Toward 2050, it is required to implement the EEC program in collaboration with other energy and climate change policies, with in-depth evaluation on strengthening EEC regulations such as wider coverage of DC entities, lowering energy consumption criteria, expanding S&L program targets, and higher standards for machinery energy efficiencies. The above-mentioned “Updated Action Plan and Roadmap” are extended to include agricultural and transportation sectors.

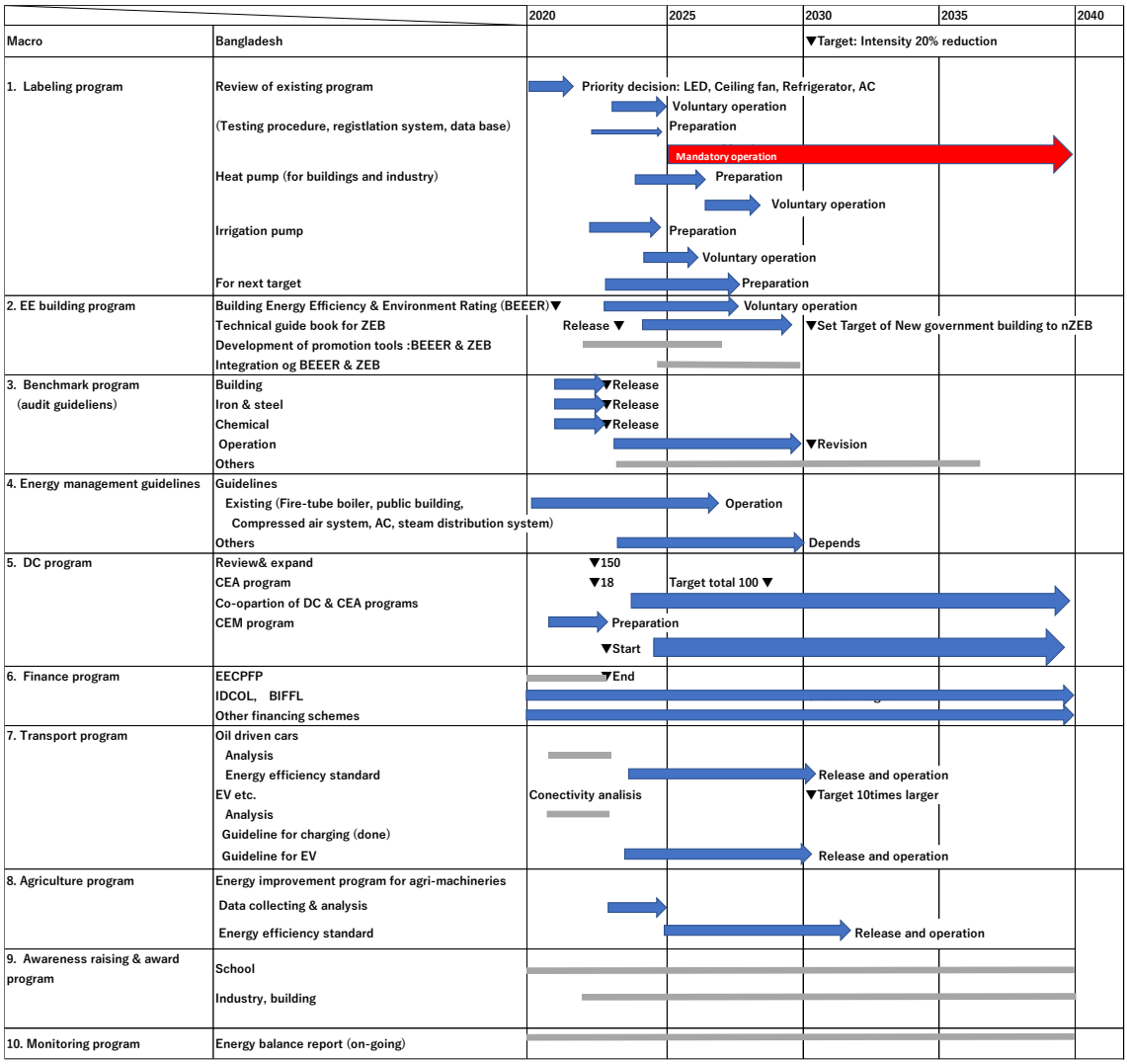
The updated tentative EEC action plan is as shown in Figure B.6-1 which includes not only the industry sector and residential & commercial sector but also the transportation sector and agriculture sector. The effective programs for each sector such as the Energy management program, EE labeling program, EE building program, Energy improvement program, EE finance program and Awareness raising program are being implemented. In their progress, each program will be checked and reviewed via energy data collection and EE market research, and further actions will be taken accordingly.



Source: SREDA

Figure 6-1 Updated Action Plan

The implementation roadmap also needs to be updated in accordance with progress. Programs being implemented under the EECMP2016 are reviewed and updated and the updated implementation roadmap incorporating these is shown in Figure 6-2.



Source: SREDA

Figure 6-2 Energy Efficiency Updated Implementation Roadmap

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Appendix C

Long Term Energy Outlook

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1. Socio-economic Development and Energy

Economic growth enabling people to enjoy greater material prosperity in their lives requires consumption of energy to drive the economy. For this reason, the conventional energy outlook used to focus on prediction, and accordingly preparation, for factors such as the approximate scale and growth rate of future energy consumption necessary to realize the economic growth targets. However, concerns are rising especially in developed countries not only on the importance of material wealth, but also on the spiritual affluence including coexistence with the natural environment. Over recent years, an energy outlook has become required to provide analysis on two sides of a same coin; energy consumption projections and supply planning on one hand, and direction, scale and growth rate of energy-related CO_2 emissions on the other. The background to this change in the significance of energy outlook is characterized by changes in the relative values of economic growth and the environment as well as the increased importance of "3Es" as a basic policy for energy measures.

Since the industrial revolution, mankind has consumed vast quantities of fossil fuels such as coal, petroleum and natural gas as the economy grew, giving rise to new social problems including air pollution, water contamination and other environmental problems. This is because countries around the world tended to ignore these environmental problems in their pursuit of economic growth in the past.

Subsequently, especially after the Stockholm Conference of 1972, in their pursuit of economic growth to ensure an affluent lifestyle for their citizens, many governments began to understand the need for measures to cope with environmental problem-related externalities; in other words, environmental policies. However, the degree of enthusiasm for such initiatives differed from country to country. Recognizing the great value of the environment as global public goods, as well as strengthening their own environmental policies, developed countries have called on developing countries to do likewise. In response, burdened with many issues requiring priority in these developing countries apart from environmental problems, while measures have been taken to cope with local environmental problems such as air pollution and water contamination that directly affect human health, responses to environmental problems on a global scale such as global warming and climate change have sometimes been given lower levels of priority.

However, particularly since the Rio de Janeiro Conference of 1992, recent years have seen the beginning of wider-ranging responses to environmental problems in almost all countries. The reason for this is that the problems of global warming and climate change have become more evident and severe, giving rise to the need to seek means to achieve economic growth while dealing with problems on a global scale. In more specific terms, many countries wish to pursue paths to cope with CO_2 emissions such as minimizing total costs of mitigation, adaptation and damage, taking into consideration costs not only in the present, but also for future generations. As a result, many countries including developing countries, have begun to declare their aims to achieve decarbonization of energy used in the long-term targeting years such as 2050, 2060 and

2070.

In decades to come, many countries will follow this trend of strengthening environmental policies. For example, some developed countries are considering introduction of measures such as carbon border tax and environmental LCA on imported products. If these measures are adopted, countries viewed as not taking sufficient measures to address the climate change may be unilaterally imposed taxes and regulations on products they export, such as textile goods, and would possibly lose future opportunities to enter markets of such developed countries. On the other hand, as another example, countries with potential of underground CO_2 storage may enjoy reaping hefty economic benefits from CO_2 import and storage businesses.

Thus, taking into account the trend that relative value of the environment on economic growth continues to grow, environmental constraints on economic activities are likely to grow further from local minimum requirements to constraints that will have interactive impacts on a global scale. These constraints would provoke changes in the existing economic activities and give rise to new economic risks and opportunities. To put it in another way, we are on the verge of an era where environmental policies will certainly affect the medium-to-long term economic growth.

Indeed, although environmental policies to cope with global warming and climate change are of increasing importance, questions still remain about whether every country should aim to realize a decarbonized society with zero carbon emissions or a low carbon society that allows a certain level of carbon emissions. Applied technologies required for decarbonized and low-carbon societies are different. To realize a decarbonized society, maximum introduction of renewable energy as well as costly new decarbonization technologies that use ammonia, hydrogen, CCS, etc. will be essential. However, the potential for renewable energy differs from region to region, with some countries being blessed with such potential while others are not. Moreover, oil and gas-producing countries can manufacture substances such as fossil fuel-derived blue ammonia or blue hydrogen easily, and may possibly have abundant CCS potential using depleted oil and gas fields. In contrast, non-oil and gas-producing countries may find themselves struggling to use such costly fuels and technologies. In other words, decarbonization in countries not blessed with resources such as renewable energy, oil or natural gas may face rising energy costs that put a substantial burden on their citizens. In fact, the pathway forward is not easy even for developed countries that have declared their commitment to decarbonization.

Furthermore, accepting that environmental policies are important, it remains open to debate whether contributions to the global environment should go as far as importing large quantities of decarbonized energy sources that are costly such as blue ammonia, blue hydrogen, green ammonia and green hydrogen from specific regions and countries. Heavy dependence on import is by no means desirable for energy supply security, a traditional concern in terms of energy policies. Import dependence gives rise to vulnerability against effects of factors such as international energy prices and geopolitics. For the sake of national independence and stability, energy self-sufficiency rates should preferably be increased as much as possible. In addition, suppose there is

no choice but to import some energy, approaches must be taken to diversify energy sources and suppliers.

Increasing energy subsidies may be introduced as a means of reducing the burden on citizens arising from factors, such as coping with decarbonization and importing energy. However, such approaches are not sustainable, if one takes into consideration government financial soundness. Accordingly, a realistic option for developing countries not blessed with resources may be aiming to realize a low carbon society focused on implementing full-fledged energy saving on the demand side, while at the same time using natural gas, a resource with a lower cost and carbon intensity, on the supply side.

If this approach is employed as the goal for realizing a low carbon society, is it not necessary to introduce renewable energies such as PV, wind power, nuclear power and decarbonization technologies including ammonia, hydrogen and CCS? If top priority is to be put on economic efficiency only, it may be better not to expand their introduction in a hurry. At present, ammonia, hydrogen, CCS and other decarbonization technologies have not yet seen any cost-down for popularity. In addition, the integration cost to connect the renewable power with the grid network cannot be ignored although each system's construction cost is beginning to fall. However, as a result of giving top priority only on economic efficiency, energy systems may be built dependent on natural gas, the majority of which will be imported as the primary source of energy in developing countries not blessed with resources. This poses risks in terms of ensuring energy supply security. Furthermore, ignoring environmental aspects in pursuit of economic growth will most likely invite criticism from the international community. As mentioned earlier, this would also result in being left behind from trading with some advanced economies. Balancing the so-called "3Es (Energy security, Economic efficiency, Environmental sustainability)", factoring in not only economic efficiency, but also supply security and the environmental aspect will be critical. As such, introduction of renewable energy, nuclear power and decarbonization technologies should be approached not in haste, steadily keeping track of technological progress and price changes.

With this backdrop of increasing the relative value of the environment and significance of "3Es", it is more important now to predict future energy demand, especially fossil fuel consumption and the resultant CO_2 emissions, and formulate appropriate supply plans, accordingly. Energy demand projections will contribute not only to ensuring energy security, but also setting goals for reduction of CO_2 emissions, and hence formulating practicable environmental policies. This work will provide a compass to lead economic growth factoring in environmental policies. In a world where greater care is needed for the environment, energy outlook, together with supply plans on the other side of the coin, is given a role to set out a development pathway under a sound balance of economic growth and environmental policies, and realize the basic energy policy to achieve "3Es".

2. Methodology and Model

2.1 Scenario Approach

To set the direction of the Bangladesh government's energy policy, the following three energy outlook scenarios are established: Reference Scenario (REF), Advanced Technology Scenario (ATS) and Net-Zero Emissions Scenario (NZS) as shown in Figure 2-1. REF follows the past trends, while NZS focuses on strong energy and environmental policies. The JICA Study Team would recommend the Bangladesh government to adopt energy policies that can realize ATS while balancing energy security, economic efficiency and environmental sustainability, which are so called the "3Es".

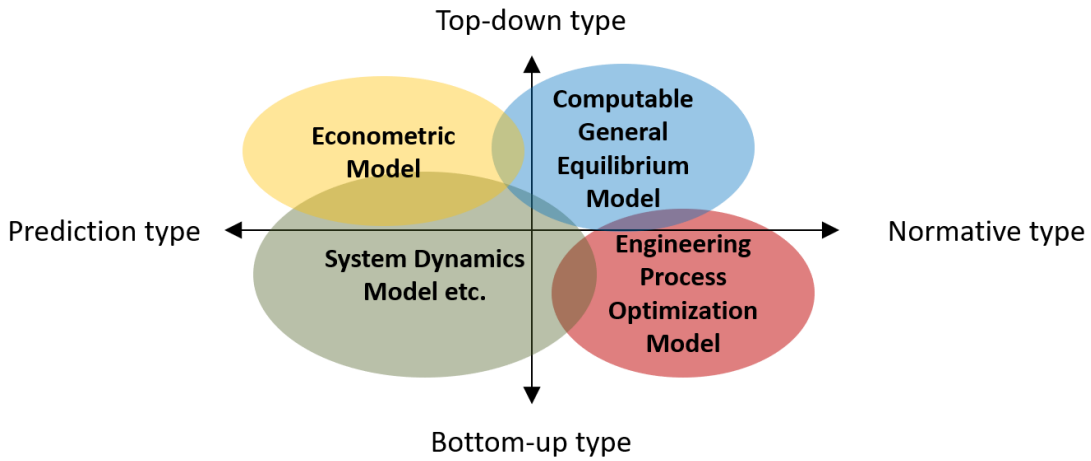
	Reference Scenario (REF)	Advanced Technology Scenario (ATS)	Net-Zero Emissions Scenario (NZS)
Characteristics	The past trends will continue based on the existing energy and environmental policies. Radical changes will not take place on energy efficiency and low carbonization policies.	Energy and environmental policies to ensure stable energy supply and strengthen climate action will be successful to a certain extent. Introduction of advanced technologies will progress.	Greenhouse gas emissions will be net zero in 2050. The transition path toward 2050 is estimated by backcasting approach.
Policy	Progressively strengthen low-carbon policies as observed in the past developments.	Significant progress in international cooperation along with strengthening domestic policies.	Extremely strong energy and environment policies are necessary to achieve net zero by 2050.
Technology	Efficiency improvement follows past trends. Cost reduction like past trends. Spread of low-carbon technologies through regulation and policy.	Technology progress accelerates cost reduction. Strengthening regulations and guidances accelerates dissemination.	Assume technologies to reduce greenhouse gas emissions to net zero in 2050. Timing and amount of introduction of each technology are assumed by backcasting approach.

Source: Prepared by the JICA Study Team

Figure 2-1 Energy Outlook Scenario

2.2 Model Structure and Design

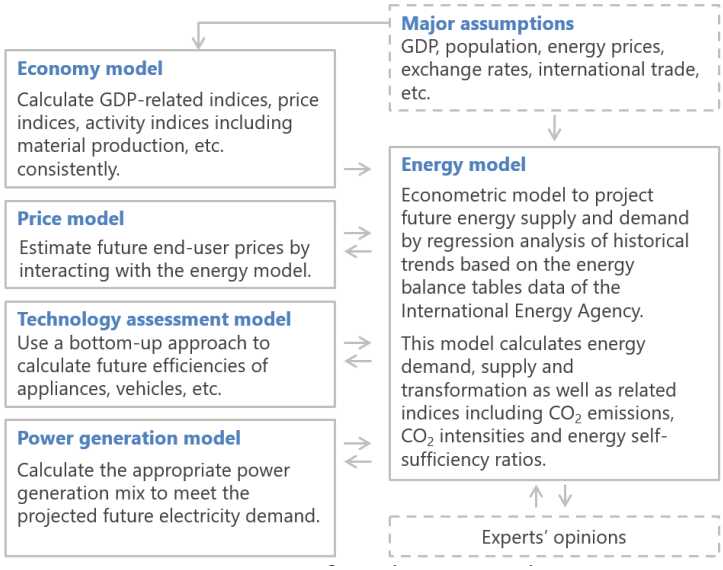
In this project, an econometric model is adopted as a tool to forecast energy outlook. It is used to forecast economic activities with an assumption that the past action pattern and its trend will be maintained in the future in principle. It generally consists of multiple behavior equations, and each equation is estimated using statistical data on past records applying regression analysis. In an environment that research on the future prospect of Bangladesh is still in its infancy, a combination of the prediction type, that endogenously calculates future energy demand, and the top-down type, that uses a macro approach based on economic indicators and economic functions, is considered to be most suitable (Figure 2-2).



Source: Created by IEEJ based on Fig. 6.2 (page 222) in *Energy Environmental Economic Systems*, by Yasumasa Fujii, Corona Publishing Co., Ltd. (2018)

Figure 2-2 Classification of the Energy Outlook Model

In contrast, the computable general equilibrium model is mainly used to evaluate the impact of a shock in an economy and it is generally not suitable for future projection. The system dynamics model is mainly applied to grasp a system structure and it is generally not suitable for future projection either. The engineering process optimization model is used to seek the optimum combination of technologies and it is impossible to predict the total level; the latter is calculated by another model and given as an assumption. Among the optimization models, the cost minimization model requires caution about its performance since only one-cent cheaper technology will diffuse at 100% in the objective area, and it ignores factors other than cost such as design, comfortability, safety, etc. unless specifically incorporated.

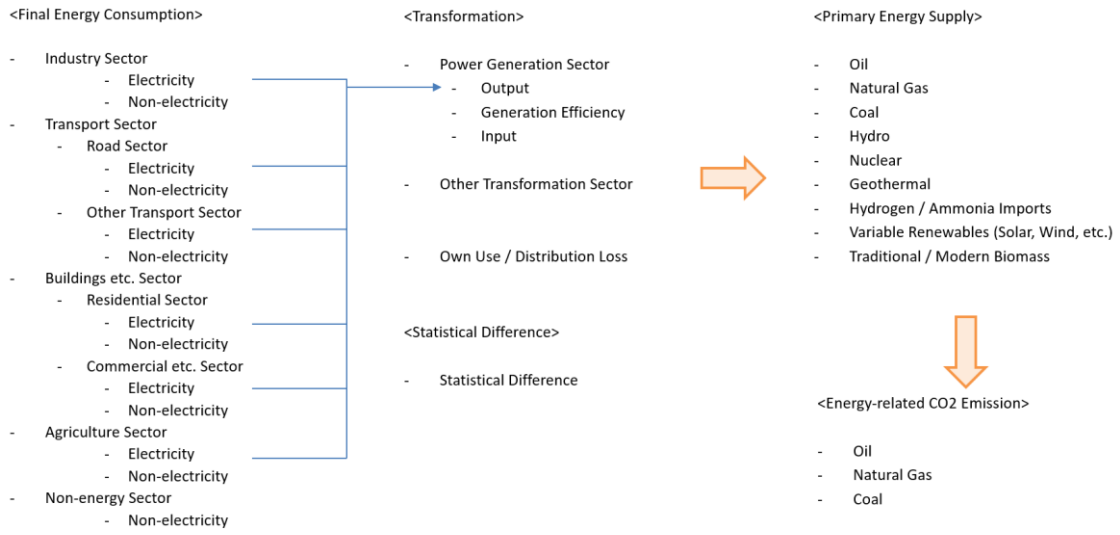


Source: Prepared by the JICA Study Team

Figure 2-3 Structure of the Econometric Model

In the econometric model used in this study, it is adopted as the core model for performing analysis by combining the economic model, price model, and other sub-models as explained later together with major assumptions as explained in Figure 2-3.

The energy model divides Final Energy Consumption into Industry, Transport (Road and Others), Buildings, etc. (Residential and Commercial), Agricultural, and Non-energy sectors. To estimate the primary energy supply and energy-related CO_2 emissions, the energy model also divides the Transformation Section into the Power Generation, Other Transformation sectors, and Own Use/Transmission and Distribution (T&D) Loss (Figure 2-4).



Source: Prepared by the JICA Study Team

Figure 2-4 Energy Model System

2.3 Energy Demand Model

The following section describes details of the energy model.

2.3.1 Basic concept

In principle, each sector's energy demand defined as Final Energy Consumption is endogenously estimated separately for electricity and non-electricity demands using the concept presented in the following estimation formula.

$$Energy\ Demand = f(income(+), energy\ price(-), previous\ demand(+))$$

The above formula uses income, price, and energy demand of the previous term as explanatory variables to estimate energy demand for the current term.

To measure the income effect, GDP, and/or other alternative indictors are specifically used as explanatory variables. If other conditions remain unchanged, a rise in income also increases

the real budget, and thus energy demand.

To measure the price effect, the electricity price or non-electricity price for each sector of the final energy consumption is specifically used as an explanatory variable. If other conditions remain unchanged, a price rise adversely reduces the real budget, and thus energy demand.

The energy demand of the previous term is used as an explanatory variable to measure the Rachet effect of consumption. If other conditions remain unchanged, a rise in energy demand during the previous term also increases the energy demand in the current term. Theoretically, the parameter of the lagged subjective is used to identify short-term and long-term elasticities of other factors such as GDP, price, etc.

In principle, the ordinary squares regression (OLS) is used as the estimator.

While future demand for REF is estimated simply reflecting the past trend, demands for ATS and NZS are estimated with exogenously considered energy conservation and electrification in each sector.

2.3.2 Industry sector

To endogenously estimate electricity and non-electricity demands in the Industry sector, in principle, the secondary industry GDP and the electricity/non-electricity prices in that sector are used as the explanatory variables for the income effect and the price effect, respectively.

The estimated electricity demand is aggregated in the Power Generation sector, while non-electricity demand is classified into different energy sources by share function which is given by regression analysis or preconditions based on literature, interviews, normative analysis, etc.

2.3.3 Road sector

To exogenously estimate the electricity demand in the Road sector, a technology assessment model is used that multiplies the number of registered electric vehicles (EVs), the fuel consumption per vehicle and the mileage per vehicle.

To endogenously estimate the non-electricity demand, in principle, the number of registered vehicles (excluding EVs) and the non-electricity price in the Road sector are used as explanatory variables for the income effect and price effect, respectively.

The estimated electricity demand is aggregated in the Power Generation sector, while non-electricity demand is classified into different energy sources by share function which is given by regression analysis or based on literature, interviews, etc.

2.3.4 Other Transport sector

To endogenously estimate total energy demand for railroads, aviation, navigation, etc. in the Other Transport sector, in principle, GDP and energy prices in that sector are used as

explanatory variables for the income effect and the price effect, respectively. The breakdown of electricity demand is exogenously given for mass rapid transit (MRT) and railway applications.

The estimated electricity demand is aggregated in the Power Generation sector, while non-electricity demand is classified into different energy sources by share function which is given by regression analysis or based on literature, interviews, etc.

2.3.5 Residential sector

To endogenously estimate electricity and non-electricity demands in the Residential sector, in principle, GDP per capita and the electricity/non-electricity price in that sector are used as explanatory variables for the income effect and the price effect, respectively.

The estimated electricity demand is aggregated in the Power Generation sector, while non-electricity demand is classified into different energy sources by share function which is given by regression analysis or based on literature, interviews, etc.

2.3.6 Commercial sector

To endogenously estimate electricity and non-electricity demands in the Commercial sector, in principle, the tertiary industrial GDP and the electricity/non-electricity price in that sector are used as the explanatory variables for the income effect and the price effect, respectively.

The estimated electricity demand is aggregated in the Power Generation sector, while non-electricity demand is classified into different energy sources by share function which is given by regression analysis or based on literature, interviews, etc.

2.3.7 Agricultural sector

To endogenously estimate electricity/non-electricity demands in the Agricultural sector, in principle, the primary industrial GDP and the electricity/non-electricity price in that sector are used as the explanatory variables for the income effect and the price effect, respectively.

The estimated electricity demand is aggregated in the Power Generation sector, while non-electricity demand is classified into different energy sources by share function which is given by regression analysis or based on literature, interviews, etc.

2.3.8 Non-energy Sector

The energy demand in the non-energy sector is estimated as the energy demand consumed as feed stock for fertilizer and petrochemical applications. Therefore, there is no electricity demand; only non-electricity demand exists. Non-electricity demand in the non-energy sector is given exogenously, while considering the policies of the Bangladesh government.

2.3.9 Power generation sector

Firstly, in the Power Generation sector of the Transformation section, total power generation is endogenously estimated based on the electricity demand aggregated from each sector within Final Energy Consumption, exogenously considering electricity consumption in the Other Transformation sector, Own use/T&D Loss, electricity imports, statistical differences, etc.

Then, each energy input to the Power Generation sector is endogenously estimated by using each energy ratio, capacity factor for each form of power generation, power generation efficiency, etc. in power generation model exogenously developed for each scenario and each GDP cases.

2.3.10 Primary Energy Supply

The Primary Energy Supply for each energy source is endogenously estimated mainly from each non-electricity demand in Final Energy Consumption and each energy input in Transformation.

2.3.11 Energy-related CO_2 emissions

Energy-related CO_2 emissions are endogenously estimated by multiplying energy consumption, which is calculated by excluding demand in the Non-energy sector from the primary energy supply of oil, coal, and natural gas, by each CO_2 intensity.

2.4 Economy model

2.4.1 GDP

GDP development scenarios are developed for three cases. To help estimate energy demand in each Final Energy Consumption sector, GDP by primary, secondary, and tertiary industries, is assumed.

2.4.2 Population

Population is assumed for one case.

2.4.3 Automobile

Numbers of registered vehicles are separately considered for passenger light-duty vehicles (PLDVs) and trucks/buses (TRBSs). The total number of conventional vehicles, EVs, and FCVs is endogenously estimated by using GDP and energy price as explanatory variables, while the breakdown of Evs and FCVs is assumed to be exogenous.

2.5 Price model

2.5.1 Imported fuel price

Of the fuels that need to be imported, World Bank data is used for the actual international

prices of oil, coal and natural gas, while IEA data is used for future projections. Regarding the international prices of hydrogen, the outlook used is the targets by the Japanese government. On the international prices of ammonia, the outlook is developed by experts of the JICA Study Team.

2.5.2 Power generation cost (excluding fuel price)

For power plants, BPDB data is used for the actual construction and O&M costs, while IEA data is used for future projection.

2.5.3 End-user price

Regarding actual end-user prices, BPDB data is used for the prices of high-speed diesel oil and furnace oil, while the import price is used to calculate the prices of coal and natural gas. A private database is used for gasoline and diesel prices in the Road sector, as well as for the electricity prices in the Industry and Residential sectors.

On the outlook of end-user prices, regression equations are used to estimate prices of high-speed diesel oil and furnace oil, while import price is used to calculate prices of coal, natural gas, hydrogen and ammonia. Regression equations are also used to estimate gasoline and diesel prices in the Road sector, as well as electricity prices for the Industry and Residential sectors.

2.6 Technology assessment model

A technology assessment model is considered a reference for the road sector demand estimation. As regression analysis is used in the energy model, the road sector demand may also be estimated considering three factors: registered vehicles, the fuel consumption per vehicle and the mileage per vehicle. These will be considered by type such as 4-wheeled, 3-wheeled and 2-wheeled passenger light-duty vehicles (PLDVs), and trucks and buses (TRBSs). In this study, however, the technology assessment model is considered just a reference.

2.7 Power generation model

The Power generation model is used for estimation of power generation. In the model, firstly, renewable and nuclear power are estimated exogenously based on literature, interviews, etc. Secondly, coal-fired power, coal-fired power with ammonia co-firing and oil-fired power are estimated in the same manner. Thirdly, gas-fired power with hydrogen co-firing, hydrogen single-fired power and gas-fired power with CCS are estimated in the same way. Lastly, the rest of the requirement is made up by gas-fired power. However, this power generation model is used for interim calculation only; the final generation forecast is calculated by the TWG2 with a more detailed model.

2.8 Adopted Data

Table 2-1 shows the major data used for estimating energy demand.

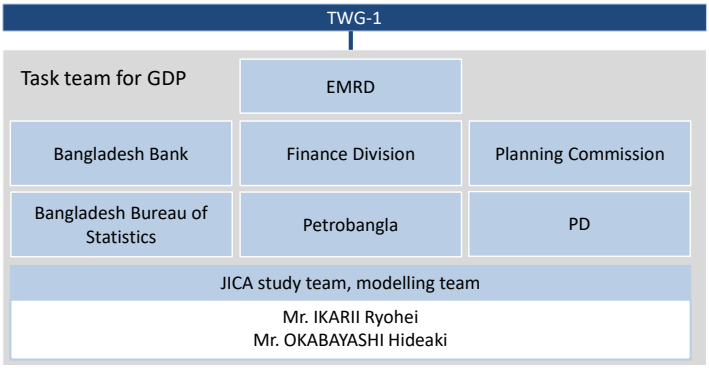
Table 2-1 Main Data to use

Model name		Main data to use (common among REF, ATS and NZS)
Energy model		Actual data: IEA (2021.7)
		Outlook: Regression equation, etc.
Economy model	GDP	Actual data: BBS (2022.2), World Bank (2021.7), United Nations (2021.7), etc.
		Outlook: Perspective Plan 2041 (2020.3), 8th Five-Year Plan (2020.12), IMF (2022.4), etc.
	Population	Actual data: BBS (2021.6)
		Outlook: Perspective Plan 2041 (2020.3), etc.
	Automobile	Actual data: BBS (2021.5)
		Outlook: Regression equation, etc.
Price model	Imported fuel price	Actual data: World Bank (2021.7)
		Outlook: IEA (2021.10), etc.
	Power generation cost (excluding fuel price)	Actual data: BPDB (2021.7)
		Outlook: IEA (2022.1), etc.
	End-user price	Actual data: BPDB (2021.7), private database (2021.7), etc.
		Outlook: Regression equation, etc.

Source: Prepared by the JICA Study Team

3. GDP Assumptions

3.1 GDP Task Team structure



Source: Prepared by the JICA Study Team

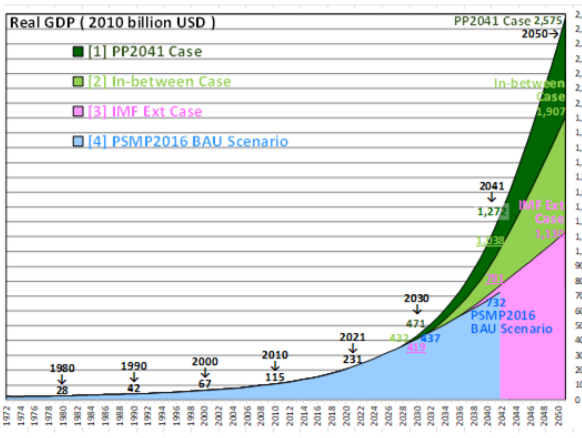
Figure 3-1 GDP Task Team Structure

To determine the validity of the GDP growth rate assumption, which is an important prerequisite for preparing the energy outlook, knowledge of external organizations other than MoPEMR such as the Planning Commission, Finance Division, Bangladesh Bank, Bangladesh Bureau of Statistics (BBS), and Petrobangla is required. Therefore, by adding members of related organizations, EMRD, responsible for the GDP assumption in the IEPMP, established the GDP Task Team and held meetings and discussions.

3.2 GDP assumption

3.2.1 Real GDP

Since the future is uncertain, the JICA Study Team proposed MoPEMR to consider three GDP cases to examine the outlook of the future energy and power demand. The GDP PP2041 Case has been set along with Perspective Plan 2041 (PP2041), achieving US$2.6 trillion of real GDP in 2050 (Figure 3-2). On the other hand, GDP in the IMF Ext Case, which is developed extending the IMF mid-term economic outlook, will be US$1.1 trillion in 2050. The GDP In-between Case is set as a projection in-between these two projections, and will reach US$1.9 trillion in 2050. The GDP path of the IMF Ext Case is almost the same with the projection made for PSMP 2016 as the BAU case.



Case	from 2021 to 2041 Annual Average GR	from 2021 to 2050 Annual Average GR	Study Team Proposal
	Times / %	Times / %	
[1] PP2041	5.5 / +8.9%	11.2 / +8.7%	→ Main Case of the Study
[2] In-between	4.5 / +7.8%	8.3 / +7.6%	→ Exercise Case 1 of the Study
[3] IMF Ext	3.4 / +6.3%	4.9 / +5.6%	→ Exercise Case 2 of the Study
[4] PSMP2016	3.2 / +5.7%		

Source: Prepared by the JICA Study Team

Figure 3-2 Real GDP

The Study Team also proposed that the PP2041 Case will be the main case of this study since it is cited from the national economic plan PP2041, the present legal document in which Bangladesh aims to become a high-income country by 2041. The In-between Case and the IMF Ext Case were run as exercise cases of this study.

3.2.2 Real GDP Growth Rate

Concerning the real GDP growth rates, the PP2041 Case will realize +9.9% in 2041 and +6.8% in 2050, reflecting the Finance Division's perspective between 2022 and 2025, PP2041 planned by the Planning Commission between 2026 and 2041 and the actual average growth rate between 2010 and 2019 after 2041 (Table 3-1).

The In-between Case will reach +8.7% in 2041 and +5.6% in 2050, whereas the IMF Ext Case will be +5.3% in 2041 and +3.6% in 2050.

All the GDP growth rates in the PP2041, In-between and IMF Ext cases are higher than those of the PSMP 2016 BAU case.

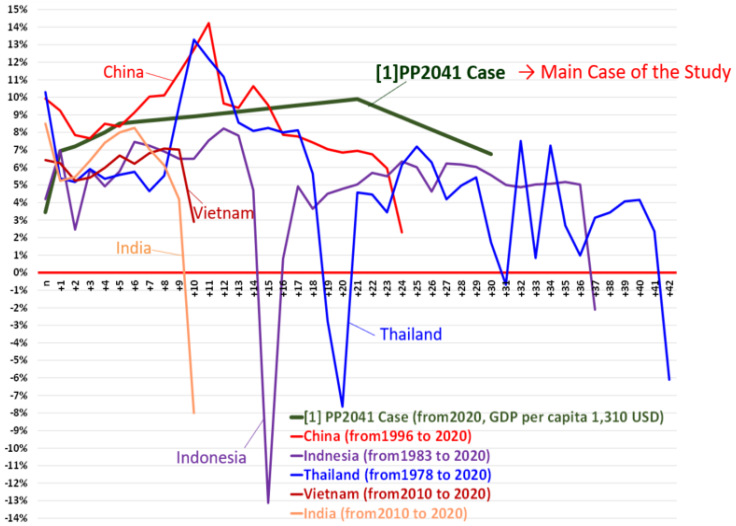
Table 3-1 GDP Growth Rate Assumptions

	PP2041	In-between	IMF Ext
2000	5.3%		
2012	6.5%		
2019	8.2%		
2020	3.5%		
2021	6.9%		
2025	8.0%	6.9%	7.2%
2030	8.9%	7.7%	6.6%
2035	9.4%	8.2%	6.0%
2041	9.9%	8.7%	5.3%
2045	8.5%	7.3%	4.3%
2050	6.8%	5.6%	3.6%
	Main Case	Exercise Case 1	Exercise Case 2

Source: JICA Study Team

3.2.3 Real GDP Growth Rate Compared with Other Asian Countries

Compared with actual GDP growth rates of other Asian countries, the assumed Bangladesh's GDP growth rate of the PP2041 Case is the highest on average, after their achieving US$1,300 (in 2010 US price) of real GDP per capita to which Bangladesh almost reached in 2020 for the first time (Figure 3-3).



Country Name (GDP capita from about $1,300)	Annual Average Real GDP G.R
[1] PP2041 Case (from2020 to 2050)	+8.6%
China (from1996 to 2020)	+8.6%
Vietnam (from2010 to 2020)	+6.0%
India (from2010 to 2020)	+4.9%
Indnesia (from1983 to 2020)	+4.8%
Thailand (from1978 to 2020)	+4.8%

Source: Prepared by the JICA Study Team

Figure 3-3 Real GDP Growth Rate Compared with Other Asian Countries

The PP2041 Case growth rate will be +8.6% per annum between 2020 and 2050 in Bangladesh. On the other hand, China's growth rate was +8.6% annually during the period of high-speed industrialization between 1996 and 2020; this is almost equal to the PP2041 Case growth rate. Growth rates for the high-speed industrialization era in Vietnam, India, Indonesia and Thailand were +6.0% between 2010 and 2020, +4.9% between 2010 and 2020, +4.8% between 1983 and 2020 and +4.8% between 1978 and 2020, respectively. All of these growth rates during industrialization in other Asian mid-income countries were lower than that assumed in the PP2041 Case in Bangladesh.

In addition, there was an opinion that the assumed GDP growth rate in Bangladesh might be too weak after 2041. However, the annual growth rate in the PP2041 Case between 2041 and 2050 was agreed to be +8.15% on average, whereas that between 2020 and 2041 would be +8.85%, so that the growth rates before and after 2041 would not show much difference.

3.2.4 Real & Nominal GDP per Capita

In the PP2041 Case, nominal GDP per capita in 2041 should be almost 17,000 US dollars for Bangladesh to become a high-income country by 2041 (Figure 3-4). According to PP2041, 16,000 US dollars of nominal GDP per capita indicates the threshold of the high-income countries in 2041.

Real GDP per capita (2010 USD)

	2021	2030	2041	2050
Main Case → [1] PP2041 Case	Actual 1,387 (2010 USD)	2,472	6,048	12,022
Exercise Case 1→ [2] In-between Case		2,269	4,934	8,905
Exercise Case 2→ [3] IMF Ext Case		2,196	3,716	5,276
[4] PSMP2016 BAU Scenario	1,417	2,292	3,482	

Nominal GDP per capita

	2021	2030	2041	2050
Main Case → [1] PP2041 Case	2022/2/8 BBS GDP 2,462 (GNI 2,591)	5,453	16,739	37,946
Exercise Case 1→ [2] In-between Case		4,938	13,160	26,566
Exercise Case 2→ [3] IMF Ext Case		4,801	9,329	13,984
[4] PSMP2016 BAU Scenario	2,789	4,986	8,935	

Source: Prepared by the JICA Study Team

Figure 3-4 Real & Nominal GDP per Capita

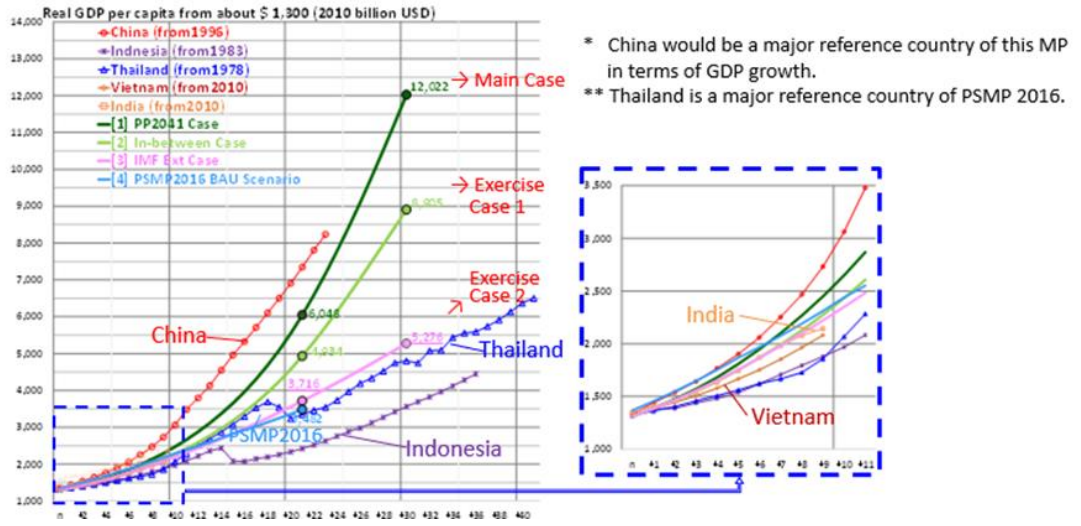
3.2.5 Real GDP per Capita Compared with Other Asian Countries

The growth rate of real GDP per capita in the PP2041 Case until 2050 will be a little higher than that in China's actual growth between 1996 and 2019 (Figure 3-5).

The growth rate for the In-between Case will be between the PP2041 Case and the IMF Ext

Case by definition as well as between China's and Thailand's actual growth.

The growth rate for the IMF Ext Case will be a little higher than Thailand's actual growth record, and it shows more moderate growth than the PP2041 Case or the In-between Case. It may involve the long-term COVID-19 effect on Bangladesh's economy.



Source: Prepared by the JICA Study Team

Figure 3-5 Real GDP per Capita Compared with Other Asian Countries

3.2.6 PP2041 Case as Main Case and IMF Ext Case a Conservative Exercise Case

On the left figure of Figure 3-6, the vertical axis shows the average GDP growth rate for five years. The horizontal axis means real GDP per capita. The dotted line, or the trend line, shows that GDP growth rates in other countries go down gradually as real GDP per capita increase.

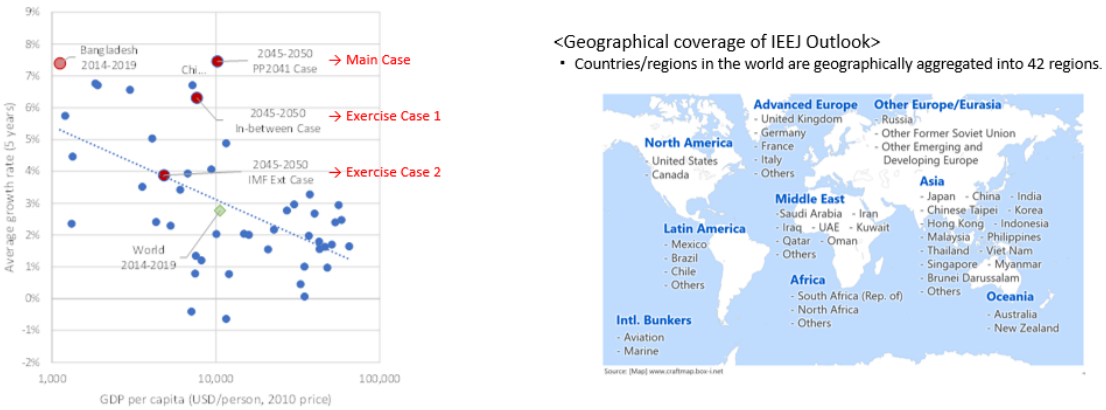


Figure 3-6 International Comparison of Real GDP per Capita and Geographical Coverage of IEEJ Outlook

It is true that Bangladesh experienced quite high growth to date as the dots in the top-left figure show compared with other countries or regions in the world between 2014 and 2019. As the dot for the PP2041 Case shows, the above discussion assumes that Bangladesh will keep this high

growth pace all the way through 2050.

On the other hand, the dot of the IMF Ext Case is on a trend line which indicates the world average for the real GDP per capita in 2019. Although the IMF Ext Case growth will be lower than those of the PP2041 and the In-between cases, it is just the world average case projected before the COVID-19 pandemic. The JICA Study Team considers that the IMF Ext Case growth is not too low and may become reality if any economic stagnation is incurred due to the COVID-19 pandemic, Ukraine war, and other elements.

Under the circumstance, while the PP2041 Case is set as the main case of the study, the JICA Study Team proposed adding the IMF Ext Case as a GDP assumption exercise case to see the impact of changes in the world average GDP on the energy and power demand.

3.2.7 GDP In-between Case

The In-between case is set according to the deviation rates between planned and actual growth rates during the 6th and the 7th five-year plan periods (Table 3-2). The annual deviation rate is estimated at -1.1% in the In-between Case on average. This estimation method was developed by the discussion between the Planning Commission and JICA Study Team.

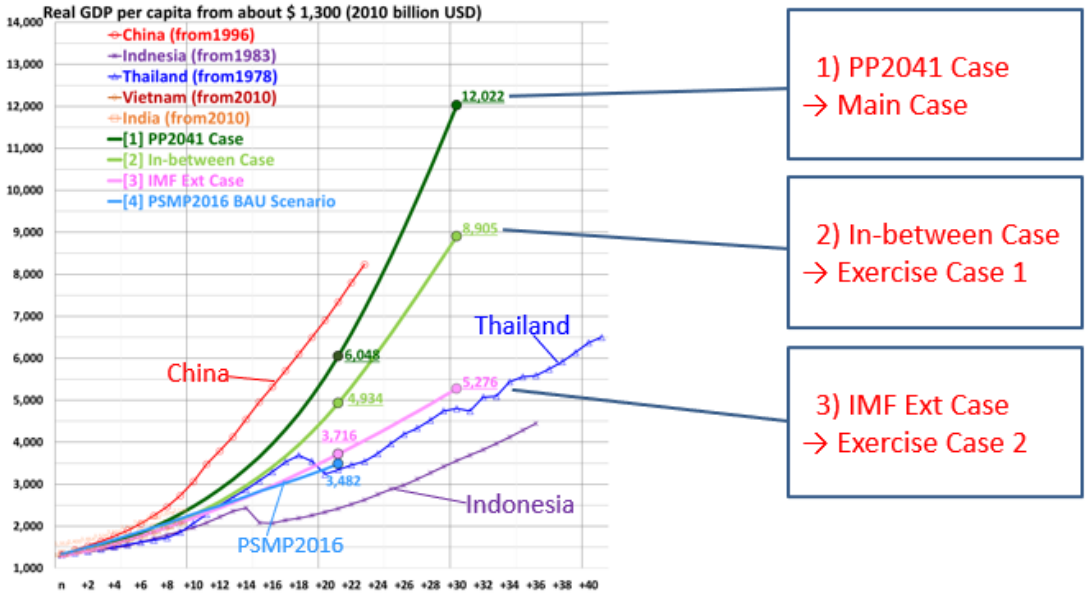
Table 3-2 GDP Setting for In-between Case

			6th Five Year Plan					7th Five Year Plan				
			2010-11 FY2011	2011-12 FY2012	2012-13 FY2013	2013-14 FY2014	2014-15 FY2015	2015-16 FY2016	2016-17 FY2017	2017-18 FY2018	2018-19 FY2019	2019-20 FY2020
Five Year Plan GDP growth rate		(a)	6.70%	6.90%	7.20%	7.60%	8.00%	7.00%	7.20%	7.40%	7.60%	8.00%
Actual result GDP growth rate		(b)	6.46%	6.52%	6.01%	6.06%	6.55%	7.11%	7.28%	7.86%	8.15%	3.45%
Diviation rate		(c): (1+b)/(1+a)-1	±0.22%	±0.35%	±1.11%	±1.43%	±1.34%	±0.11%	±0.08%	±0.43%	±0.51%	±4.21%
In-between Case	Deviation rate	(d): -c	-0.22%	-0.35%	-1.11%	-1.43%	-1.34%	-0.11%	-0.08%	-0.43%	-0.51%	-4.21%
	Cumulative deviation rate	(e): 1-(1+d(-1))×(1+d)	2010-11 -0.22%	2010-12 -0.58%	2010-13 -1.69%	2010-14 -3.14%	2010-15 -4.53%	2010-16 -4.64%	2010-17 -4.72%	2010-18 -5.17%	2010-19 -5.71%	2010-20 -10.17%
	Annual average deviation rate											-1.1%

Source: Prepared by the JICA Study Team

3.2.8 Three GDP Cases (One Main Case and Two Exercise Cases)

In sum, the JICA Study Team proposed to examine three GDP cases as the MP assumption: the PP2041 Case, the In-between Case and the IMF Ext Case (Figure 3-7; Table 3-3). The PP2041 Case is the main case of the study, and the other two cases are exercise cases.



Source: Prepared by the JICA Study Team

Figure 3-7 Three GDP Cases (One Main Case and Two Exercise Cases)

Table 3-3 Real GDP by Case (2010 billion USD)

GDP Case	Actual	Assumption				
	2021	2025	2030	2035	2041	2050
PP2041	231	310	471	731	1,272	2,575
In-between	231	300	432	636	1,038	1,907
IMF Ext	231	301	419	566	781	1,130

Source: Prepared by the JICA Study Team

3.3 Status of examining GDP assumptions

3.3.1 First GDP Task Team meeting

The first meeting of the GDP Task Team took place on Monday, November 15, 2021. Since Planning Commission and Finance Division members were absent from the meeting, the JICA Study Team had individual in-person meetings with them after the Task Team meeting. These meetings covered the following points of discussion.

1) While MoPEMR will stipulate IEPMP, MoPEMR will respect the Planning Commission's and Finance Division's views in addition to BBS's, Bangladesh Bank's and Petrobangla's opinions.

2) MoPEMR will take account of Bangladesh's national economic plans such as PP2041, and 6th, 7th and 8th five-year plans.

3) MoPEMR will refer to the past trends of Bangladesh's GDP growth.

4) MoPEMR may refer to the past trends of GDP growth in other Asian middle-income countries.

5) MoPEMR will consider the empirical fact that GDP growth rates will decline as the GDP becomes larger in general.

Accordingly, the GDP Task Team decided to continue discussions on GDP assumptions.

3.3.2 Second GDP Task Team meeting

The second meeting of the GDP Task Team took place on Monday, February 15, 2022. The Planning Commission, the organization in charge of long-term GDP perspectives, attended, and the meeting covered the following points of discussion.

1) The Planning Commission in charge of the GDP long-term assumption in the Bangladesh government agreed with the JICA Study Team's proposal.

2) The GDP Task Team basically accepted the three GDP cases which the JICA Study Team proposed.

3) The GDP Task Team suggested that GDP growth rates after 2041 might be too weak.

4) The GDP Task Team suggested that the JICA Study Team may conduct sectoral GDP analysis.

The GDP Task Team decided to pass the above discussions to TWG1, which is an upper organization.

3.3.3 TWG1 meeting for GDP assumption

The TWG1 meeting for GDP assumption was held on Wednesday, March 9, 2022, and the JICA Study Team provided supplementary explanations on the above discussions.

1) For the suggestion from the GDP Task Team in the above 3.3.2-3), the JICA Study Team commented that the annual growth rate in the PP2041 Case between 2041 and 2050 will be expected to become +8.15% on average, whereas between 2020 and 2041 it would be +8.85%, so the growth rates before and after 2041 do not show much difference.

2) For the suggestion from the GDP Task Team in the above 3.3.2-4), the JICA Study Team supplemented that it would analyze not the entire Bangladesh economy, in principle, but only the energy sector including energy and power demand and supply forecast and analysis; however, it would try to consider an easy sectoral GDP analysis when estimating the energy demand and supply perspectives.

As a result, TWG1 approved the GDP assumption without any objections.

3.3.4 Joint Steering Committee meeting for GDP assumption

The Joint Steering Committee meeting for GDP assumption, chaired by EMRD, took place on Wednesday, March 30, 2022. The meeting covered the following points of discussion.

1) The GDP Task Team under TWG1 explained the GDP cases, and the Bangladesh side had no questions at that moment and preferred to discuss "three cases of GDP growth rate assumptions" along with the results of demand forecasts.

2) The JICA Study Team agreed to explain the result of demand forecasts based on the GDP growth rate assumptions to EMRD, PD and utility companies at the same time and discuss these items online. In addition, the JICA Study Team agreed to visit Bangladesh to discuss these topics in person from April 23rd to the 28th.

3) The JICA Study Team agreed to review the demand forecasts based on the discussions with the Bangladesh side. The JICA Study Team agreed to visit Bangladesh in May 2022 to discuss assumptions and outcome of the energy demand forecast including primary energy supply mix, power generation mix, and CO_2 emissions.

4) Because the GDP IMF Ext Case seemed to be too conservative, the JICA Study Team should take extra caution to develop the energy demand outlook based on the GDP assumption.

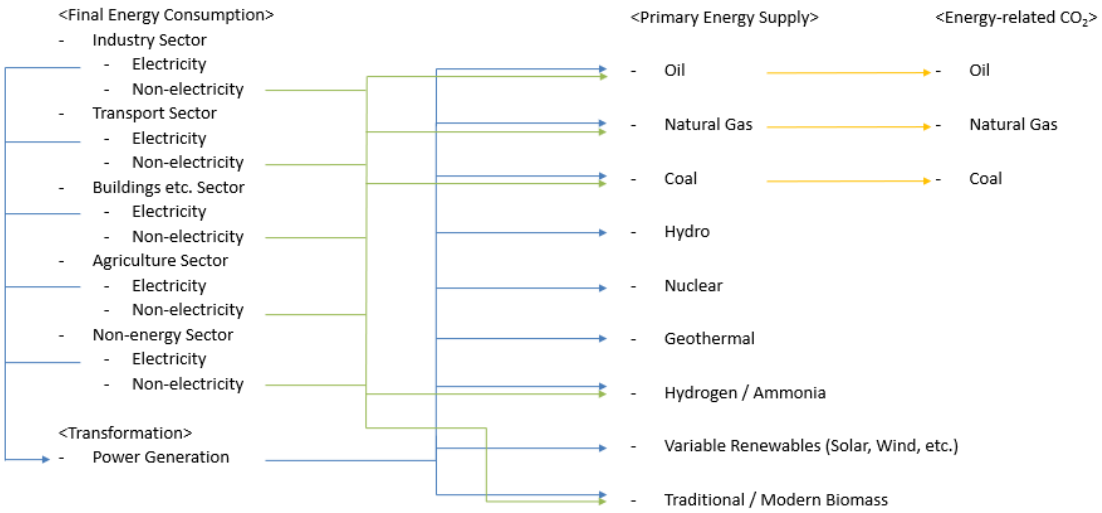
5) The Steering Committee recognized that GDP assumption is a critical assumption in energy demand forecast analysis and a change of its assumption will greatly affect the level of energy demand outlook and other associated analyses in the IEPMP and is likely to cause further delay of the study.

4. Energy Demand Outlook

4.1 Settings and assumptions

4.1.1 Analytical framework

The energy demand forecast starts from the analysis of the final energy consumption (FEC) (Figure 4.1-1). FEC is composed of five sectors, namely, industry, transport, buildings (residential and commercial), agricultural, and non-energy sectors. Demand of each FEC sector is estimated based on extrapolation by econometric analysis as well as setting assumptions for various determinants, which do not have any relevant historical figures or information but will affect the level of future demand. Types of energy sources (coal, oil, gas, electricity etc.) for each FEC demand sector is estimated based on multiple factors, such as relative price, historical trend, government's policy (power and energy mix targets, if any), and existing and planned infrastructure.



Source: Prepared by the JICA Study Team

Figure 4.1-1 Analytical Framework

Among energy sources that are consumed in each FEC sector, electricity has a unique characteristic as "secondary energy" that is produced from other primary energy sources such as gas and coal.[1] Electricity consumed in each FEC sector is summed up, and the primary energy supply utilized for power generation is calculated based on the assumed heat efficiency, power generation mix, transmission and distribution loss percentage, etc. Aggregating the primary energies consumed in each FEC sector together with those used in the power generation sector yields the figure of total primary energy supply (TPES). CO_2 emissions is estimated based on the estimated volume of TPES of fossil fuels (coal, gas, and oil) applying respective carbon intensity factors.

[1] Hydrogen and ammonia have similar characteristic, but if hydrogen and ammonia is produced from renewable electricity, instead of fossil fuels, it will be "tertial energy."

4.1.2 Scenario setting

As described in 2.1, this study assumes three different scenarios for the future energy demand patterns, namely Reference Scenario (REF, hereinafter), Net Zero Scenario (NZS) and Advanced Technologies Scenario (ATS) (Table 4.1-1). The reason for applying scenario analysis is the high uncertainty of the future political, economic, and social conditions surrounding the energy supply and demand in Bangladesh. If, for instance, the global requirement to cut greenhouse gas emissions became more stringent and an emerging country such as Bangladesh also is required to achieve net zero emissions in a shorter time horizon, its energy mix and power generation mix would become very different. Conducting scenario analysis brings useful reference and implications to examine the magnitude of such differed conditions to its future energy demand.

Table 4.1-1 Scenario Setting

	Reference Scenario (REF)	Advanced Technology Scenario (ATS)	Net Zero Scenario (NZS)
Characteristics	The past trends will continue based on the existing energy and environmental policies. Radical changes will not take place on energy efficiency and low carbonization policies.	Energy and environmental policies to ensure stable energy supply and strengthen climate action will be successful to a certain extent. Introduction of advanced technologies will progress.	Greenhouse gas emissions will be net zero in 2050. The transition path toward 2050 is estimated by backcasting approach.
Policy	Progressively strengthen low-carbon policies as observed in the past developments.	Significant progress in international cooperation along with strengthening domestic policies.	Extremely strong energy and environment policies are necessary to achieve net zero by 2050.
Technology	Efficiency improvement follows past trends. Cost reduction like past trends. Spread of low-carbon technologies through regulation and policy.	Technology progress accelerates cost reduction. Strengthening regulations and guidances accelerates dissemination.	Assume technologies to reduce greenhouse gas emissions to net zero in 2050. Timing and amount of introduction of each technology are assumed by backcasting approach.

Source: Prepared by the JICA Study Team

Among the three scenarios, REF is a scenario where the past trends will continue in the future. The scenario assumes that carbon emissions reduction will be pursued both globally and in Bangladesh, but the degree of progress will not significantly deviate from the historical trend. In terms of assumed technologies, some progresses will be observed in efficiency improvement, cost reduction of energy supply, adoption of low carbon technologies, but they will be on the extension of the past trend and will not see any acceleration despite the recent growing concerns on carbon neutrality.

NZS, by contrast, is the scenario where the most aggressive GHG emissions reduction actions are assumed. NZS assumes that GHG emissions from Bangladesh will be net zero through 2050 by adopting all available policy arrangements and technologies. While REF is estimated by the "forecasting" approach where the future is estimated based on the historical data and assumptions derived from the currently available information, NZS is estimated by a "back-casting" approach where the final goal at a specific point of the future (year 2050 in this case) is predetermined and the hypothetical pathway to this goal (future status required to realize the predetermined goal) is

sought. In other words, the scenario is a normative scenario for Bangladesh to achieve the net zero status in 2050 on a mandatory basis. It should be noted that in reality, given the development stage of Bangladesh economy and difficulty of the expected path outlined by the NZS, the target year for the Bangladesh economy to reach net zero emissions will be 2070 or after.

ATS sits somewhere between REF and NZS. In this scenario, the balance of the 3Es, or energy security, economic affordability and environmental sustainability of Bangladesh is seriously considered. The scenario is far more progressive than REF in terms of adoption of climate actions and innovative technologies to cut GHG emissions reflecting the growing interests to climate change issue globally. The scenario, however, is less progressive than NZS because pursuing net zero emissions in an emerging country within a limited period of time while development is necessary is highly likely to cause significant economic burden and social stresses. ATS is the scenario that the JICA study team recommends Bangladesh consider as the future energy demand and supply path.

4.1.3 Technology setting

In NZS, carbon emissions will be net zero by 2050. Technology development and international cooperation will be promoted at maximum (Table 4.1-2). For the technology development, energy conservation, electrification and hydrogen utilization have to be introduced at maximum in the industry sector. As well, thorough energy conservation and electrification must penetrate the residential and commercial sectors. In the road sector, almost all the cars must become electric vehicles (EVs) except for some hydrogen-type trucks and buses.

Table 4.1-2 Technology Setting: Industry, Road, Residential and Commercial Sectors

Demand Side		Net-Zero Scenario (NZS)	Advanced Technology Scenario (ATS)
Industry Sector	Energy Conservation	-43.2% (-2.0%/year) in 2050 from the REF level, holding other conditions constant	-24.5% (-1.0%/year) in 2050 from the REF level, holding other conditions constant
	Electrification	+15% points in 2050 from the REF level, holding other conditions constant	+10% (+5%*) points in 2050 from the REF level, holding other conditions constant
	Hydrogen	Non-electricity energy will shift to hydrogen through 2050.	—
Road Sector	Fuel Economy	IMF Ext: +130% in 2050 from the 2019 level, In-between: +170%, PP2041: +200%	IMF Ext: +5% in 2050 from the 2019 level, In-between: +35%, PP2041: +65%
	EVs	100% of passenger light-duty vehicles (PLDVs) and 90% of trucks and buses (TRBSs) will shift to electric vehicles (EVs) in 2050.	About 40% of PLDVs and 10% of TRBSs will shift to EVs in 2050.
	Hydrogen	10% of TRBSs will become fuel-cell vehicles (FCVs) in 2050.	—
Residential Sector	Energy Conservation	-34.5% (-1.5%/year) in 2050 from the REF level, holding other conditions constant	-13.1% (-0.5%/year) in 2050 from the REF level, holding other conditions constant
	Electrification	100% electrification	+15% (+7.5%*) points in 2050 from the REF level, holding other conditions constant
Commercial Sector	Energy Conservation	-43.2% (-2.0%/year) in 2050 from the REF level, holding other conditions constant	-13.1% (-0.5%/year) in 2050 from the REF level, holding other conditions constant
	Electrification	100% electrification	+1% points in 2050 from the REF level, holding other conditions constant

* ATS In-between & ATS IMF Ext cases

Source: JICA Study Team

In ATS, in contrast, environmental regulations and targets will be enhanced. Technology development and international cooperation will show significant progress. In the industry sector, considerable energy conservation and electrification will be expected as well as in the residential and commercial sectors. In the road sector, 40% of PLDVs and 10% of TRBSs in terms of registered car numbers are expected to shift from conventional gasoline or diesel driven to EVs.

In the power sector, clean energies such as renewables, nuclear and decarbonization technologies including ammonia co-firing, hydrogen single-firing and gas-fired power with CCS are expected to start diffusing in both NZS and ATS (Table 4.1-3). On the contrary, traditional captive power will decrease along with grid stabilization in both cases, while small amounts of high-efficiency co-generation systems will be introduced in some economic zones and large facilities through 2050 in ATS.

Table 4.1-3 Technology Setting (Power generation sector)

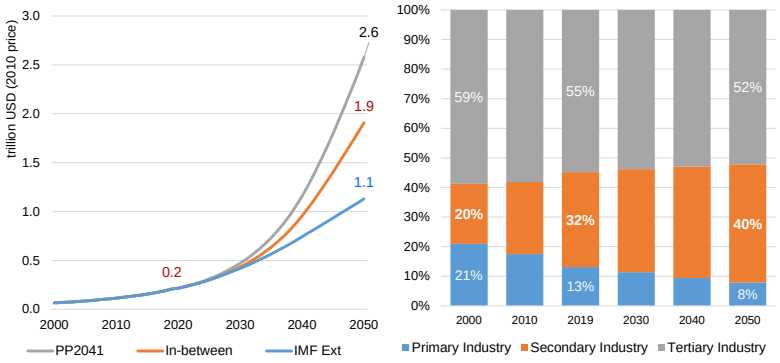
Supply Side		Net-Zero Scenario (NZS)		Advanced Technology Scenario (ATS)	
Power Sector	Renewables	Solar PV (Solar Park, Irrigation)	16 GW in 2050 with land use restrictions	Solar PV (Solar Park, Irrigation)	6 GW in 2050 without land use restrictions
		Solar PV (Rooftop)	12 GW in 2050 on rooftops of the buildings	Solar PV (Rooftop)	12 GW in 2050 on rooftops of the buildings
		Onshore wind	5 GW in 2050, mainly coasts	Onshore wind	5 GW in 2050, mainly coasts
		Offshore wind	50 GW (near seas + EEZ) in 2050 excl. heritages	Offshore wind	15 GW (only near seas) in 2050 excl. heritages
	Nuclear	Eight (8) units by 2050		Six (6) units (four (4) units*) by 2050	
	Coal-fired	50% ammonia co-firing around 2030 and 100% ammonia single-firing around 2042		20% ammonia co-firing around 2030 (2035*) and 50% ammonia co-firing around 2035 (2040*)	
	Gas-fired	100% hydrogen single-firing will start around 2035 and replace 70% of gas-fired power through 2050.Gas-fired with CCS will start around 2036 and achieve 30% of the gas-fired power in 2050.		20% hydrogen co-firing will start around 2035 (2037*), 100% hydrogen single-firing will start around 2040. Gas-fired with CCS will start around 2036 (2040*) and achieve 77 TWh (38 TWh**) in 2050.	
	Oil-fired	For about 1% of grid net power generation in 2041, oil-fired power will remain through 2050.		For about 1% of grid net power generation in 2041, oil-fired power will remain through 2050.	
	Captive	Conventional captive power will be zero in 2050.		Conventional captive power will remain a little in 2050, while high-efficiency co-gen system will be introduced from 2031 and reach 300 MW (app. 30 MW*10 towns) in 2050 nationally.	
	Import	15% of total electricity demand through 2050		Less than 12% of total electricity capacity through 2050	

* ATS In-between & ATS IMF Ext cases
** ATS IMF Ext case

Source: JICA Study Team

4.1.4 GDP assumptions

As explained in 2.4, GDP growth rate is a critical factor with high uncertainty while it largely determines the level of future energy demand. This study therefore analyzes three different GDP growth cases: PP2041 Case, In-between Case, and IMF Ext Case (Figure 4.1-2). In the highest GDP growth case (PP2041 Case), the Bangladesh economy is forecast to grow to 11.2-fold of the current level, while in the lowest growth case (IMF Ext Case), its economy will grow to 4.9-fold. Even in the lowest growth case, the Bangladesh economy will experience significant expansion and thus require massive infrastructure development to ensure adequate energy supply to sustain the economic growth.



	PP2041	In-Between	IMF Ext.
2000	5.3%		
2012	6.5%		
2019	8.2%		
2020	3.4%		
2021	6.9%		
2025	8.0%	6.9%	7.2%
2030	8.9%	7.7%	6.6%
2035	9.4%	8.2%	6.0%
2040	9.8%	8.6%	5.4%
2045	8.5%	7.3%	4.3%
2050	6.8%	5.6%	3.6%

GDP Growth | GDP Composition | GDP Growth Rate

Source: Prepared by the JICA Study Team

Figure 4.1-2 GDP Assumptions

What should also be noted here is the structure of industry. Currently the tertiary industry (services, etc.) takes the largest share of Bangladesh's economy. The relative share of the primary industry is likely to decline as Bangladesh evolves to a more matured economy. The share of secondary industry (manufacturing industry) is assumed to grow from 32% as of 2019 to 40% in 2050. This assumption is in line with the outlook provided in the PP2041. The policy document assumes that the major manufacturing industry is shifting from textile to light manufacturing industries such as machinery toward 2041, which will bring larger value-added and push up the share of the secondary industry.

4.1.5 International energy price assumption

International oil, coal and natural gas price assumption in real term is based on the IEA World Energy Outlook 2021 (Table 4.1-4). The international hydrogen price is the targeted price by the Japanese government. The international ammonia price is assumed by the JICA Study Team (IEEJ). In ATS, the oil price is expected to rise from 2020 to 2030 since 2020 had an impact of COVID-19 and decreased demand, and the price will gradually rise after 2030, reflecting oil demand and supply balance. While the natural gas price has experienced an increase in 2021, the price in ATS is expected to decline toward 2050 since developed countries are supposed to reduce fossil fuel consumption, and their natural gas demand will decline.

Since early 2022, world energy prices have soared significantly reflecting the Ukraine war and reduced the supply of oil and gas from Russia. In the long run, however, it is assumed that energy prices will come back on the traditional track as previously projected.

Table 4.1-4 International Energy Price Assumptions

Real price (US$ 2020)

	Oil			Coal			Natural Gas			Hydrogen	Ammonia
	(US$/bbl)			(US$/tonne)			(US$/MBtu)			(US$/Nm3)	(US$/tonne)
	REF	ATS	NZS	REF	ATS	NZS	REF	ATS	NZS	All scenarios	All scenarios
2020	41.3			60.8			8.3			-	-
2030	77.0	66.5	56.0	77.0	72.0	67.0	8.5	7.0	5.4	0.28	300
2041	83.1	67.9	52.7	73.2	69.0	64.8	8.7	7.0	5.3	0.23	278
2050	88.0	69.0	50.0	70.0	66.5	63.0	8.9	7.1	5.3	0.20	250

Nominal price

	Oil			Coal			Natural Gas			Hydrogen	Ammonia
	(US$/bbl)			(US$/tonne)			(US$/MBtu)			(US$/Nm3)	(US$/tonne)
	REF	ATS	NZS	REF	ATS	NZS	REF	ATS	NZS	All scenarios	All scenarios
2020	41.3			60.8			8.3			-	-
2030	108.2	93.4	78.7	108.2	101.2	94.1	11.9	9.8	7.6	0.39	409
2041	163.9	134.0	104.0	144.4	136.1	127.9	17.2	13.9	10.5	0.45	531
2050	229.4	179.9	130.3	182.5	173.4	164.2	23.2	18.5	13.8	0.50	632

Source: Prepared by the JICA Study Team based on IEA World Energy Outlook 2021

4.2 Final Energy Consumption

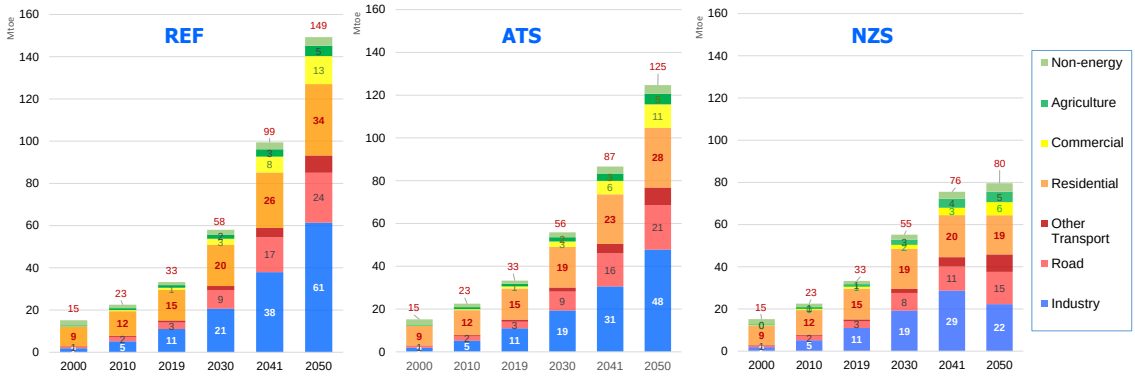
4.2.1 Comparison of Three Scenarios

Reflecting the differed levels of energy efficiency improvement and adopted technologies, total final energy consumption in 2050 will be the largest in the Reference Scenario (REF) followed by the Advanced Technology Scenario (ATS) and the Net-Zero Emissions Scenario (NZS). These scenarios are compared for the GDP PP2041 Case as below.

Final energy consumption (FEC) will be larger for REF than ATS or NZS because ATS assumes greater energy efficiency improvement than REF, and NZS assumes even stricter energy conservation actions than ATS. GDP intensity of energy consumption will keep decreasing in all three scenarios. The annual decline rate of the intensity between 2019 and 2050 will be -3.2%/year for REF, -3.8%/year for ATS and -5.2%/year for NZS. For reference, intensity improvements in other countries were -2.3% for India, -3.4% for Vietnam, and -4.0% for China after achieving US$1,300 (2010 price) of real GDP per capita which is close to the current level in Bangladesh. Thus, the energy demand growth path in REF is similar to that of Vietnam while the demand growth path in ATS is similar to that of China.

Among sectors, the industrial sector will be the largest demand sector for all three GDP cases in both 2041 and 2050, reflecting the sustainable economic growth and expansion of the country's industrial activities (Figure 4.2-1). This suggests that the future energy demand growth of Bangladesh largely rests on the preconditions that defines the development speed of the domestic industry. The second largest and the third largest demand sector in FEC are the residential and road transport sectors, respectively. Since the population of Bangladesh is expected to grow with the living standard of the people likely to keep rising during the entire period of this analysis, it

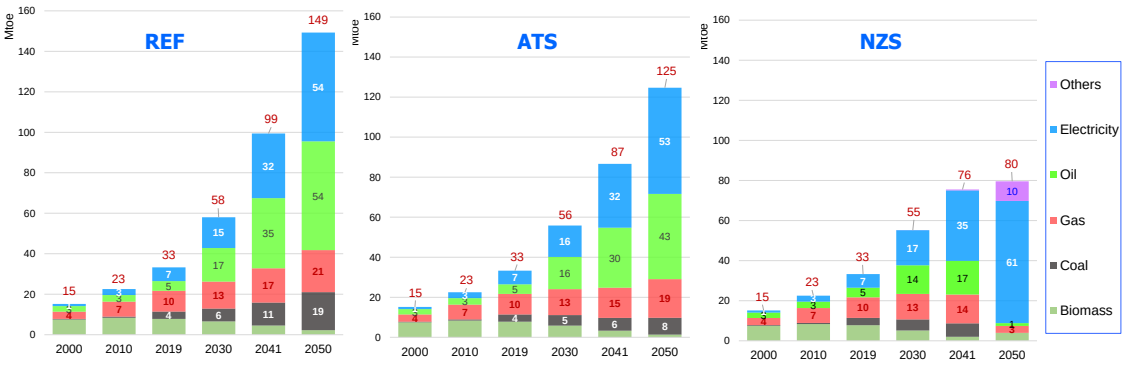
is inevitable to incur a steep demand increase in these two sectors.



Source: Prepared by the JICA Study Team

Figure 4.2-1 Final Energy Consumption by Sector: PP2041

By energy source, electricity will be the largest energy source for ATS and NZS (Figure 4.2-2). Besides electricity, a different mix of energy sources will be utilized in each scenario. In NZS, for instance, a substantial amount of hydrogen and ammonia will be used through 2050 based on the assumption that hydrogen (and ammonia as its carrier) will be a major energy source in the industry sector and in the maritime transport sector to realize net-zero emissions through 2050. In REF, by contrast, fossil fuels such as oil, gas and coal will still remain with relatively large shares.



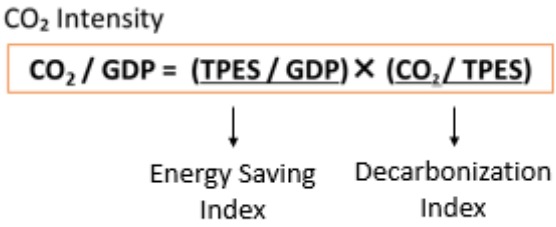
Source: Prepared by the JICA Study Team

Figure 4.2-2 Final Energy Consumption by Source: PP2041

4.2.2 Energy Saving and Decarbonization Indices

CO_2 intensity is a well-known benchmark index to evaluate low carbonization of a society. It is defined as CO_2 emissions divided by GDP. CO_2 intensity can be divided into two indices, energy saving index, or GDP intensity of total primary energy supply (TPES), and the decarbonization index as shown in Figure 4.2-1. The energy saving index is TPES divided by GDP, and the decarbonization index is CO_2 emissions divided by TPES. When the energy saving index is multiplied by the decarbonization index, it means CO_2 intensity. These two indices are

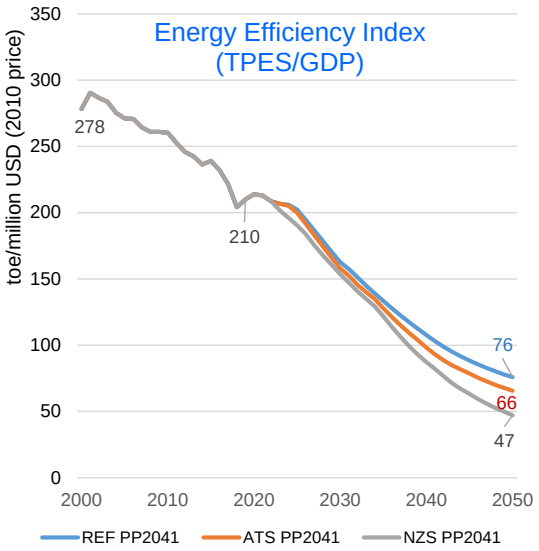
important to monitor status of CO_2 emissions reduction and increase in GDP simultaneously.



Source: JICA Study Team

Figure 4.2-3 Energy Saving Index and Decarbonization Index

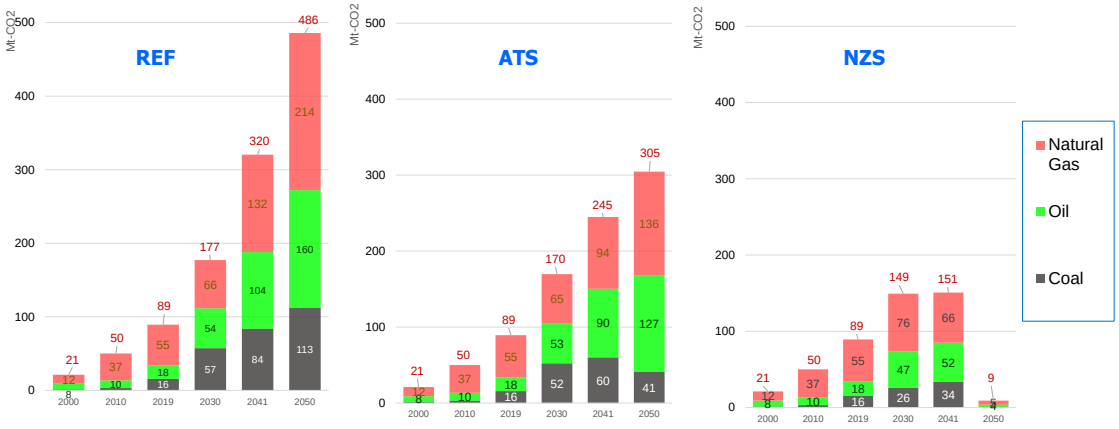
The energy efficiency index (EEI: TPES/GDP) declines along with technology progress and energy conservation efforts (Figure 4.2-4). It falls 64% between 2019 and 2050 in REF (3.2% annual decline), 69% in ATS (3.7%), and 78% in NZS (4.7%). As a reference, India's EEI reduced 2.4% annually between 2010 and 2019, and China's EEI reduced 3.5% annually between 1996 and 2019 after achieving the US$1,300 (2010 price) of real GDP per capita, respectively, which is close to the present status in Bangladesh. The estimated EEI improvement in ATS is almost the same as China's experience, and the estimated EEI improvement in NZS is considerably greater than China's experience.



Source: Prepared by the JICA Study Team

Figure 4.2-4 Energy Efficiency Index: Primary Energy Supply / GDP

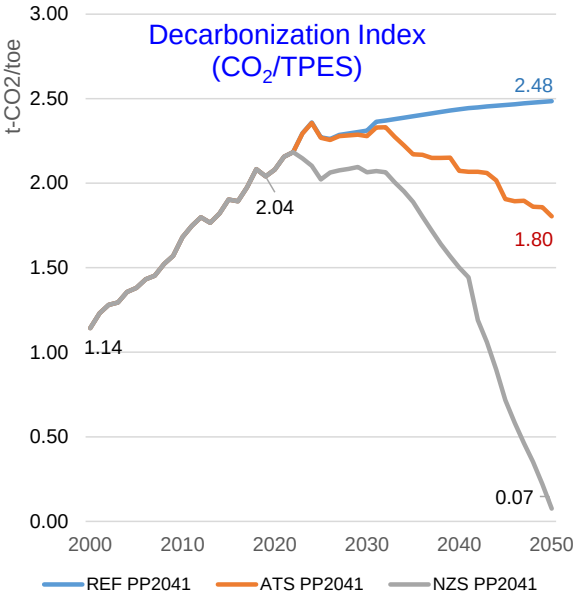
CO_2 emissions from energy use reflect the amount of fossil fuels in TPES (Fig. 4.2-5). Emissions will be the largest in REF, followed by ATS and NZS. The emissions of REF will significantly grow to around 401 million tons-CO_2 in 2050, which is about half of Japan's emissions in 2019. The emissions of ATS will be much more moderate at 248 million tons- CO2 in 2050, which is almost two-thirds of the level of REF. The emissions of NZS will be, by definition, almost zero in 2050. In NZS, drastic emissions reduction measures will be needed to significantly cut down the emissions from 145 million tons in 2041 to almost zero within a very short period of time.



Source: Prepared by the JICA Study Team

Figure 4.2-5 Energy-related CO_2 Emissions by Source: PP2041

The Decarbonization Index (DCI: CO_2/TPES) follows very different paths in three scenarios (Figure 4.2-6). It will continue to grow in REF, while it will gradually decline in ATS, reflecting the accelerated efforts to manage carbon emissions and adoption of advanced decarbonization technologies in the 2030s and 2040s. In NZS, applying the back-casting approach, it needs to drop sharply to achieve net zero in 2050. It is apparently difficult unless putting an extreme stress on the economy.



Source: Prepared by the JICA Study Team

Figure 4.2-6 Decarbonization Index: CO_2 Emissions / Primary Energy Supply

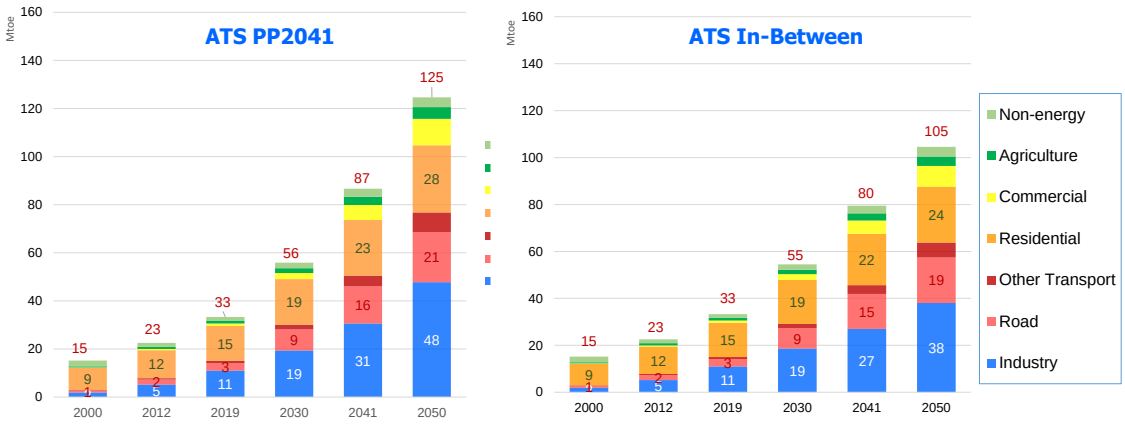
It is not an easy task to reduce carbon emissions in the process of economic development. In Asia, no country, such as Thailand, Indonesia, China, India, and Vietnam, has experienced a reduction of DCI on average in the industrialization period after achieving US$1,300 (2010 price) of real GDP per capita. Bangladesh has to make contributions to mitigate the global concerns on energy security and climate change as suggested by ATS rather than following REF. However, it will be a really challenging task to reduce DCI in the industrialization stage, save for the NZS scenario with substantial difficulties.

Based on the discussions above, the energy demand/supply forecast is run on the Advanced Technology Scenario (ATS) with two GDP projections of the PP2041 case and In-Between Case.

4.2.3 Main Scenario for Master Plan

With the pre-study on the three scenarios on energy efficiency and technology development as above, the Advanced Technology Scenario (ATS) is selected as the main scenario for the Integrated Energy and Power Master Plan (IEPMP). Then, future energy demand is projected for the GDP scenarios of PP 2041 and In-Between cases as below.

In accordance with high economic growth, the final energy consumption of Bangladesh is expected to expand 3.75-fold between 2019 and 2050 for ATS scenario with PP2041 GDP assumption at an average annual growth rate of 4.4%, while it will expand 3.14-fold at an annual 3.8% with In-between GDP assumption (Figure 4.2-7; Table 4.2-1).



Source: JICA Study Team

Figure 4.2-7 Final Energy Demand by Sector

Table 4.2-1 Final Energy Consumption by Sector

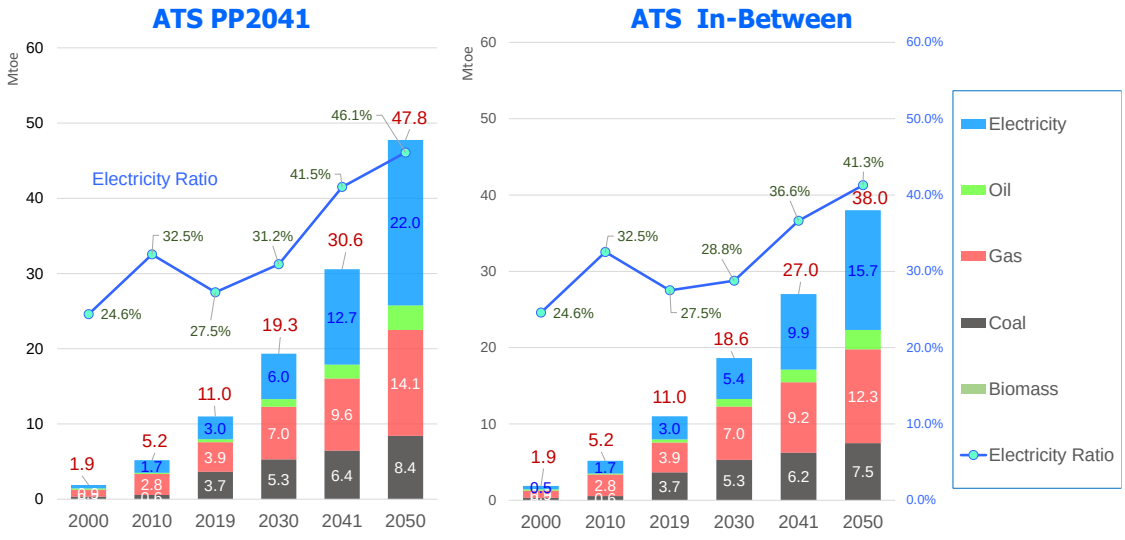
ATS	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Industry	11.0	19.3	30.6	47.8	33.1	34.6	35.3	38.3	5.3	4.3	5.1	4.34
Transport	4.0	10.7	19.9	29.0	12.2	19.2	22.9	23.3	9.2	5.8	4.3	7.16
Residential	14.6	19.0	23.2	27.9	43.7	34.0	26.8	22.4	2.5	1.8	2.1	1.92
Commercial	1.0	2.6	6.3	11.0	2.9	4.6	7.2	8.8	9.3	8.5	6.4	11.49
Agriculture	1.2	2.0	3.5	4.9	3.7	3.5	4.0	3.9	4.3	5.2	3.9	3.94
Non energy	1.5	2.3	3.3	4.1	4.4	4.1	3.8	3.3	4.1	3.3	2.5	2.76
Total	33.3	55.9	86.6	124.7	100.0	100.0	100.0	100.0	4.8	4.1	4.1	3.75
In-Between					%	%	%	%	%	%	%	times
Industry	11.0	18.6	27.0	38.0	33.1	34.2	34.0	36.4	4.9	3.4	3.9	3.46
Transport	4.0	10.5	18.6	25.8	12.2	19.2	23.4	24.6	9.0	5.4	3.7	6.36
Residential	14.6	18.8	21.9	23.8	43.7	34.4	27.5	22.8	2.3	1.4	0.9	1.64
Commercial	1.0	2.5	5.7	8.8	2.9	4.5	7.2	8.5	9.0	7.8	5.0	9.24
Agriculture	1.2	1.9	3.1	4.1	3.7	3.5	3.9	3.9	3.9	4.5	3.2	3.28
Non energy	1.5	2.3	3.3	4.1	4.4	4.2	4.1	3.9	4.1	3.3	2.5	2.76
Total	33.3	54.5	79.5	104.6	100.0	100.0	100.0	100.0	4.6	3.5	3.1	3.14

Source: JICA Study Team

Among sectors, the industry sector, which will lead the country's economic growth, will increase energy consumption rapidly even after significant energy efficiency and conservation measures are introduced. Consumption of transport fuel will also grow fast to reflect increasing demand for mobility. On the other hand, energy consumption at home will remain relatively slow. This is because inefficient traditional biomass, mainly firewood, will be replaced with modern energies such as electricity and LPG accompanied with significant efficiency improvement. Energy consumption of the commercial sector will grow fast to support modernization of life, but it remains relatively small. Agriculture will continue to consume a certain amount of energy for irrigation and agricultural machines. Non-energy consumption will also expand mainly as feedstock for fertilizer and petrochemical industries. Sectoral trends are analyzed as below.

1) Industry Sector

The industry sector will become the largest demand segment in Bangladesh around 2030 (Table 4.2-1). Without energy intensive heavy industries such as cement, steel by blast furnace and petrochemicals, electricity will be the main energy source to drive the industry sector (Figure 4.2-8; Table 4.2-2). Further electrification will progress in the textile industry, steel by electric furnace, and other high-tech sectors. Besides electricity, gas and coal will remain as the key energy sources. These fossil fuels will keep providing high temperature heat at relatively low costs.



Source: JICA Study Team

Figure 4.2-8 Industry-sector Energy Demand

It should be highlighted here that coal will be the third largest energy source. This is because of the existing infrastructure and its cost competitiveness compared to other energy options such as electricity supply from grid or natural gas.

The energy conservation rate for the industry sector, holding other conditions constant (without price effect, etc.), will be -24.5% (annual -1.0%) in 2050 compared with the demand estimated

for REF.

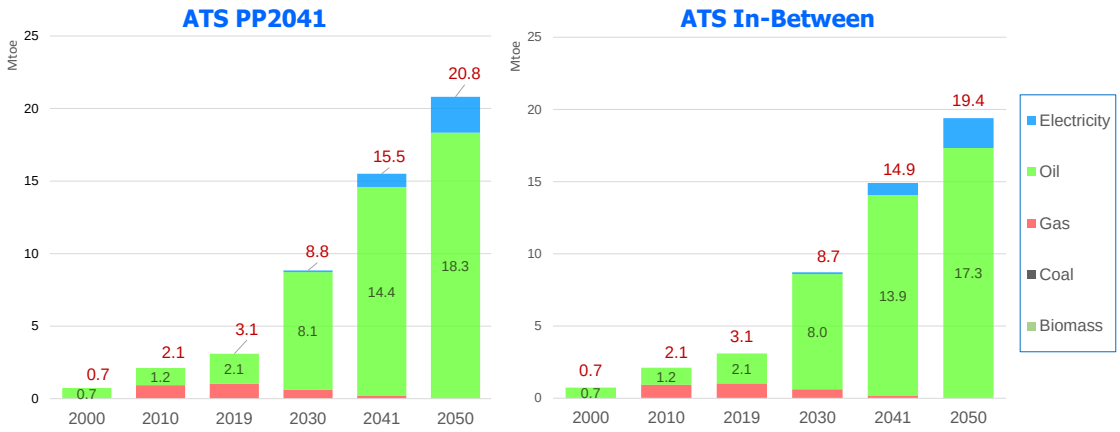
Table 4.2-2 Final Energy Consumption: Industry

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Coal	3.7	5.3	6.4	8.4	33.3	27.4	21.1	17.7	3.4	1.8	2.5	2.30
Oil	0.4	1.0	1.8	3.2	3.6	5.3	6.0	6.8	8.9	5.6	5.2	8.13
Natural Gas	3.9	7.0	9.6	14.1	35.6	36.1	31.4	29.5	5.4	2.9	3.5	3.59
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	8.0	13.3	17.9	25.8	72.5	68.8	58.5	53.9	4.8	2.7	3.4	3.23
Electricity	3.0	6.0	12.7	22.0	27.5	31.2	41.5	46.1	6.5	7.0	5.1	7.27
Total	11.0	19.3	30.6	47.8	100.0	100.0	100.0	100.0	5.3	4.3	4.1	4.34
In-Between					%	%	%	%	%	%	%	times
Coal	3.7	5.3	6.2	7.5	33.3	28.4	23.1	19.7	3.4	1.5	1.7	2.05
Oil	0.4	1.0	1.7	2.5	3.6	5.3	6.1	6.7	8.6	4.8	4.0	6.38
Natural Gas	3.9	7.0	9.2	12.3	35.6	37.5	34.2	32.3	5.4	2.6	2.6	3.14
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	8.0	13.3	17.1	22.3	72.5	71.2	63.4	58.7	4.7	2.3	2.4	2.80
Electricity	3.0	5.4	9.9	15.7	27.5	28.8	36.6	41.3	5.3	5.7	4.3	5.19
Total	11.0	18.6	27.0	38.0	100.0	100.0	100.0	100.0	4.9	3.4	3.2	3.46

Source: JICA Study Team

2) Road Sector

In the road sector, oil demand mainly comprising gasoline and diesel will dominate and significantly increase from the current level through 2050 (Figure 4.2-9; Table 4.2-3). As the country's per capita income increases together with population, demand for mobility will grow fast and boost car ownership. This will be accelerated by switching from two-wheeled motorcycles to four-wheeled conventional cars.



Source: JICA Study Team

Figure 4.2-9 Road-sector Energy Demand

In ATS, a growing number of EVs will penetrate the entire vehicle stock compared to REF, although its share will remain constrained. Road vehicles will continue to shift from internal combustion engine vehicles to Evs through 2050. The share of Evs in the vehicle stock in 2050

will be about 40% for PLDVs and 10% for trucks and buses. The EV production factory planned in the Mirsarai Economic Zone will be expanded to the maximum space capacity; the EVs produced there will become popular in the Bangladesh auto market.

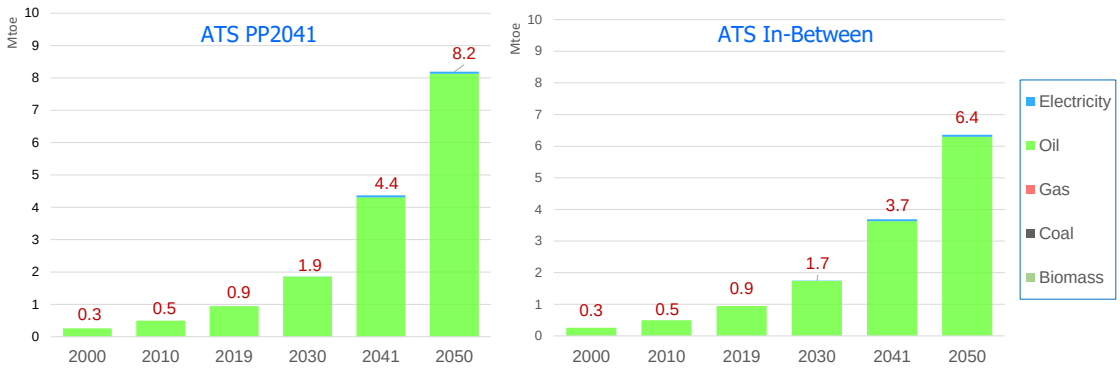
Table 4.2-3 Final Energy Consumption: Road

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	2051
PP 2041					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	2.1	8.1	14.4	18.3	66.9	91.7	92.9	88.2	13.2	5.4	2.2	8.84
Natural Gas	1.0	0.6	0.2	0.0	33.1	7.0	1.2	0.0	-4.5	-10.2	-100.0	0.00
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	3.1	8.7	14.6	18.3	100.0	98.7	94.2	88.2	9.9	4.8	2.1	5.91
Electricity	0.0	0.1	0.9	2.5	0.0	1.3	5.8	11.8	-	20.3	9.5	-
Total	3.1	8.8	15.5	20.8	100.0	100.0	100.0	100.0	10.0	5.2	2.7	6.71
In-Between					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	2.1	8.0	13.9	17.3	66.9	91.5	93.1	89.3	13.0	5.2	2.0	8.35
Natural Gas	1.0	0.6	0.2	0.0	33.1	7.1	1.3	0.0	-4.5	-10.2	-100.0	0.00
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	3.1	8.6	14.1	17.3	100.0	98.6	94.4	89.3	9.7	4.6	1.9	5.59
Electricity	0.0	0.1	0.8	2.1	0.0	1.4	5.6	10.7	-	19.2	8.6	-
Total	3.1	8.7	14.9	19.4	100.0	100.0	100.0	100.0	9.9	5.0	2.4	6.25

Source: JICA Study Team

3) Other Transport Sectors

Energy demand in the other transport sectors is relatively small (Figure 4.2-10; Table 4.2-4). It includes various transportation modes such as railways, domestic navigation, and domestic aviation. The non-road transport sector's demand is about one third of the road sector's demand. Infrastructures for these will keep developing, but the demand will not grow as fast as that of the road transport. As the past trend continues, most of the sectors' energy demand will be supplied by oil. A small amount of electricity will be used for Mass Rapid Transit, high-speed railway, etc.



Source: JICA Study Team

Figure 4.2-10 Other-transport-sector Energy Demand

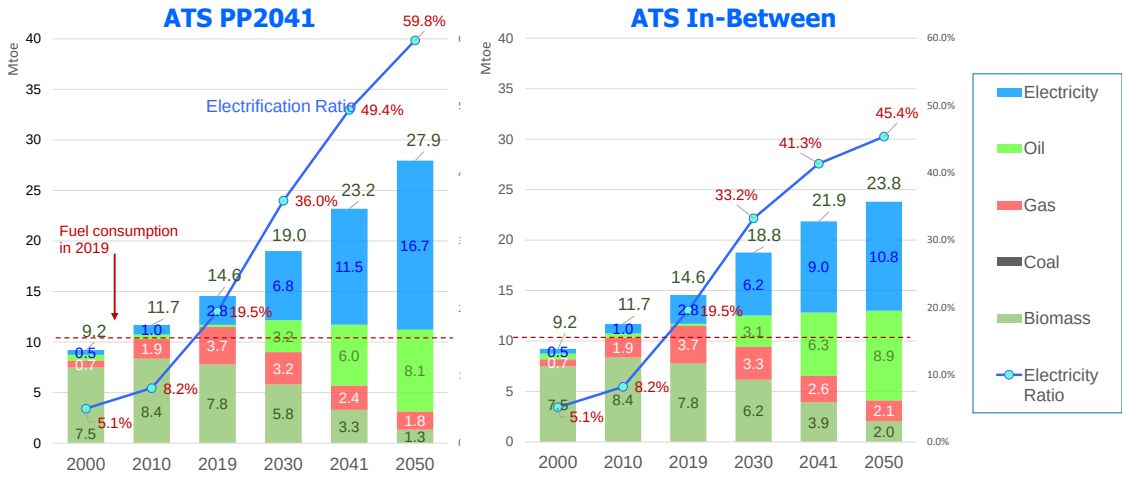
Table 4.2-4 Final Energy Consumption: Other Transport

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	2051
PP 2041					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	0.9	1.9	4.3	8.1	100.0	99.5	98.6	99.2	6.3	7.9	5.9	8.60
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	0.9	1.9	4.3	8.1	100.0	99.5	98.6	99.2	6.3	7.9	5.9	8.60
Electricity	0.0	0.0	0.1	0.1	0.0	0.5	1.4	0.8	-	19.7	0.0	-
Total	0.9	1.9	4.4	8.2	100.0	100.0	100.0	100.0	6.4	8.0	5.9	8.67
In-Between					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	0.9	1.7	3.6	6.3	100.0	99.5	98.3	99.0	5.7	6.9	5.1	6.67
Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	0.9	1.7	3.6	6.3	100.0	99.5	98.3	99.0	5.7	6.9	5.1	6.67
Electricity	0.0	0.0	0.1	0.1	0.0	0.5	1.7	1.0	-	19.7	0.0	-
Total	0.9	1.7	3.7	6.4	100.0	100.0	100.0	100.0	5.7	7.0	5.1	6.73

Source: JICA Study Team

4) Residential Sector

In the residential sector, electricity will become the largest energy source (Figure 4.2-11; Table 4.2-5). It will be the enabler for people to enjoy a high-quality life with convenient and multi-functional electric appliances such as refrigerators, washing machines, vacuum cleaners, IH cookers and air conditioners. As the GDP per capita grows and the living standard improves, electricity demand by these appliances will inevitably increase. Thus, most of the demand increase occurs for electricity, and its share in the residential sector energy consumption will exceed 50% by 2050.



Source: JICA Study Team

Figure 4.2-11 Residential-sector Energy Demand

As for non-electricity energies for the residential sector, LPG, categorized as oil, and city gas will be used as the main modern fuel for cooking and hot water supply through 2050. Since the

incremental demand for both natural gas and LPG must be imported, their roles must be sorted out appropriately. Traditional biomass will rapidly decrease replaced by electricity, LPG and gas along with the rise of living standards. This will improve the domestic air quality and human health. It will also materialize significant energy efficiency improvement and thus the overall fuel demand except for electricity will remain almost the same as shown in Figure 4.2-11.

Table 4.2-5 Final Energy Consumption: Residential Sector

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	0.2	3.2	6.0	8.1	1.4	16.6	26.0	29.0	28.3	6.1	2.7	39.75
Natural Gas	3.7	3.2	2.4	1.8	25.6	16.8	10.4	6.4	-1.4	-2.5	-2.7	0.48
Biomass	7.8	5.8	3.3	1.3	53.5	30.7	14.2	4.8	-2.6	-5.1	-7.8	0.17
Combustible Fuel	11.7	12.2	11.7	11.2	80.5	64.0	50.6	40.2	0.3	-0.3	-0.4	0.96
Electricity	2.8	6.8	11.5	16.7	19.5	36.0	49.4	59.8	8.3	4.8	3.5	5.87
Total	14.6	19.0	23.2	27.9	100.0	100.0	100.0	100.0	2.5	1.8	1.7	1.92
In-Between					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	0.2	3.1	6.3	8.9	1.4	16.5	28.6	37.4	28.0	6.6	3.3	43.59
Natural Gas	3.7	3.3	2.6	2.1	25.6	17.5	12.0	8.7	-1.2	-2.0	-2.2	0.56
Biomass	7.8	6.2	3.9	2.0	53.5	32.8	18.0	8.6	-2.1	-4.0	-5.8	0.26
Combustible Fuel	11.7	12.5	12.8	13.0	80.5	66.8	58.7	54.6	0.6	0.2	0.1	1.11
Electricity	2.8	6.2	9.0	10.8	19.5	33.2	41.3	45.4	7.4	3.4	1.6	3.80
Total	14.6	18.8	21.9	23.8	100.0	100.0	100.0	100.0	2.3	1.4	0.8	1.64

Source: JICA Study Team

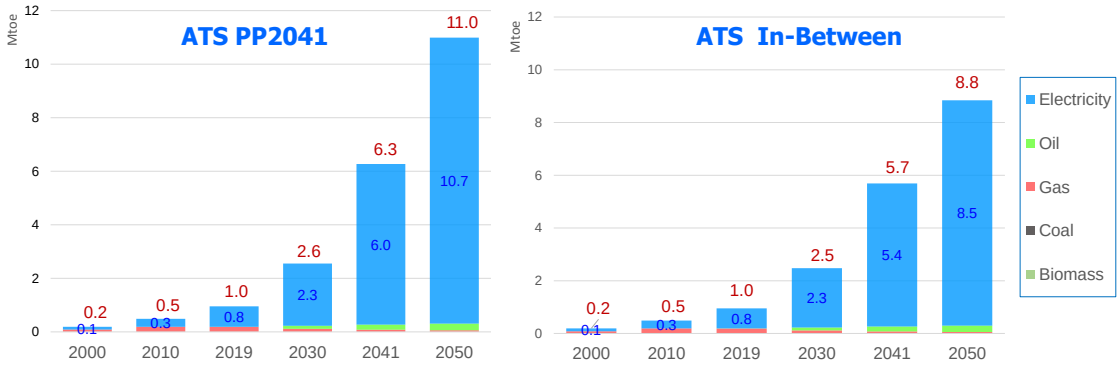
The energy conservation rate for the residential sector, holding other conditions constant (without price effect, etc.), will be -13.1% (annual -0.5%) in 2050 compared with the demand estimated for REF. It is relatively more moderate than that for the industry sector. This is because people tend to purchase more appliances as their income increases, and implementation of energy conservation policy for residential sector is usually more challenging being confined to upgrading the performance of appliances.

5) Commercial Sector

In the commercial sector, electricity already plays a pivotal role, and this status will continue long into the future (Figure 4.2-12; Table 4.2-6). In this, more than 90% of the energy supply was electricity in 2019, which makes the sector the most electrified sector in Bangladesh. A small amount of the commercial sector's demand is supplied with natural gas and oil (LPG) mainly used for cooking and hot water supply at restaurants, hotels and public facilities.

The energy conservation rate for the commercial sector, holding other conditions constant (without price effect, etc.), will be -13.1% (annual -0.5%) in 2050 compared with the demand estimated for REF. It is the same rate as that for the residential sector since energy conservation for the commercial sector is also challenging as performances are mostly fixed at the time when building and facilities are built. The incremental demand in the commercial sector will be mostly supplied by electricity. Natural gas will be utilized in the sector, but its share will be limited.

Possibility of introducing co-generation (CHP: combined heat and power) with high efficiency of 70-80% may be considered in special economic zones including large-scale complexes and shopping malls.



Source: JICA Study Team

Figure 4.2-12 Commercial-sector Energy Demand

Table 4.2-6 Final Energy Consumption: Commercial Sector

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	0.0	0.1	0.2	0.2	0.5	4.5	3.0	2.3	33.0	4.7	2.4	49.74
Natural Gas	0.2	0.1	0.1	0.1	19.5	4.5	1.3	0.5	-4.3	-3.0	-2.8	0.32
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	0.2	0.2	0.3	0.3	20.1	9.0	4.4	2.8	1.7	1.6	1.1	1.61
Electricity	0.8	2.3	6.0	10.7	79.8	91.0	95.6	97.2	10.6	9.0	5.4	13.98
Total	1.0	2.6	6.3	11.0	100.0	100.0	100.0	100.0	9.3	8.5	5.2	11.49
In-Between					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	0.0	0.1	0.2	0.2	0.5	4.6	3.3	2.7	32.9	4.6	2.3	48.02
Natural Gas	0.2	0.1	0.1	0.1	19.5	4.6	1.4	0.7	-4.3	-3.2	-2.9	0.31
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	0.2	0.2	0.3	0.3	20.1	9.2	4.7	3.4	1.6	1.4	1.0	1.55
Electricity	0.8	2.3	5.4	8.5	79.8	90.8	95.3	96.6	10.3	8.3	4.2	11.18
Total	1.0	2.5	5.7	8.8	100.0	100.0	100.0	100.0	9.0	7.8	4.1	9.24

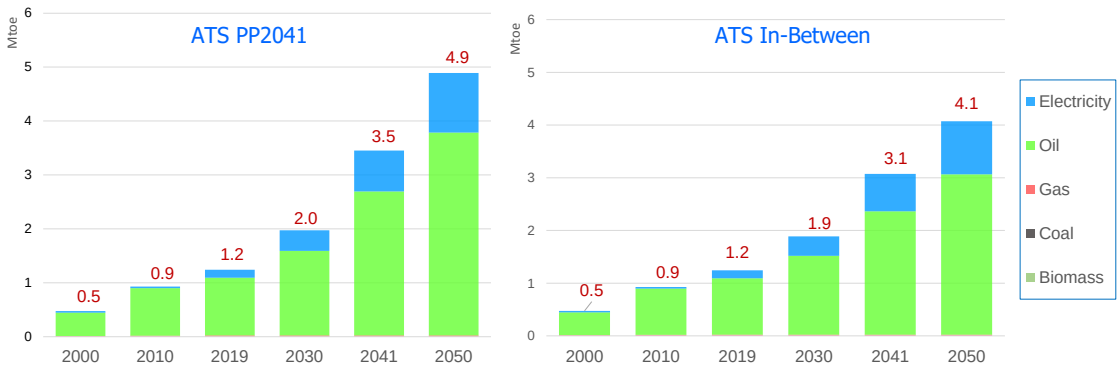
Source: JICA Study Team

6) Agricultural Sector

The size of the energy demand in the agricultural sector is smaller than those of other final consumption sectors although the sector occupies a very important position in the Bangladesh economy as it is closely related to the daily life of the citizens (Figure 4.2-13; Table 4.2-7). Most of the energy in the agricultural sector is used for irrigation, and oil products are the dominant fuel in the sector. While the sector will continue its high dependence on oil, electricity consumption will also increase by introduction of PVs and connections to the grid system.

To rationalize the energy use in this sector, a nationwide rational irrigation system together with flood prevention measures may also be considered covering from the upstream through

downstream of the water flow connecting users by water channels.



Source: JICA Study Team

Figure 4.2-13 Agricultural-sector Energy Demand

Table 4.2-7 Final Energy Consumption: Agricultural Sector

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	1.1	1.6	2.7	3.8	86.0	79.5	77.3	76.9	3.5	5.0	3.2	3.52
Natural Gas	0.0	0.0	0.0	0.0	1.9	1.2	0.7	0.5	0.0	0.0	0.0	1.00
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	1.1	1.6	2.7	3.8	87.9	80.7	78.0	77.4	3.5	4.9	3.1	3.46
Electricity	0.2	0.4	0.8	1.1	12.1	19.3	22.0	22.6	8.8	6.5	3.5	7.37
Total	1.2	2.0	3.5	4.9	100.0	100.0	100.0	100.0	4.3	5.2	3.9	3.94
In-Between					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	1.1	1.5	2.3	3.0	86.0	79.2	76.1	74.7	3.1	4.2	2.4	2.85
Natural Gas	0.0	0.0	0.0	0.0	1.9	1.3	0.8	0.6	0.0	0.0	0.0	1.00
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	1.1	1.5	2.4	3.1	87.9	80.5	76.9	75.3	3.0	4.1	2.4	2.81
Electricity	0.2	0.4	0.7	1.0	12.1	19.5	23.1	24.7	8.5	6.1	3.2	6.70
Total	1.2	1.9	3.1	4.1	100.0	100.0	100.0	100.0	3.9	4.5	3.2	3.28

Source: JICA Study Team

7) Non-energy Sector

Contrary to the declining trend in the last two decades, the energy demand for the non-energy sector will start to grow again towards 2050. This demand growth will be generated mainly because natural gas for the fertilizer industry will regain its production, while naphtha demand will also increase in line with the increase of chloroethylene (PVC) for

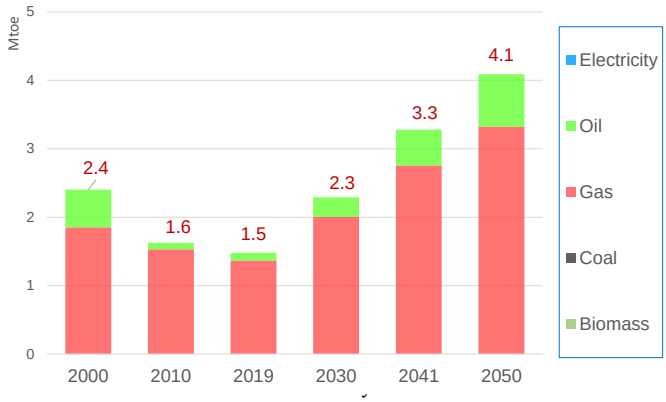


Figure 4.2-14 Non-energy-sector Energy Demand

buildings. Energy demand for the non-energy sector will increase to around 4 Mtoe in 2050, but still remain at a relatively low level. On the non-energy demand, the same projection is assumed for both the PP2041 and In-between cases.

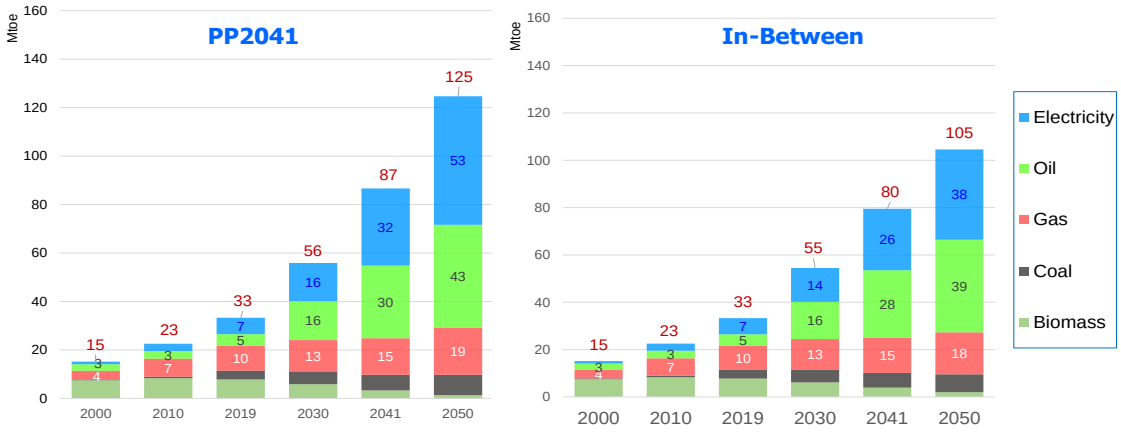
Table 4.2-8 Final Energy Consumption: Non-Energy

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Oil	0.1	0.3	0.5	0.8	7.6	12.4	16.0	18.8	8.8	5.7	3.5	6.79
Natural Gas	1.4	2.0	2.8	3.3	92.4	87.6	84.0	81.2	3.5	2.9	1.7	2.43
Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Combustible Fuel	1.5	2.3	3.3	4.1	100.0	100.0	100.0	100.0	4.1	3.3	2.0	2.76
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Total	1.5	2.3	3.3	4.1	100.0	100.0	100.0	100.0	4.1	3.3	2.5	2.76

Source: JICA Study Team

4.2.4 Energy Demand by Energy Source

The final energy consumption by energy source is summarized in Figure 4.2-15 and Table 4.2-9. Among energy sources, electricity consumption will grow as the largest energy provider, and oil consumption will also grow fast mainly as transportation fuel. On the other hand, natural gas consumption will remain relatively slow reflecting energy efficiency and conservation efforts in the industry sector and less utilization in the road, residential and commercial sectors. Coal will be consumed only in the industry sector for certain heat demand. Consumption of traditional biomass will decrease and will almost disappear in the 2040s.



Source: JICA Study Team

Figure 4.2-15 Final Energy Consumption by Energy

Requirement for each energy is discussed in Chapter 6 Primary Energy Supply, adding the final energy demand as discussed above and the energy consumed by the transformation sector such as power generation and refinery operation.

Table 4.2-9 Final Energy Consumption by Energy Source

	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Coal	3.7	5.3	6.4	8.4	11.0	9.5	7.4	6.8	3.4	1.8	3.0	2.30
Oil	4.8	16.1	30.0	42.6	14.5	28.8	34.6	34.2	11.6	5.8	4.0	8.86
Natural Gas	10.2	12.9	15.0	19.3	30.8	23.1	17.4	15.5	2.1	1.4	2.8	1.88
Biomass	7.8	5.8	3.3	1.3	23.4	10.4	3.8	1.1	-2.6	-5.1	-9.5	0.17
Combustible Fuel	26.5	40.2	54.8	71.6	79.6	71.9	63.2	57.5	3.9	2.9	3.0	2.70
Electricity	6.8	15.7	31.9	53.0	20.4	28.1	36.8	42.5	7.9	6.6	5.8	7.82
Total	33.3	55.9	86.6	124.7	100.0	100.0	100.0	100.0	4.8	4.1	4.1	3.75
In-Between					%	%	%	%	%	%	%	times
Coal	3.7	5.3	6.2	7.5	11.0	9.7	7.8	7.2	3.4	1.5	2.1	2.05
Oil	4.8	15.7	28.5	39.1	14.5	28.8	35.8	37.4	11.3	5.6	3.6	8.13
Natural Gas	10.2	13.0	14.9	17.8	30.8	23.9	18.8	17.0	2.2	1.2	2.0	1.73
Biomass	7.8	6.2	3.9	2.0	23.4	11.3	4.9	2.0	-2.1	-4.0	-7.0	0.26
Combustible Fuel	26.5	40.2	53.6	66.4	79.6	73.7	67.3	63.5	3.9	2.6	2.4	2.51
Electricity	6.8	14.3	26.0	38.2	20.4	26.3	32.7	36.5	7.0	5.5	4.4	5.63
Total	33.3	54.5	79.5	104.6	100.0	100.0	100.0	100.0	4.6	3.5	3.1	3.14

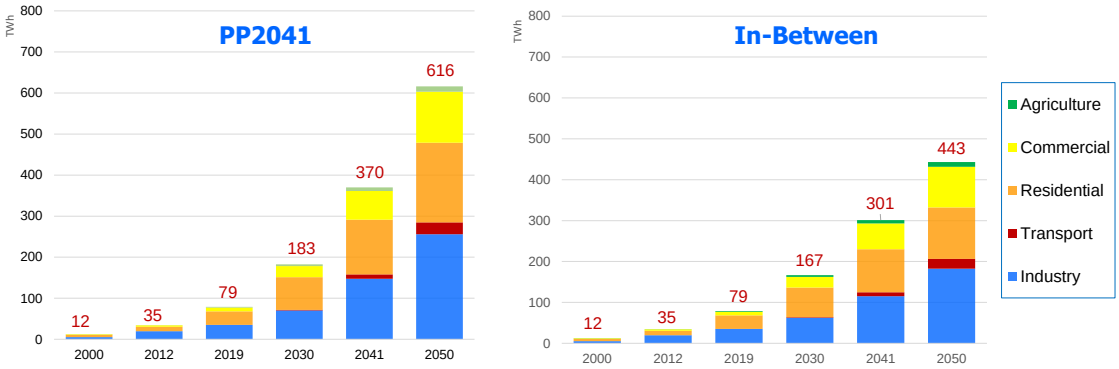
Source: JICA Study Team

Electricity is the key element for modernization of life and economy (Table 4.2-10). Its demand is expected to expand 7.81-fold in the PP2041 case between 2019 and 2050, and 5.62-fold in the In-Between case. The industrial sector will be the largest demand sector followed by residential and commercial sectors. Though still small, electricity consumption for transport will start to grow fast from the 2030s and onwards.

Table 4.2-10 Final Energy Demand: Electricity

	Final Energy Demand (TWh)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Industry	35.2	70.2	147.6	255.9	44.6	38.5	39.9	41.5	6.5	7.0	5.1	7.27
Transport	0.0	1.4	10.5	28.7	0.0	0.8	2.8	4.7	-	20.3	9.5	-
Residential	33.1	79.5	133.3	194.3	41.9	43.6	36.0	31.5	8.3	4.8	3.5	5.87
Commercial	8.9	27.0	69.7	124.2	11.3	14.8	18.8	20.2	10.6	9.0	5.4	13.98
Agriculture	1.7	4.4	8.8	12.9	2.2	2.4	2.4	2.1	8.8	6.5	3.5	7.37
Total	78.9	182.6	370.1	616.0	100.0	100.0	100.0	100.0	7.9	6.6	4.7	7.81
In-Between					%	%	%	%	%	%	%	times
Industry	35.2	62.3	115.1	182.5	44.6	37.4	38.2	41.2	5.3	5.7	4.3	5.19
Transport	0.0	1.4	9.7	24.1	0.0	0.8	3.2	5.4	-	19.2	8.6	-
Residential	33.1	72.5	105.1	125.6	41.9	43.5	34.9	28.3	7.4	3.4	1.6	3.80
Commercial	8.9	26.2	63.1	99.4	11.3	15.7	20.9	22.4	10.3	8.3	4.2	11.18
Agriculture	1.7	4.3	8.2	11.7	2.2	2.6	2.7	2.6	8.5	6.1	3.2	6.70
Total	78.9	166.7	301.3	443.2	100.0	100.0	100.0	100.0	7.0	5.5	3.6	5.62

Source: JICA Study Team



Source: JICA Study Team

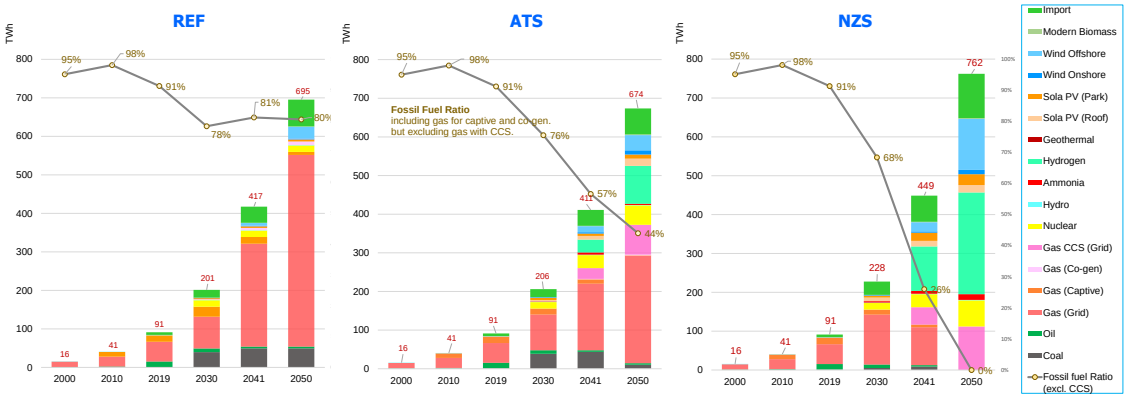
Figure 4.2-16 Final Energy Demand: Electricity

4.3 Power generation

Power generation is estimated based on the electricity demand as discussed above. In view of the rising concern on the climate change, the power sector is the most important sector to challenge low carbonization of the country.

4.3.1 Comparison of Three Scenarios

The size of estimated power generation of the three scenarios has a different order from FEC as shown in Figure 4.3-1.



Source: Prepared by the JICA Study Team

Figure 4.3-1 Power Generation

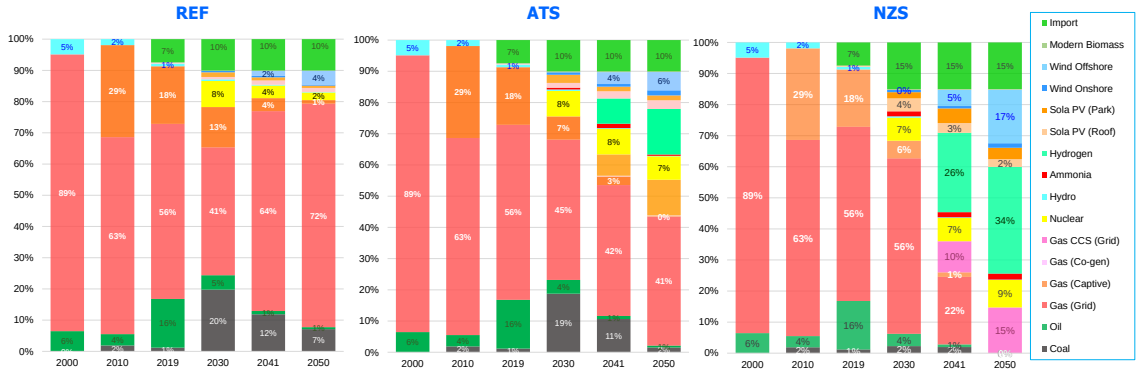
NZS requires the largest power generation in 2050 followed by REF and ATS. This is because electrification will be pursued at maximum in all demand sectors in NZS. Power generation of ATS is smaller than that of REF because ATS assumes greater energy efficiency improvement[2]. In NZS, coal-fired power will shift to ammonia after its introduction as co-firing fuel. Gas-fired

[2] Total power generation for different scenarios needs to consider price effect (-), energy conservation effect (-) and electrification effect(+) while income effect is common among the three scenarios with the GDP PP2041 Case.

power, likewise, will be replaced by hydrogen-fired power very rapidly after its introduction. Ammonia will also be adopted in ATS, but its penetration will be relatively more moderate than in NZS. It should also be highlighted that, in renewable energy, both NZS and ATS expect significant expansion of offshore wind energy as the country is likely to be blessed with large resource potential and its generation cost is expected to fall in the future.

The power generation mix apparently varies among the three scenarios. The largest power generation source in 2050, for example, is natural gas for REF and ATS, while it is hydrogen for NZS (Figure 4.3-2). The JICA Study Team expects that, in NZS, hydrogen instead of renewable energy will be the largest power generation source as domestic renewable energy resources are limited. Although NZS assumes the maximum introduction of on/offshore wind and solar PV, their resource potentials in Bangladesh are far short of fully decarbonizing the power generation. NZS also assumes that eight units of nuclear power generation will be installed, and CCS will be applied to some of the gas-fired power generation as Bangladesh has suitable geological structures for CO_2 storage under the ground. Nevertheless, such additions of zero-emission power sources will have only limited contributions to the country's power generation mix in NZS. Hydrogen thus needs to be adopted to make up for the shortage of decarbonized power generation to achieve net-zero power generation mix through 2050. NZS assumes that the global hydrogen market will be developed through 2050 and any shortfall of domestic hydrogen supply will be procured from the international market.

Renewable power for REF will achieve the NDC unconditional target by 2030, and that for NZS will reach the NDC conditional target by 2030.



Source: Prepared by the JICA Study Team

Figure 4.3-2 Power Generation Mix

4.3.2 Main Scenario for Master Plan

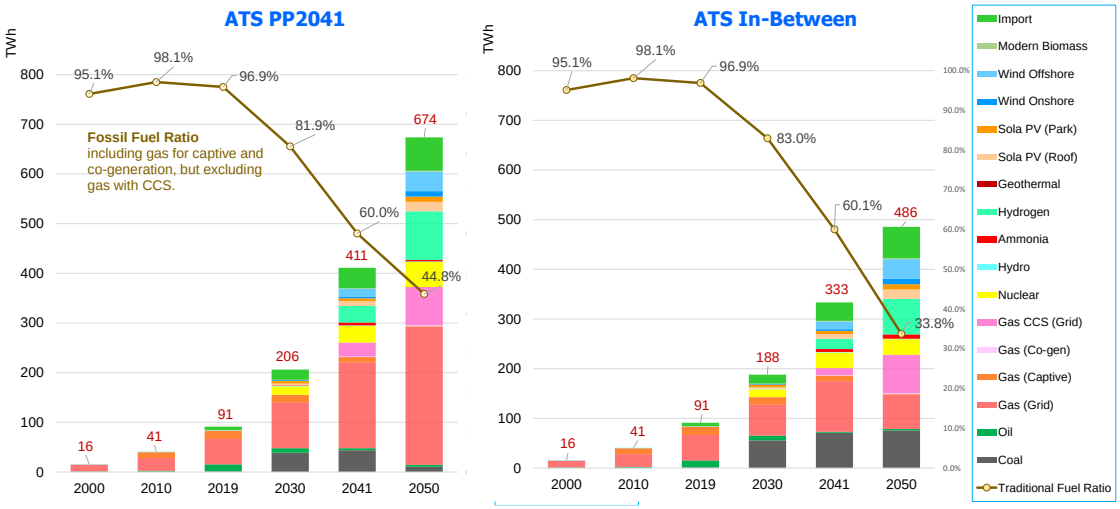
With high-speed industrialization and income growth, electricity demand will grow fastest among the energy sources. The requirement for power supply will expand 7.38-fold in the PP 2041 case between 2019 and 2050, and 5.32-fold in the In-between case (Table 4.3-1). At present,

91.3% of the power supply comes from thermal power plants burning conventional fossil fuels such as coal, oil and natural gas. Only 1.2% is supplied by clean energy mainly PVs and 7.5% comes from import. With a view to construct a low-carbon economy, every clean energy such as nuclear, hydro, PV, wind, CCS, ammonia, hydrogen, etc. must be introduced extensively. And thus, the conventional fossil fuel ratio including natural gas used at captive and co-generation users needs to be decreased from 91% in 2019 to about 40% in 2050.

Table 4.3-1 Outlook of Power Supply: ATS

	Power Generation (TWh)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Traditionl Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Coal	1.1	38.7	43.8	10.4	1.2	18.8	10.7	1.5	38.4	1.1	-12.3	9.58
Oil	14.3	9.1	4.0	4.0	15.6	4.4	1.0	0.6	-4.0	-7.2	0.0	0.28
Natural Gas - Grid	51.2	92.6	172.4	277.8	56.1	44.9	41.9	41.2	5.5	5.8	4.4	5.43
Natural gas - Captive	16.9	15.3	11.3	1.3	18.5	7.4	2.7	0.2	-0.9	-2.7	-17.8	0.08
Naturall Gas - Co-gen.	0.0	0.0	1.0	1.8	0.0	0.0	0.2	0.3	-	-	5.6	-
Import (Trad Fuel)	5.1	13.1	14.3	6.5	5.6	6.4	3.5	1.0	9.0	0.7	-6.9	1.28
Tradditional Fuel	88.5	168.9	246.7	301.9	96.9	81.9	60.0	44.8	6.1	3.5	1.9	3.41
Naturlal Gas - CCS	0.0	0.0	28.0	77.1	0.0	0.0	6.8	11.4	-	-	9.6	-
Nuclear	0.0	16.8	33.6	50.5	0.0	8.2	8.2	7.5	-	6.5	3.8	-
Hydro	0.8	1.0	1.0	1.0	0.8	0.5	0.2	0.1	2.4	0.0	0.0	1.30
Ammonia	0.0	1.2	5.8	2.9	0.0	0.6	1.4	0.4	-	15.8	-6.1	-
Hydrogen	0.0	0.0	33.3	98.1	0.0	0.0	8.1	14.6	-	-	10.3	-
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar (Roof)	0.3	3.2	9.5	18.9	0.4	1.5	2.3	2.8	22.5	10.5	6.5	56.15
Solar (Park)	0.0	5.4	6.1	10.5	0.0	2.6	1.5	1.6	58.9	1.2	5.0	318.55
Wind - onshore	0.0	1.6	3.4	11.0	0.0	0.8	0.8	1.6	66.6	7.0	11.1	1825.00
Wind - Offshore	0.0	0.0	15.7	39.4	0.0	0.0	3.8	5.9	-	-	8.8	-
Modern Biomass	0.0	0.7	1.1	1.6	0.0	0.3	0.3	0.2	-	4.4	4.0	-
Import (Clean Energy)	1.7	7.5	26.9	60.9	1.9	3.6	6.5	9.0	14.4	12.3	7.7	35.91
Clean Energy	2.8	37.3	164.4	371.8	3.1	18.1	40.0	55.2	26.4	14.4	7.7	130.92
Total	91.3	206.1	411.1	673.7	100.0	100.0	100.0	100.0	7.7	6.5	4.6	7.38
In-Between					%	%	%	%	%	%	%	times
Traditionl Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Coal	1.1	55.7	71.0	75.7	1.2	29.7	21.3	15.6	43.0	2.2	0.6	69.73
Oil	14.3	9.5	2.0	2.9	15.6	5.1	0.6	0.6	-3.6	-13.3	3.7	0.21
Natural Gas - Grid	51.2	62.2	101.9	69.1	56.1	33.1	30.5	14.2	1.8	4.6	-3.5	1.35
Natural gas - Captive	16.9	15.3	11.3	1.3	18.5	8.2	3.4	0.3	-0.9	-2.7	-17.8	0.08
Naturall Gas - Co-gen.	0.0	0.0	1.0	1.8	0.0	0.0	0.3	0.4	-	-	5.6	-
Import (Trad Fuel)	5.1	13.1	13.1	13.1	5.6	7.0	3.9	2.7	9.0	0.0	0.0	2.58
Tradditional Fuel	88.5	156.0	200.3	164.0	96.9	83.0	60.1	33.8	5.3	2.3	-1.8	1.85
Naturlal Gas - CCS	0.0	0.0	14.0	77.1	0.0	0.0	4.2	15.9	-	-	16.8	-
Nuclear	0.0	15.8	31.5	31.5	0.0	8.4	9.5	6.5	-	6.5	0.0	-
Hydro	0.8	1.0	1.0	1.0	0.8	0.5	0.3	0.2	2.4	0.0	0.0	1.30
Ammonia	0.0	0.0	5.8	8.4	0.0	0.0	1.7	1.7	-	-	3.5	-
Hydrogen	0.0	0.0	21.0	71.8	0.0	0.0	6.3	14.8	-	-	11.8	-
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar (Roof)	0.3	3.2	9.5	18.9	0.4	1.7	2.8	3.9	22.5	10.5	6.5	56.15
Solar (Park)	0.0	5.4	6.1	10.5	0.0	2.9	1.8	2.2	58.9	1.2	5.0	318.55
Wind - onshore	0.0	1.6	3.4	11.0	0.0	0.9	1.0	2.3	66.6	7.0	11.1	1825.00
Wind - Offshore	0.0	0.0	15.7	39.4	0.0	0.0	4.7	8.1	-	-	8.8	-
Modern Biomass	0.0	0.7	1.1	1.6	0.0	0.3	0.3	0.3	-	4.4	4.0	-
Import (Clean Energy)	1.7	4.4	24.1	50.4	1.9	2.3	7.2	10.4	9.0	16.7	6.9	29.72
Clean Energy	2.8	32.0	133.2	321.7	3.1	17.0	39.9	66.2	24.6	13.9	8.3	113.26
Total	91.3	187.9	333.5	485.7	100.0	100.0	100.0	100.0	6.8	5.4	3.5	5.32

Source: JICA Study Team



Source: JICA Study Team

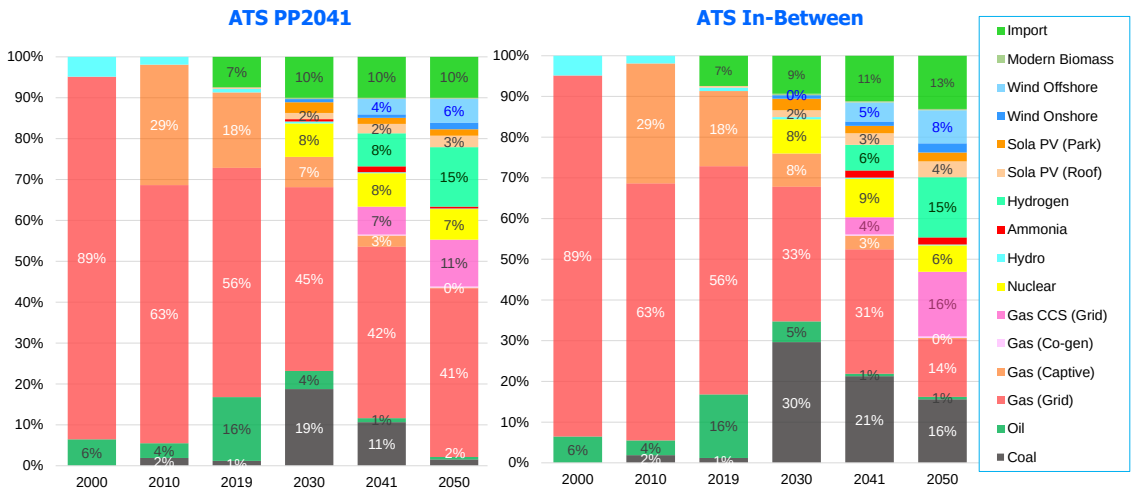
Note: Net power generation is more detailly analyzed in Chapter 5 Power System Development Plan.

Figure 4.3-3 Power Generation

As shown in Table 4.3-1 and Figure 4.3-3, coal-fired power will introduce ammonia as co-firing fuel, and gas-fired power will be replaced by hydrogen-fired. Gas-fired power with CCS will be adopted as Bangladesh is blessed with suitable geological structures for underground storage of CO_2. Significant expansion of offshore wind is also expected as large resource potential is expected with relatively low generation cost. Many of these technologies are still in their infancy. Their introduction must be considered with deliberate evaluation along the timeline of the power system development as discussed in Chapter 5 of the principal report.

4.3.3 Power Generation Mix

The ratio of clean energy attains 40% in 2050 though natural gas will continue to be the largest power generation source (Figure 4.3-4). Hydrogen-fired power and gas-fired power with CCS will occupy remarkable shares in 2050. Power import from neighboring countries and nuclear power also have considerable shares. In contrast, the share of renewable energies will be relatively small mainly due to limited availability of suitable land areas. Coal-fired power remains more than 10% in 2041, but will almost disappear towards 2050.



Source: JICA Study Team

Note: Net power generation is more detailly analyzed in Chapter 5 Power System Development Plan.

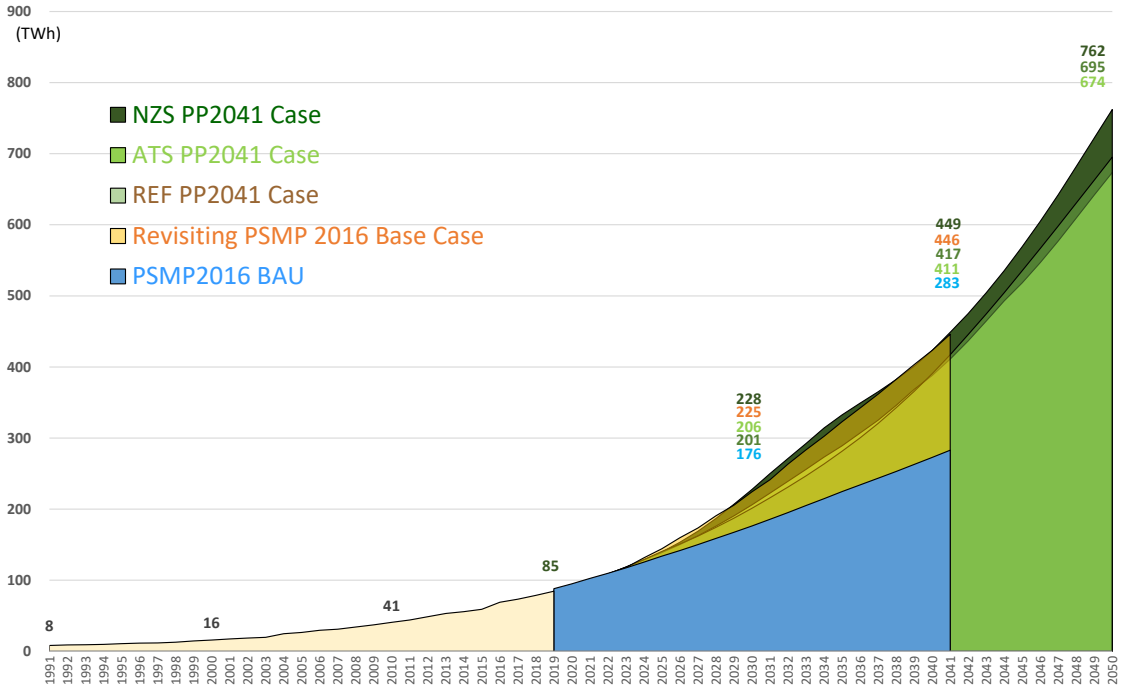
Figure 4.3-4 Power Generation Mix

ATS is a well-balanced scenario from the viewpoint of energy security, compared with REF which depends greatly on natural gas, and NZS which has to consume a significantly large amount of hydrogen according to the back-casting approach. In terms of environmental sustainability, total renewable power capacity for ATS will achieve the NDC conditional target by 2030. Above all, achieving 40% of clean energy in 2041 will be consistent with the declaration made by the Prime Minister at COP26 in 2021[3].

4.3.4 Comparison with Past Plans

Three scenarios of power generation in the PP2041 GDP growth case are compared to those of the past power system master plans as shown in Figure 4.3-5. Power generation of REF and ATS with the GDP growth assumption of the PP2041 Case is close to that of the Base Case of the Revisiting Power System Master Plan 2016. Power generation for NZS, meanwhile, exceeds that for BAU of Revisiting PSMP2016 because the NZS assumes a very aggressive electrification process until 2050 to reduce fossil fuel consumption and the associated GHG emissions. This suggests that realizing NZS will require power development projects of far larger size which the Bangladesh power sector has never studied or planned.

[3] https://unfccc.int/sites/default/files/resource/BANGLADESH_cop26cmp16cma3_HLS_EN.pdf



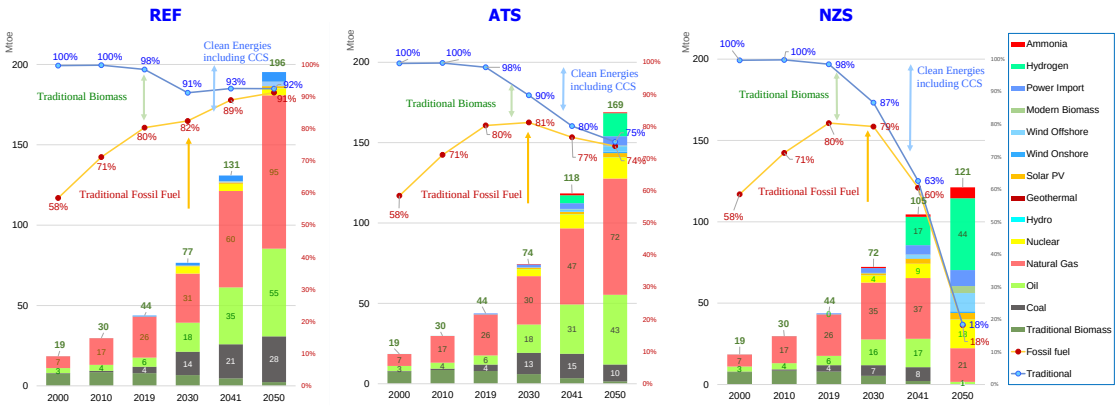
Source: Prepared by the JICA Study Team

Figure 4.3-5 Power Generation – comparison with the past master plans

4.4 Primary Energy Supply and CO_2 Emissions

4.4.1 Comparison of Three Scenarios

In the Reference Scenario (REF), the size of the total primary energy supply (TPES) will be different across three different energy scenarios (Figure 4.4-1). TPES in REF will grow by more than four-fold to 196 million tons oil equivalent (Mtoe) in 2050 from 44 Mtoe in 2019. The size of TPES in 2050 is close to that of Mexico in 2019, a G20 country. ATS will have the second largest TPES among the three scenarios at 169 Mtoe, approximately 10% below the level of REF. This is because, in ATS, more energy efficiency improvement is expected, and the higher average energy supply cost will curb the energy demand growth. For the same reasons, TPES of NZS will be the smallest among the three scenarios. The size of TPES is much smaller than those of the other two scenarios. This suggests that, in order to achieve net-zero status in Bangladesh in 2050, extreme energy efficiency improvement will be required.



Source: Prepared by the JICA Study Team

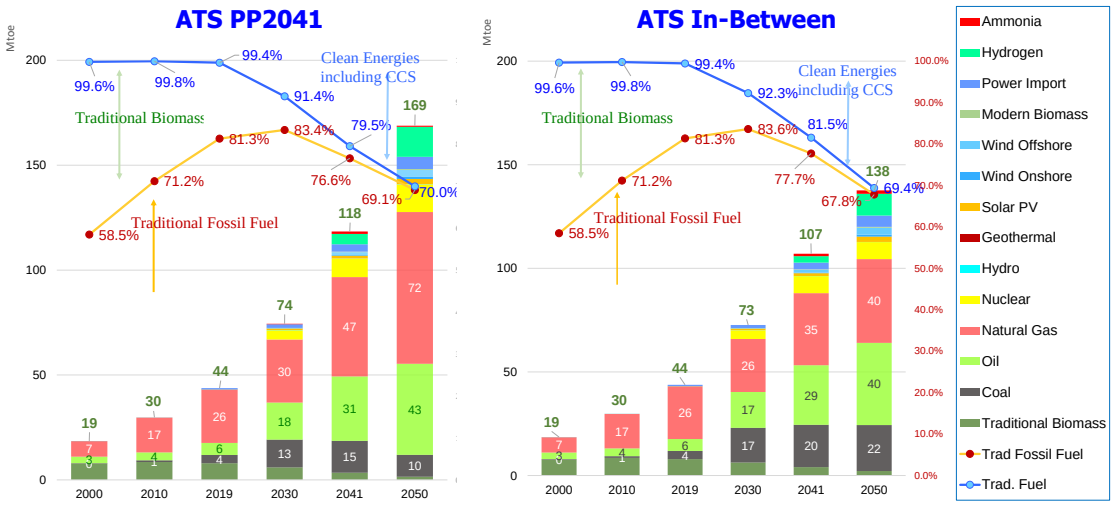
Figure 4.4-1 Primary Energy Supply: PP2041

In terms of the primary energy supply mix, gas will remain as the largest energy supply source in REF and ATS. A relatively low carbon footprint of natural gas and the existence of domestic supply infrastructure will keep gas as the most preferred energy source in these two scenarios. Adoptions of renewable energy, nuclear, and hydrogen (including ammonia) will occupy larger shares in ATS than in REF, but they will not completely overhaul the existing primary energy supply mix where traditional fossil fuels play major roles. It should also be noted that coal will maintain a certain role in Bangladesh's primary energy mix in 2050 even in ATS because industrial steam boilers with coal and ammonia co-firing coal power plants will remain due to its competitive fuel cost.

The primary energy mix of NZS will be very different from those of REF and ATS. The largest energy supply source for NZS in 2050 will be hydrogen that occupies approximately 40% of the TPES. The high share of hydrogen largely derives from its extensive utilization in the power generation sector. In this scenario, while clean hydrogen can be produced from either a combination of renewable energy and electrolysis or fossil fuels with carbon dioxide capture and storage (CCS) arrangement, renewable energy resources in Bangladesh would be limited and utilized mainly for power generation in a direct manner. Bangladesh will only have a limited capability to produce hydrogen including ammonia by itself and thus most of its hydrogen supply will be imported.

4.4.2 Main Scenario for Master Plan

The total primary energy supply (TPES) is a sum of the final energy consumption except for electricity and the fuel input in power sector. In the ATS PP2041 case, TPES will expand about four-fold to 169 million tons oil equivalent (Mtoe) in 2050 from 44 Mtoe in 2019 (Figure 4.4-2; Table 4.4-1). The size of TPES in 2050 is close to that of the United Kingdom in 2019. In the ATS In-between, TPES will expand about three-fold to 138 Mtoe in 2050, which is close to that of Thailand in 2019.



Source: JICA Study Team

Figure 4.4-2 Total Primary Energy Supply

To date, traditional biomass consumption mainly firewood has been replaced with modern fossil fuels such as coal, oil and natural gas. This trend will continue and traditional biomass consumption will almost disappear by 2050. On the other hand, with a view to constructing a low carbon economy, clean energies such as nuclear, solar PVs, wind, CCS, ammonia and hydrogen will be introduced. The share of these clean energies will exceed 20% by 2041 and reach almost 30% in 2050.

In the primary energy supply mix, gas will remain as the largest energy source. Its relatively low carbon footprint and the existence of domestic supply infrastructure will keep gas as the most preferred energy. Clean energies such as renewable energy, nuclear, and hydrogen (including ammonia) will increase their shares, but the present primary energy supply mix will be kept generally where traditional fossil fuels still play major roles. Coal will continue to play a certain role even in 2050; industrial steam boilers with coal and ammonia co-firing coal power plants will remain in view of the competitive fuel cost.

Table 4.4-1 Total Primary Energy Supply: ATS

	Total Primary Energy Supply (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Traditional Biomass	7.9	6.0	3.4	1.5	18.1	8.0	2.9	0.9	-2.5	-4.9	-7.3	0.19
Coal	4.0	13.2	15.2	10.5	9.0	17.8	12.8	6.2	11.6	1.3	-3.3	2.64
Oil	5.7	17.6	30.7	43.4	13.0	23.7	25.9	25.7	10.8	5.2	3.2	7.61
Natural Gas	25.5	30.1	39.9	52.1	58.3	40.4	33.7	30.9	1.5	2.6	2.5	2.04
Power Import (Trad Fuel)	0.4	1.1	1.2	0.6	1.0	1.5	1.0	0.3	9.0	0.7	-6.9	1.28
Traditional Fuel	43.5	68.0	90.4	108.0	99.4	91.4	76.4	64.0	4.1	2.6	1.6	2.48
Nuclear	0.0	4.4	8.8	13.1	0.0	5.9	7.4	7.8	-	6.5	3.8	-
Natural Gas - CCS	0.0	0.0	3.7	10.1	0.0	0.0	3.2	6.0	-	-	9.5	-
Hydro	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	2.4	0.0	0.0	1.30
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar PV	0.0	0.7	1.3	2.5	0.1	1.0	1.1	1.5	32.9	5.7	5.9	79.09
Wind - Onshore	0.0	0.1	0.3	0.9	0.0	0.2	0.3	0.6	56.8	7.0	11.1	941.53
Wind - Offshore	0.0	0.0	1.3	3.4	0.0	0.0	1.1	2.0	-	-	8.8	-
Modern Biomass	0.0	0.2	0.3	0.4	0.0	0.2	0.2	0.2	-	4.4	4.0	-
Ammonia	0.0	0.2	1.2	0.6	0.0	0.3	1.0	0.3	-	15.5	-6.4	-
Hydrogen	0.0	0.0	4.9	14.3	0.0	0.0	4.2	8.5	-	-	10.2	-
Power Import (Clean Energy)	0.1	0.6	2.3	5.2	0.3	0.9	2.0	3.1	14.4	12.3	7.7	35.91
Clean Energy	0.2	6.4	24.2	50.7	0.6	8.6	20.5	30.0	34.5	12.9	7.0	207.21
Total	43.8	74.4	118.4	168.9	100.0	100.0	100.0	100.0	4.9	4.3	3.3	3.86
In-Between												
Traditional Biomass	7.9	6.3	4.1	2.2	18.1	8.7	3.8	1.6	-2.1	-3.9	-5.5	0.28
Coal	4.0	16.7	20.4	22.2	9.0	23.0	19.1	16.1	14.0	1.8	0.8	5.60
Oil	5.7	17.3	28.8	39.7	13.0	23.8	26.9	28.9	10.6	4.7	3.0	6.96
Natural Gas	25.5	25.6	31.0	20.2	58.3	35.2	29.0	14.6	0.0	1.8	-3.8	0.79
Power Import (Trad Fuel)	0.4	1.1	1.1	1.1	1.0	1.6	1.1	0.8	9.0	0.0	0.0	2.58
Traditional Fuel	43.5	67.1	85.4	85.3	99.4	92.3	79.8	62.0	4.0	2.2	0.0	1.96
Nuclear	0.0	4.1	8.2	8.2	0.0	5.7	7.7	6.0	-	6.5	0.0	-
Natural Gas - CCS	0.0	0.0	1.9	10.1	0.0	0.0	1.7	7.4	-	-	16.6	-
Hydro	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	2.4	0.0	0.0	1.30
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar PV	0.0	0.7	1.3	2.5	0.1	1.0	1.3	1.8	32.9	5.7	5.9	79.09
Wind - Onshore	0.0	0.1	0.3	0.9	0.0	0.2	0.3	0.7	56.8	7.0	11.1	941.53
Wind - Offshore	0.0	0.0	1.3	3.4	0.0	0.0	1.3	2.5	-	-	8.8	-
Modern Biomass	0.0	0.2	0.3	0.4	0.0	0.2	0.2	0.3	-	4.4	4.0	-
Ammonia	0.0	0.0	1.2	1.6	0.0	0.0	1.1	1.2	-	-	3.2	-
Hydrogen	0.0	0.0	3.1	10.5	0.0	0.0	2.9	7.6	-	-	11.7	-
Power Import (Clean Energy)	0.1	0.4	2.1	4.3	0.3	0.5	1.9	3.1	9.0	16.7	6.9	29.72
Clean Energy	0.2	5.6	19.7	42.1	0.6	7.7	18.5	30.6	32.9	12.1	7.1	172.08
Total	43.8	72.7	107.0	137.6	100.0	100.0	100.0	100.0	4.7	3.6	2.3	3.14

Source: JICA Study Team

4.4.3 Comparison of Natural Gas Outlook with Past Plans

Pathway of natural gas demand will be of critical importance in Bangladesh because natural gas will be the most important energy source in terms of the volume and its usages among various demand segments (Figure 4.4-3). Natural gas demand will keep growing, but the pace will slow down. Then the demand growth will be kept somewhat sustained. This projection is significantly lower compared with the Gas Sector Master Plan of 2017 reflecting efforts to control carbon emissions. Various advanced technologies that substitute natural gas will become commercially available from the 2030s and onwards, and will gradually be adopted in Bangladesh.

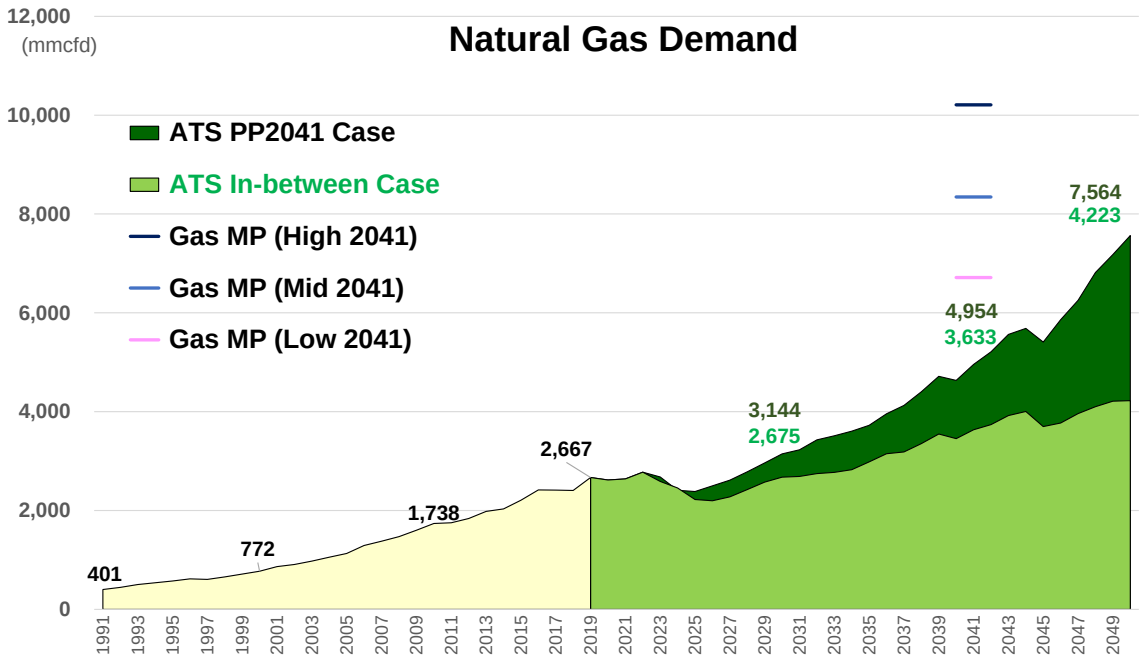


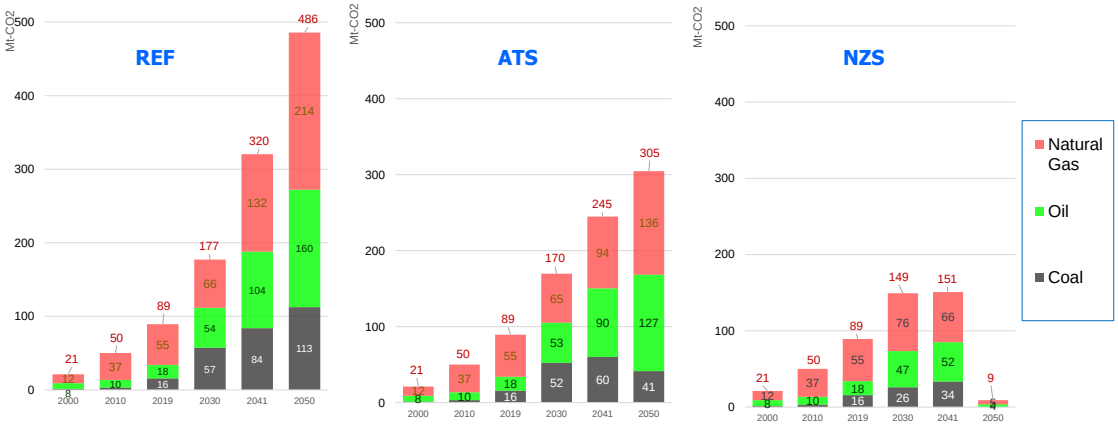
Figure 4.4-3 Natural Gas Demand

Source: JICA Study Team

4.4.4 CO_2 Emissions

1) Comparison of Three Scenarios

CO_2 emissions from energy use reflect the amount of fossil fuels in TPES in the three scenarios (Figure 4.4-4). The emissions will be the largest in REF, followed by ATS and NZS. The emissions of REF will significantly grow to around 486 million tons-CO_2 in 2050, which is about half of the Japan's emissions in 2019. The emissions of ATS will be relatively moderate at 305 million tons-CO_2 in 2050, which is almost two thirds of the level of REF. The emissions of NZS will be, by definition, almost zero in 2050. In NZS, drastic emissions reduction measures will be needed to significantly cut down the emissions from 150 million tons in 2041 to almost zero within a very short period of time (nine years).

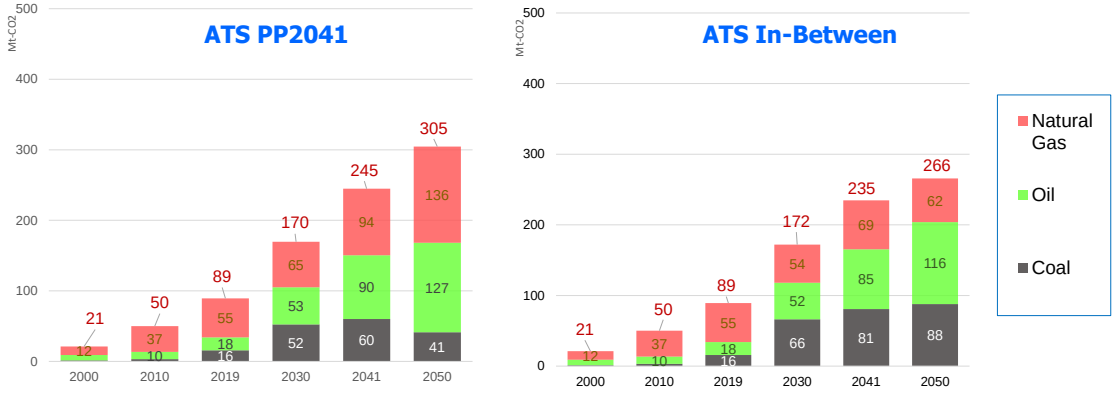


Source: JICA Study Team

Figure 4.4-4 Energy-related CO_2 Emissions by Source: PP2041

2) Main Scenario for Master Plan

CO_2 emissions from energy use reflect the amount of fossil fuels in TPES. The emissions of ATS PP2041 will be much more moderate at 305 million tons-CO_2 in 2050 than REF PP2041 (Figure 4.4-5). As well, that of ATS In-between will be even slower at 266 million tons-CO_2 in 2050.



Source: JICA Study Team

Figure 4.4-5 Energy-Related CO_2 Emissions by Source

4.5 Exercise on GDP In-between Case for Three Scenarios

4.5.1 Possibility of In-between Case

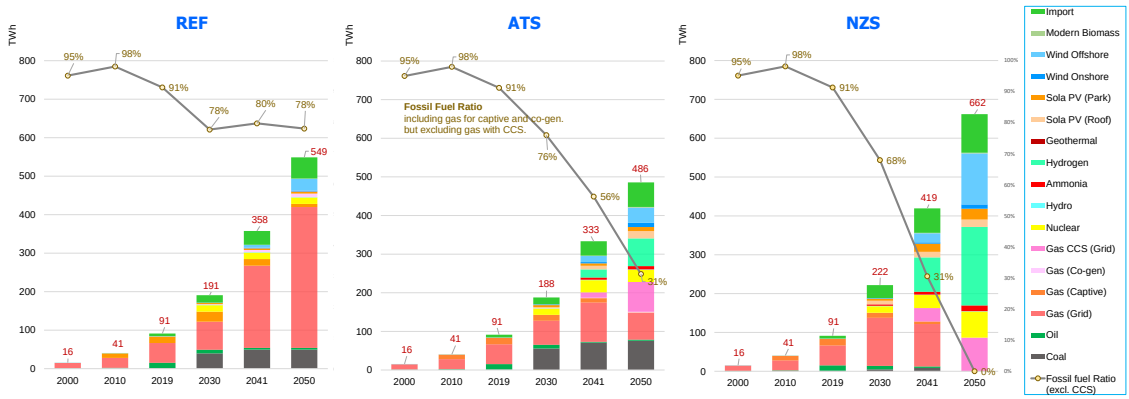
When the JICA Study Team was preparing the master plan, the world economic situation was drastically changing due to the outbreak of two unexpected events: the COVID-19 pandemic in 2019 and the Ukraine crisis in 2022. The pandemic continues to have negative impacts on major developed and emerging economies thorough lockdowns, etc. The Ukraine war has caused inflation across the world through price rises especially in food and energy, leading to a sharp slowdown in global growth. Both incidents seem to be more prolonged than people had

anticipated. As the World Bank[4] and the IMF[5] revised its world economic growth perspective downward in June and July 2022, respectively, this situation would likely affect the Bangladesh economy as well. If the impact on the world economy continues further, the In-between Case would become more realistic than the PP2041 Case for GDP assumption even in the long run.

Because of the uncertainties, the PP2041 GDP assumption adopted for the Master Plan may need to be reviewed. In view of this, some exercises are provided below applying the ATS In-between case.

4.5.2 Power generation

In In-between cases, the final electricity demand will become lower than those of PP2041 cases reflecting the smaller GDP assumption, leading to smaller electricity generation (Figure 4.5-1). ATS In-between is deemed as a well-balanced power generation mix, utilizing diversified energy sources, while REF In-between heavily depends on natural gas, and NZS In-between relies heavily on hydrogen and offshore wind. As well as ATS PP2041, ATS In-between will achieve 40% of clean energy in 2041.



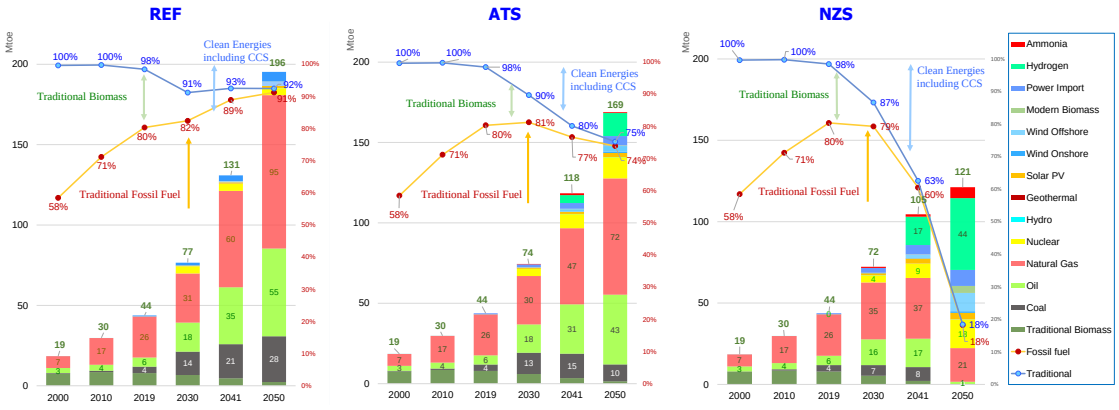
Source: Prepared by the JICA Study Team

Figure 4.5-1 Power generation (In-between Case)

4.5.3 Primary energy supply and CO_2 emissions

In GDP In-between cases, total primary energy supply (TPES) will be smaller than those estimated for PP2041 cases reflecting lower final energy consumption and power input (Figure 4.5-2). In REF and ATS, natural gas and oil will be the most consumed energy. In contrast, NZS In-between illustrates that hydrogen will occupy the largest share. These tendencies would be largely the same for GDP assumptions of PP2041 and In-between cases, though a greater amount of clean energies will be required for the former case.

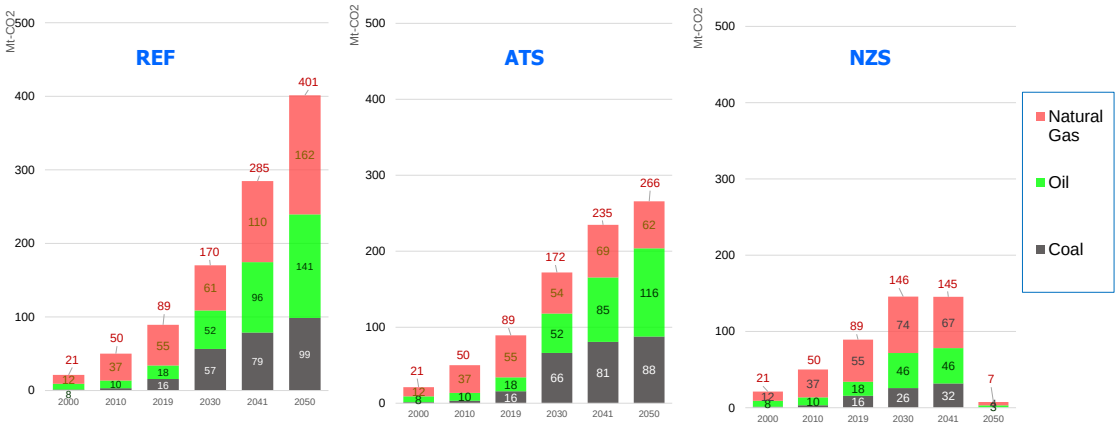
[4] World Bank Group (2022), "Global Economic Perspective (June)"
[5] International Monetary Fund (2022), "World Economic Outlook (July)"



Source: Prepared by the JICA Study Team

Figure 4.5-2 Primary Energy Supply (In-between Case)

Accordingly, energy-related CO_2 emissions are also smaller than PP2041 cases (Figure 4.5-3). Although CO_2 emissions of the REF In-between Case exceed 400 million tonnes (Mt)-CO_2, that of the ATS In-between Case will be sustained at around 270 Mt-CO_2. In the NZS In-between Case, CO_2 emission will be almost zero since the case takes a back-casting approach.



Source: Prepared by the JICA Study Team

Figure 4.5-3 Energy-related CO_2 Emissions by Source (In-between Case)

4.6 Comparison of scenarios

The master plan aims at balancing energy security, economic efficiency and environmental sustainability, which are so called the “3Es”. This section tries to quantify change of the status in different scenarios and cases. We employ the following indexes that can represent the status of each 3Es. Among the indexes, the Herfindahl-Hirschman Index (HHI) can explain diversity of the energy portfolio. Diversity is a key to reduce inherent risk of each energy thereby enhance energy security since there is no perfect energy in the world. Therefore, a more diversified energy

portfolio, i.e. lower HHI number, can be understood as a more secure state.

Energy security	Herfindahl-Hirschman Index (HHI) of primary energy supply mix and power generation mix
Economic efficiency	Weighted average of levelized cost of electricity (LCOE)
Environmental sustainability	CO_2 emission

4.6.1 Energy security

In the REF PP2041, performance improves through 2030 as the share of natural gas declines due to coal-fired power in electricity generation and oil in primary energy supply increases. After that, however, performance deteriorates compared to 2019 due to higher reliance on natural gas.

In the ATS PP2041, performance deteriorates slightly after 2030 as the share of natural gas increases, but remains generally flat. Under the ATS In-between, the increased use of clean energies in addition to coal after 2030 eases the concentration on natural gas and results in even better performance.

In the NZS, performance improves to a level comparable to the in-between scenario, as diversification into clean energy sources such as hydrogen and renewable energy increases after 2030. However, by 2030, the NZS performs worse than the other scenarios because the concentration on natural gas does not ease.

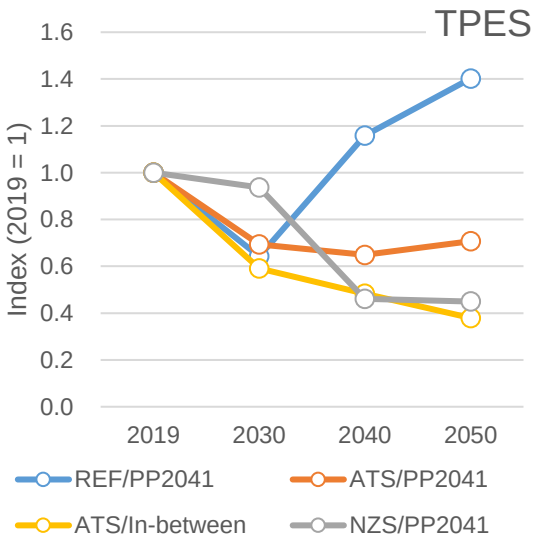


Figure 4.6-1 Change of HHI (Total Primary Energy Supply)

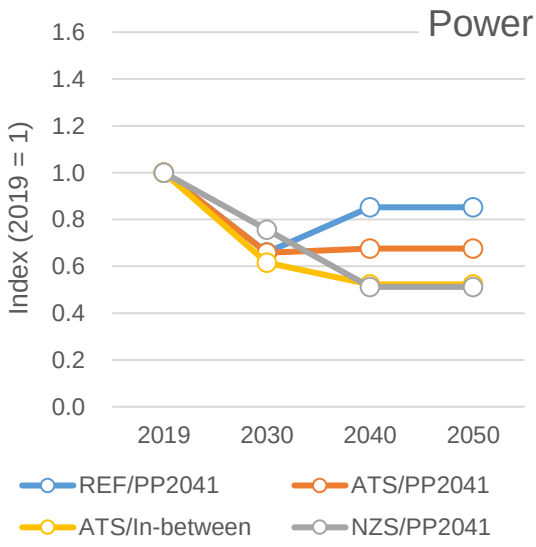


Figure 4.6-2 Change of HHI (Power Generation)

Note: The smaller, the better

Source: Prepared by the JICA Study Team

4.6.2 Economic efficiency

In every scenario, the weighted average LCOE decreases as the use of coal and renewable

energy sources, which are less expensive than natural gas power, increases through 2030. After 2030, the weighted average LCOE increases as the share of ammonia co-firing, hydrogen generation, and thermal power with CCS increases. In other words, the weighted average LCOE will be the highest throughout all periods for NZS that need to introduce a larger amount of high-cost power generation technologies for the purpose of zero emissions in 2050. Conversely, the weighted average LCOE will be lowest in REF where less high-cost generation technologies are introduced.

4.6.3 Environmental sustainability

Other than the NZS, CO_2 emissions will continue to increase through 2050. However, the ATS, which assumes more intense climate measures, emits less than the REF. For the same ATS, PP2041 and In-between, emissions are smaller for In-between, which uses more coal but has lower energy demand growth.

NZS will continue to increase CO2 emissions until 2030, but emissions will level off to decrease with subsequent measures. Here, we have to bear in mind that the nature of NZS is different from others since NZE is a back cast-type approach, i.e. net-zero goal is a predetermined condition, while REF and ATS are the forecast-type.

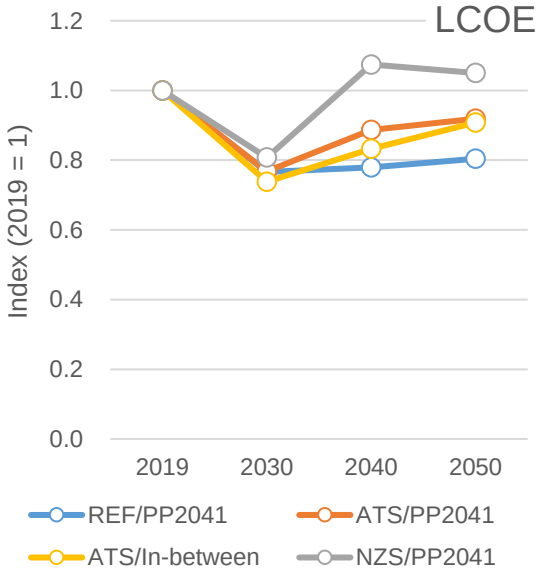


Figure 4.6-3 Change of Weighted Average LCOE

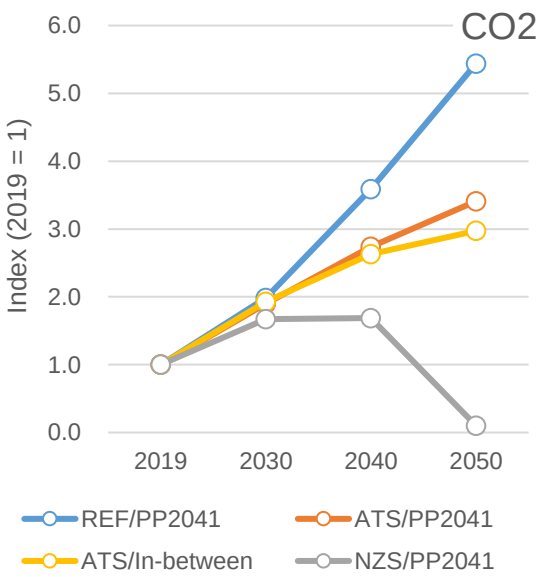


Figure 4.6-4 Change of CO_2 Emission

Source: Prepared by the JICA Study Team

4.6.4 Conclusion

As we have repeatedly discussed, balance is at the core of any energy policy. The results show that the ATS provides a better balance between energy security, economic efficiency, and environmental sustainability throughout the analysis period. The REF is superior in terms of

economic efficiency, but at the expense of environmental sustainability. The NZS is superior in terms of environmental sustainability, but it places a greater economic burden on Bangladesh and increases energy security risks up until 2030. While the ATS is not outstanding, it can balance the fundamental requirements of energy policy.

4.7 Long-term energy policy under Advanced Technology Scenario

While it is quite a challenging target, the Advanced Technology Scenario (ATS) is adopted as the main scenario of the energy demand outlook on which Bangladesh should design the future energy infrastructure and the long-term energy policy.

The demand scenario is structured with four pillars on the long-term energy policy, as far as practicable and affordable, as follows:

1) To enhance energy conservation and electrification of the demand
2) To maximize utilization of lower-cost clean energies
3) To diversify the types of energy sources
4) To invest in the energy infrastructure prudently with a long-term view toward decarbonization

The scenario envisages that the years to 2050 will be a period of transition for Bangladesh to become a “Decarbonization-ready” country for eventual achievement of carbon neutrality in 2070±α.

The adopted scenario assumes that the effect of the COVID-19 pandemic and the Ukraine war will be fleeting and will not affect the super long-term trends. On the other hand, with the backdrop of accelerating concerns on climate change, new technologies that we don’t currently know about may emerge much earlier. All in all, the future is uncertain and unpredictable; the adopted scenario must be examined and updated periodically in due course.

5. Tables on Energy Demand Outlook

5.1 Final energy consumption for REF

5.1.1 Final energy consumption by sector for REF

REF PP2041	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	20.7	37.9	61.4	33.1	35.6	38.2	41.1	5.9	5.7	5.5	5.58
Road	3.1	8.8	16.6	23.7	9.3	15.2	16.7	15.8	10.0	5.9	4.0	7.62
Other Transport	0.9	1.9	4.3	8.1	2.8	3.2	4.4	5.5	6.3	8.0	7.2	8.62
Residential	14.6	19.6	26.2	33.8	43.7	33.7	26.4	22.7	2.7	2.7	2.9	2.32
Commercial	1.0	2.8	7.5	13.3	2.9	4.9	7.6	8.9	10.4	9.3	6.5	13.88
Agriculture	1.2	2.0	3.5	4.9	3.7	3.4	3.5	3.3	4.3	5.2	3.9	3.94
Non energy	1.5	2.3	3.3	4.1	4.4	3.9	3.3	2.7	4.1	3.3	2.5	2.76
Total	33.3	58.0	99.4	149.3	100.0	100.0	100.0	100.0	5.2	5.0	4.6	4.49

REF In-between	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	19.7	32.9	49.2	33.1	35.1	36.7	39.1	5.5	4.8	4.6	4.47
Road	3.1	8.7	16.1	22.4	9.3	15.5	17.9	17.8	9.8	5.7	3.8	7.23
Other Transport	0.9	1.7	3.7	6.3	2.8	3.1	4.1	5.0	5.7	7.0	6.2	6.69
Residential	14.6	19.1	23.9	28.9	43.7	34.0	26.7	22.9	2.5	2.1	2.1	1.98
Commercial	1.0	2.7	6.7	10.8	2.9	4.8	7.4	8.6	9.9	8.5	5.6	11.32
Agriculture	1.2	1.9	3.1	4.1	3.7	3.4	3.4	3.2	3.9	4.5	3.2	3.28
Non energy	1.5	2.3	3.3	4.1	4.4	4.1	3.7	3.3	4.1	3.3	2.5	2.76
Total	33.3	56.1	89.5	125.8	100.0	100.0	100.0	100.0	4.9	4.3	3.9	3.78

REF IMF Ext	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	19.5	27.6	33.3	33.1	35.0	34.8	34.7	5.3	3.2	2.1	3.03
Road	3.1	8.7	15.4	20.7	9.3	15.6	19.5	21.6	9.8	5.4	3.3	6.67
Other Transport	0.9	1.7	2.9	4.1	2.8	3.1	3.7	4.2	5.5	5.1	3.7	4.32
Residential	14.6	18.9	21.7	22.9	43.7	34.0	27.3	23.9	2.4	1.2	0.6	1.58
Commercial	1.0	2.7	5.7	8.0	2.9	4.8	7.2	8.3	9.8	7.2	3.8	8.35
Agriculture	1.2	1.9	2.7	3.0	3.7	3.3	3.3	3.1	3.7	3.3	1.3	2.40
Non energy	1.5	2.3	3.3	4.1	4.4	4.1	4.1	4.3	4.1	3.3	2.5	2.76
Total	33.3	55.6	79.3	96.1	100.0	100.0	100.0	100.0	4.8	3.3	2.2	2.89

5.1.2 Final energy consumption by energy source for REF

REF PP2041	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	6.3	11.3	18.8	11.0	10.9	11.4	12.6	5.1	5.4	5.8	5.14
Oil	4.8	16.6	34.6	53.7	14.5	28.5	34.8	36.0	11.9	6.9	5.0	11.17
Natural Gas	10.2	13.3	17.0	20.8	30.8	23.0	17.1	13.9	2.4	2.2	2.3	2.03
Biomass	7.8	6.6	4.5	2.2	23.4	11.3	4.6	1.5	-1.5	-3.3	-7.6	0.29
Fuel Total	26.5	42.8	67.5	95.6	79.6	73.7	67.8	64.0	4.5	4.2	3.9	3.61
Electricity	6.8	15.2	32.0	53.7	20.4	26.3	32.2	36.0	7.6	7.0	5.9	7.92
Total	33.3	58.0	99.4	149.3	100.0	100.0	100.0	100.0	5.2	5.0	4.6	4.49

REF In-between	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	6.1	10.0	15.3	11.0	10.9	11.2	12.2	4.8	4.6	4.9	4.18
Oil	4.8	15.9	31.9	47.5	14.5	28.4	35.6	37.8	11.5	6.5	4.5	9.87
Natural Gas	10.2	13.0	15.4	17.8	30.8	23.1	17.2	14.1	2.2	1.6	1.6	1.73
Biomass	7.8	6.7	4.8	2.8	23.4	11.9	5.4	2.2	-1.4	-2.9	-5.9	0.36
Fuel Total	26.5	41.7	62.1	83.3	79.6	74.3	69.4	66.2	4.2	3.7	3.3	3.15
Electricity	6.8	14.4	27.4	42.5	20.4	25.7	30.6	33.8	7.1	6.0	5.0	6.26
Total	33.3	56.1	89.5	125.8	100.0	100.0	100.0	100.0	4.9	4.3	3.9	3.78

REF IMF Ext	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	6.1	8.6	10.7	11.0	10.9	10.9	11.2	4.7	3.3	2.4	2.93
Oil	4.8	15.8	28.9	39.1	14.5	28.4	36.4	40.7	11.4	5.7	3.4	8.13
Natural Gas	10.2	12.9	13.8	13.6	30.8	23.1	17.4	14.2	2.1	0.6	-0.1	1.33
Biomass	7.8	6.7	5.1	3.6	23.4	12.0	6.5	3.8	-1.4	-2.4	-3.8	0.47
Fuel Total	26.5	41.4	56.4	67.1	79.6	74.4	71.2	69.8	4.1	2.9	1.9	2.53
Electricity	6.8	14.2	22.8	29.0	20.4	25.6	28.8	30.2	7.0	4.4	2.7	4.28
Total	33.3	55.6	79.3	96.1	100.0	100.0	100.0	100.0	4.8	3.3	2.2	2.89

5.1.3 Final energy consumption by sector for ATS

ATS PP2041	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	19.3	30.6	47.8	33.1	34.6	35.3	38.3	5.3	4.3	5.1	4.34
Road	3.1	8.8	15.5	20.8	9.3	15.8	17.9	16.7	10.0	5.2	3.3	6.71
Other Transport	0.9	1.9	4.4	8.2	2.8	3.3	5.0	6.6	6.4	8.0	7.2	8.67
Residential	14.6	19.0	23.2	27.9	43.7	34.0	26.8	22.4	2.5	1.8	2.1	1.92
Commercial	1.0	2.6	6.3	11.0	2.9	4.6	7.2	8.8	9.3	8.5	6.4	11.49
Agriculture	1.2	2.0	3.5	4.9	3.7	3.5	4.0	3.9	4.3	5.2	3.9	3.94
Non energy	1.5	2.3	3.3	4.1	4.4	4.1	3.8	3.3	4.1	3.3	2.5	2.76
Total	33.3	55.9	86.6	124.7	100.0	100.0	100.0	100.0	4.8	4.1	4.1	3.75

ATS In-between	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	18.6	27.0	38.0	33.1	34.2	34.0	36.4	4.9	3.4	3.9	3.46
Road	3.1	8.7	14.9	19.4	9.3	16.0	18.7	18.6	9.9	5.0	3.0	6.25
Other Transport	0.9	1.7	3.7	6.4	2.8	3.2	4.6	6.1	5.7	7.0	6.2	6.73
Residential	14.6	18.8	21.9	23.8	43.7	34.4	27.5	22.8	2.3	1.4	0.9	1.64
Commercial	1.0	2.5	5.7	8.8	2.9	4.5	7.2	8.5	9.0	7.8	5.0	9.24
Agriculture	1.2	1.9	3.1	4.1	3.7	3.5	3.9	3.9	3.9	4.5	3.2	3.28
Non energy	1.5	2.3	3.3	4.1	4.4	4.2	4.1	3.9	4.1	3.3	2.5	2.76
Total	33.3	54.5	79.5	104.6	100.0	100.0	100.0	100.0	4.6	3.5	3.1	3.14

ATS IMF Ext	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	19.0	24.0	26.0	33.1	34.6	33.2	32.1	5.1	2.2	0.9	2.36
Road	3.1	8.7	14.2	17.4	9.3	15.9	19.7	21.6	9.8	4.6	2.3	5.62
Other Transport	0.9	1.7	3.0	4.1	2.8	3.1	4.1	5.1	5.5	5.1	3.7	4.34
Residential	14.6	18.8	20.2	19.6	43.7	34.3	27.9	24.2	2.3	0.7	-0.4	1.34
Commercial	1.0	2.5	5.0	6.7	2.9	4.6	7.0	8.3	9.1	6.6	3.3	7.05
Agriculture	1.2	1.9	2.7	3.0	3.7	3.4	3.7	3.7	3.7	3.3	1.3	2.40
Non energy	1.5	2.3	3.3	4.1	4.4	4.2	4.5	5.1	4.1	3.3	2.5	2.76
Total	33.3	54.8	72.4	80.9	100.0	100.0	100.0	100.0	4.6	2.6	1.2	2.43

5.1.4 Final energy consumption by energy source for ATS

ATS PP2041	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	5.3	6.4	8.4	11.0	9.5	7.4	6.8	3.4	1.8	3.0	2.30
Oil	4.8	16.1	30.0	42.6	14.5	28.8	34.6	34.2	11.6	5.8	4.0	8.86
Natural Gas	10.2	12.9	15.0	19.3	30.8	23.1	17.4	15.5	2.1	1.4	2.8	1.88
Biomass	7.8	5.8	3.3	1.3	23.4	10.4	3.8	1.1	-2.6	-5.1	-9.5	0.17
Fuel Total	26.5	40.2	54.8	71.6	79.6	71.9	63.2	57.5	3.9	2.9	3.0	2.70
Electricity	6.8	15.7	31.9	53.0	20.4	28.1	36.8	42.5	7.9	6.6	5.8	7.82
Total	33.3	55.9	86.6	124.7	100.0	100.0	100.0	100.0	4.8	4.1	4.1	3.75

ATS In-between	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	5.3	6.2	7.5	11.0	9.7	7.8	7.2	3.4	1.5	2.1	2.05
Oil	4.8	15.7	28.5	39.1	14.5	28.8	35.8	37.4	11.3	5.6	3.6	8.13
Natural Gas	10.2	13.0	14.9	17.8	30.8	23.9	18.8	17.0	2.2	1.2	2.0	1.73
Biomass	7.8	6.2	3.9	2.0	23.4	11.3	4.9	2.0	-2.1	-4.0	-7.0	0.26
Fuel Total	26.5	40.2	53.6	66.4	79.6	73.7	67.3	63.5	3.9	2.6	2.4	2.51
Electricity	6.8	14.3	26.0	38.2	20.4	26.3	32.7	36.5	7.0	5.5	4.4	5.63
Total	33.3	54.5	79.5	104.6	100.0	100.0	100.0	100.0	4.6	3.5	3.1	3.14

ATS IMF Ext	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	5.4	5.8	5.5	11.0	9.8	8.0	6.8	3.5	0.7	-0.5	1.50
Oil	4.8	15.6	25.9	31.9	14.5	28.4	35.8	39.5	11.3	4.7	2.3	6.64
Natural Gas	10.2	13.2	14.0	13.4	30.8	24.1	19.3	16.6	2.3	0.5	-0.5	1.31
Biomass	7.8	6.2	4.3	2.7	23.4	11.4	5.9	3.4	-2.0	-3.3	-4.9	0.35
Fuel Total	26.5	40.4	50.0	53.6	79.6	73.8	69.0	66.2	3.9	1.9	0.8	2.02
Electricity	6.8	14.4	22.4	27.3	20.4	26.2	31.0	33.8	7.1	4.1	2.2	4.03
Total	33.3	54.8	72.4	80.9	100.0	100.0	100.0	100.0	4.6	2.6	1.2	2.43

5.1.5 Final energy consumption by sector for NZS

NZS PP2041	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	19.3	28.7	22.3	33.1	34.9	38.0	28.0	5.2	3.7	-2.8	2.02
Road	3.1	8.4	11.5	15.3	9.3	15.1	15.2	19.2	9.4	2.9	3.3	4.94
Other Transport	0.9	1.9	4.4	8.3	2.8	3.4	5.8	10.4	6.4	8.1	7.3	8.74
Residential	14.6	19.1	19.9	18.6	43.7	34.5	26.4	23.4	2.5	0.4	-0.8	1.28
Commercial	1.0	1.8	3.5	6.2	2.9	3.3	4.6	7.7	6.1	5.9	6.6	6.43
Agriculture	1.2	2.5	4.3	4.9	3.7	4.6	5.7	6.2	6.6	5.0	1.5	3.95
Non energy	1.5	2.3	3.3	4.1	4.4	4.1	4.3	5.1	4.1	3.3	2.5	2.76
Total	33.3	55.2	75.5	79.6	100.0	100.0	100.0	100.0	4.7	2.9	0.6	2.39

NZS In-between	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	18.9	26.1	17.2	33.1	34.9	37.0	25.3	5.1	3.0	-4.5	1.56
Road	3.1	8.3	11.0	14.1	9.3	15.2	15.6	20.8	9.3	2.6	2.8	4.56
Other Transport	0.9	1.8	3.7	6.4	2.8	3.2	5.3	9.4	5.8	7.1	6.3	6.79
Residential	14.6	18.8	19.3	16.8	43.7	34.7	27.4	24.7	2.4	0.2	-1.6	1.15
Commercial	1.0	1.9	3.4	5.3	2.9	3.4	4.8	7.8	6.3	5.5	5.1	5.53
Agriculture	1.2	2.3	3.8	4.1	3.7	4.3	5.3	6.0	5.8	4.5	0.9	3.29
Non energy	1.5	2.3	3.3	4.1	4.4	4.2	4.6	6.0	4.1	3.3	2.5	2.76
Total	33.3	54.3	70.6	68.0	100.0	100.0	100.0	100.0	4.5	2.4	-0.4	2.04

NZS IMF Ext	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Industry	11.0	19.6	24.1	10.4	33.1	35.4	36.4	19.9	5.4	1.9	-9.0	0.94
Road	3.1	8.2	10.0	11.9	9.3	14.9	15.2	22.9	9.3	1.8	1.9	3.84
Other Transport	0.9	1.7	3.0	4.1	2.8	3.1	4.5	7.9	5.6	5.1	3.7	4.38
Residential	14.6	19.2	19.3	14.4	43.7	34.9	29.2	27.6	2.6	0.0	-3.2	0.99
Commercial	1.0	2.0	3.4	4.2	2.9	3.7	5.1	8.1	7.1	4.8	2.4	4.39
Agriculture	1.2	2.1	3.1	3.0	3.7	3.9	4.7	5.8	5.0	3.5	-0.4	2.41
Non energy	1.5	2.3	3.3	4.1	4.4	4.1	4.9	7.8	4.1	3.3	2.5	2.76
Total	33.3	55.2	66.2	52.1	100.0	100.0	100.0	100.0	4.7	1.7	-2.6	1.57

5.1.6 Final energy consumption by energy source for NZS

NZS PP2041	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	5.5	6.7	0.0	11.0	9.9	8.9	0.0	3.8	1.8	-86.5	0.00
Oil	4.8	14.3	16.8	1.4	14.5	25.9	22.3	1.7	10.4	1.5	-24.3	0.29
Natural Gas	10.2	12.8	14.4	3.5	30.8	23.1	19.0	4.4	2.0	1.1	-14.6	0.34
Biomass	7.8	5.2	2.0	4.0	23.4	9.4	2.7	5.0	-3.7	-8.2	7.8	0.51
Hydrogen	0.0	0.0	0.5	6.0	0.0	0.0	0.6	7.5	-	-	32.5	-
Ammonia	0.0	0.0	0.0	3.9	0.0	0.0	0.0	4.9	-	-	-	-
Fuel Total	26.5	37.7	40.4	18.6	79.6	68.3	53.5	23.4	3.3	0.6	-8.2	0.70
Electricity	6.8	17.5	35.2	61.0	20.4	31.7	46.5	76.6	9.0	6.6	6.3	8.99
Total	33.3	55.2	75.5	79.6	100.0	100.0	100.0	100.0	4.7	2.9	0.6	2.39

NZS In-between	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	5.4	6.3	0.0	11.0	10.0	8.9	0.0	3.7	1.3	-86.4	0.00
Oil	4.8	13.9	15.2	1.3	14.5	25.6	21.5	1.9	10.1	0.8	-23.9	0.27
Natural Gas	10.2	12.7	13.5	3.5	30.8	23.3	19.2	5.1	1.9	0.6	-14.0	0.34
Biomass	7.8	5.3	2.2	3.1	23.4	9.7	3.1	4.5	-3.5	-7.7	3.9	0.39
Hydrogen	0.0	0.0	0.5	4.2	0.0	0.0	0.7	6.1	-	-	26.7	-
Ammonia	0.0	0.0	0.0	2.9	0.0	0.0	0.0	4.3	-	-	-	-
Fuel Total	26.5	37.2	37.6	14.9	79.6	68.6	53.3	22.0	3.1	0.1	-9.8	0.56
Electricity	6.8	17.0	32.9	53.0	20.4	31.4	46.7	78.0	8.7	6.2	5.4	7.82
Total	33.3	54.3	70.6	68.0	100.0	100.0	100.0	100.0	4.5	2.4	-0.4	2.04

NZS IMF Ext	Final Energy Demand (million toe)				Composition				Average Growth Rate			2019 to 2050
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
					%	%	%	%	%	%	%	times
Coal	3.7	5.6	6.0	0.0	11.0	10.1	9.0	0.0	3.9	0.6	-86.3	0.00
Oil	4.8	13.9	13.7	1.2	14.5	25.2	20.7	2.2	10.1	-0.1	-23.9	0.24
Natural Gas	10.2	13.0	13.0	3.5	30.8	23.5	19.6	6.6	2.2	0.0	-13.7	0.34
Biomass	7.8	5.4	2.4	2.0	23.4	9.8	3.7	3.7	-3.3	-6.9	-2.5	0.25
Hydrogen	0.0	0.0	0.5	1.5	0.0	0.0	0.7	2.9	-	-	14.0	-
Ammonia	0.0	0.0	0.0	1.8	0.0	0.0	0.0	3.5	-	-	-	-
Fuel Total	26.5	37.9	35.6	9.9	79.6	68.6	53.7	19.0	3.3	-0.6	-13.2	0.37
Electricity	6.8	17.3	30.6	42.2	20.4	31.4	46.3	81.0	8.9	5.3	3.6	6.22
Total	33.3	55.2	66.2	52.1	100.0	100.0	100.0	100.0	4.7	1.7	-2.6	1.57

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Appendix D

Power System Development Plan

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1. Review of PSMP2016 and Revisiting PSMP2016

1.1 Background to the development of the Master Plan

In view of the fact that the Government of Bangladesh has set a target to become a high income country by 2041 and that the development of energy and power infrastructure is very important for the long term economic development of the country, the PSMP 2016 is a comprehensive energy and power development plan up to 2041. In addition to the various planning objectives, the Master Plan proposes the following five key perspectives in terms of policy:

1) Enhancement of imported energy infrastructure and its flexible operation
2) Efficient development and utilization of domestic natural resources (gas and coal)
3) Construction of a robust, high-quality power network
4) Maximization of green energy and promotion of its introduction
5) Improvement of human resources and mechanisms related to the stable supply of energy

However, even after its formulation, the vicious circle of delays in the construction and commercial operation of new power sources in Bangladesh and the decline in the power output and thermal efficiency of the various units of existing power plants leading to shortage of supply capacity and the consequent inability to carry out regular maintenance of power generation facilities in a systematic manner could not be improved. Against this backdrop, the power supply and transmission planning objectives considered in the PSMP 2016 were reviewed and a new Revisiting PSMP 2016 was developed. The Revisiting PSMP 2016 considers a wide range of issues, including regional balancing of electricity supply and demand, fuel diversification, strengthening of distribution infrastructure, demand-side management, investment, and generation costs.

In spite of these efforts, the current situation of supply and demand balance, at least in the short term, tends to be over supply capacity, which is becoming a financial burden for the BPDB and one of the new challenges for the power sector in Bangladesh.

In this country, BPDB, as a single buyer, purchases electricity from all power producers and distributes it to the distribution companies, which record significant operating losses every year and are currently supported by government subsidies. The main cause of its operating losses is that it distributes electricity wholesale to distribution companies at a lower wholesale electricity unit price (Bulk Tariff) than the price at which it is purchased from power generators.

Due to gas shortage and volatile market of crude oil, the power generation cost is increasing. That's why the gap between the generation cost and bulk supply tariff, hence the financial burden on BPDB, is increasing.

This IEPMP development project will provide a careful review of the power development plan from a long-term perspective, including a new long-term demand forecast and appropriate reserve

margin ratio, lead time for power station construction, and low and decarbonization measures.

It is also mentioned in the Revisiting PSMP 2016 that, in recent years, since the late 2010s, the growth in demand for electricity due to economic growth has not been met by domestic natural gas alone, and new large-scale power plants have been built using imported fuels such as coal and LNG. So, some plans are underway to build 400 kV and 765 kV transmission lines from the Bay of Bengal coastal areas in the south of the country to Dhaka, as well as to import power generated by neighboring countries.

In light of the situation mentioned above, the key changes in this IEPMP are the power source composition and regional distribution change due to the efforts for decarbonization, which has become a global trend.

- How will the regional distribution of power plants change, when large-scale power plants using imported fuel, especially coal-fired power plants which has been a trend in recent years, are replaced by alternative supply capacity?
- How will the regional distribution of demand change, when renewable energy power sources are installed in the distribution system?

The spread of energy conservation also effects the magnitude of demand. Regarding this point, since the demand forecast and power development plan have not yet been decided at the stage of the Interim report, especially quantitative analysis will be an item for further study. In the final report, the JICA study team will discuss the changes from the current transmission system plan based on the demand forecast and power development plan for ATS of the three scenarios.

This section outlines the information and data that should be referenced and compared in the content of the PSMP 2016 and Revisiting PSMP 2016 for consideration and analysis in future IEPMP development projects.

1.2 Maximum Electricity Demand Forecast (MW)

The maximum electricity demand in the PSMP 2016 is forecasted by the "GDP elasticity method" (GDP elasticity = 1.27).

On the other hand, in the Revisiting PSMP2016, based on the policy that the future electricity demand forecast should be calculated based on the demand forecast of the electricity distribution companies who are familiar with the characteristics of the increase in electricity consumption and its usage pattern, and based on the original plan developed by the electricity distribution companies, the demand was assumed by the bottom-up method, and the electricity demand growth rate from 2017 to 2041 was forecasted to be 14%-15%.

In the PSMP 2016, the growth rate of electricity demand in the high case, base case and low case is assumed to be up to 10.2% in 2020, and then gradually decreases, with a difference in the way the decrease is made. There is no difference in the rate of demand growth between "with EE&C" and "without EE&C".

Figures 1.2-1 and 1.2-2 show the graphs of the maximum electricity demand forecasts set in the PSMP 2016 and Revisiting PSMP 2016. For both the "without EE&C" and "with EE&C" cases, the low case forecast in the Revisiting PSMP2016 is higher than the high case forecast in the PSMP2016.

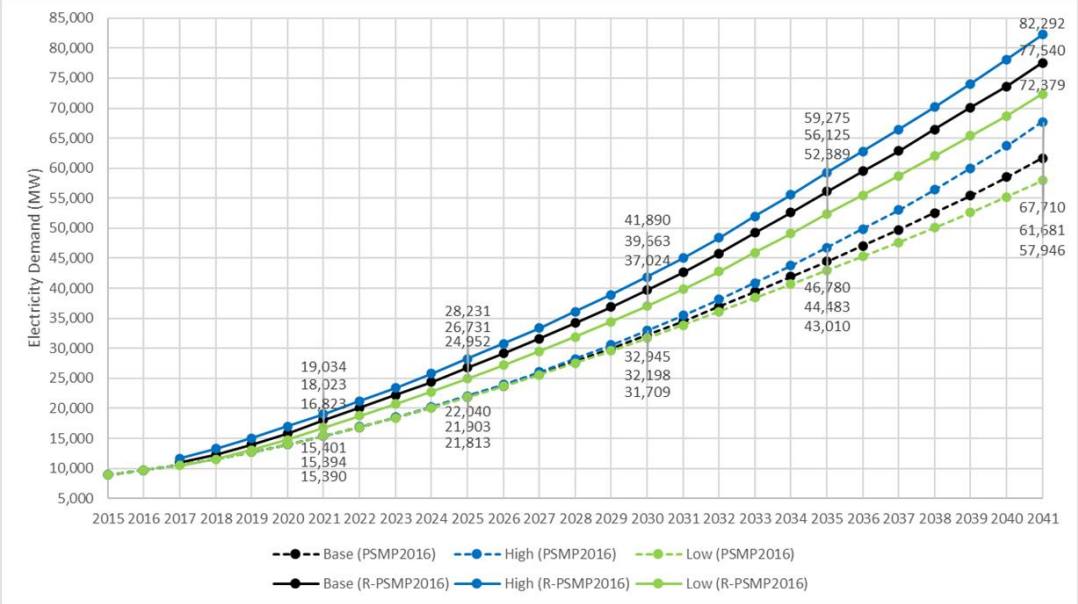


Figure 1.2-1 Forecasted Maximum Electricity Demand "without EE&C"

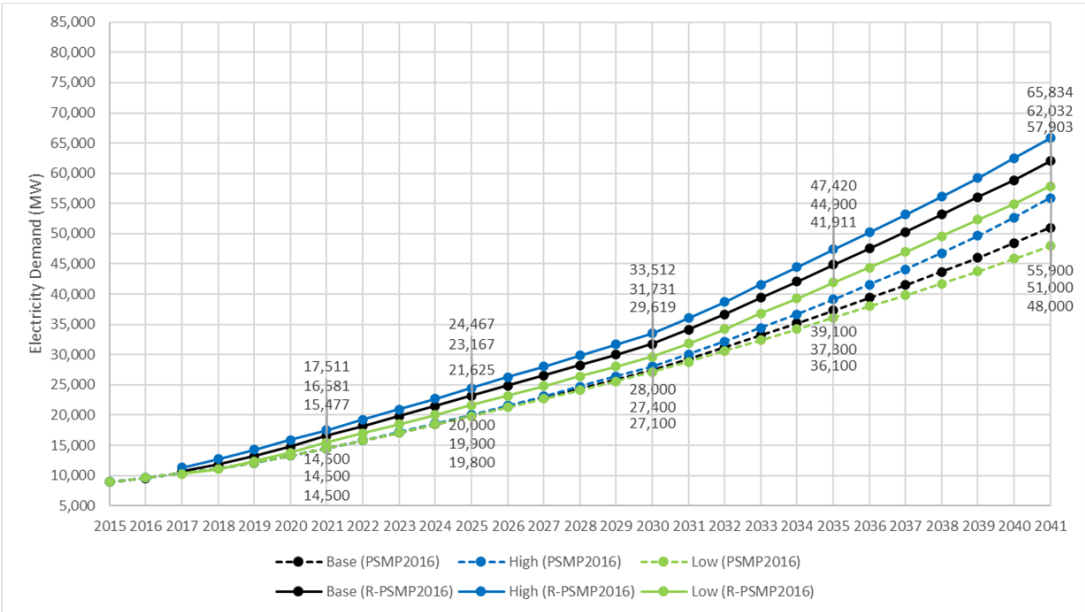


Figure 1.2-2 Forecasted Maximum Electricity Demand "with EE&C"

1) The reasons for the significant upward revision of electricity demand estimations in the Revisiting PSMP 2016 are as follows:

a. GDP Growth Rate

The PSMP 2016 considered an average GDP growth rate of 6% up to 2041.

However, in the Revisiting PSMP 2016, it is based on the fact that the GDP growth rate for the financial year 2016-17 was 7.1% and that the GDP growth rate in the Seventh Five Year Plan was expected to be 8%.

b. Per Capita Income

The PSMP 2016 set the GDP per capita at US$1,063 in 2020, US$1,444 in 2025, US$2,357 in 2035 and US$2,970 in 2041 (2005 rates).

However, according to the Bangladesh Bureau of Statistics (BBS), this is on the basis that per capita income rose from US$1,465 in 2015-16 to US$1,610 in 2016-17.

c. Industrialization

Revisiting PSMP2016 mentions that job creation through industrialization is the most important factor for the rapid economic development of the country and more power is essential for rapid industrialization.

According to the PSMP 2016, the contribution of the industrial sector to the GDP was projected to be 37%. On the other hand, the Revisiting PSMP 2016 predicted that it will be 40%, which should be taken into account when planning.

d. Population Growth

Revisiting PSMP2016 assesses that electricity demand will increase more rapidly than the rate of population growth due to a reduction in the proportion of the poor and ultra-poor and an increase in purchasing power.

e. Other factors influencing electricity demand

In order to achieve the government's target of becoming a developed country by 2041, GNI per capita needs to be at least US$12,736, which the Revisiting PSMP2016 assesses to be higher than the PSMP2016 assumptions and therefore mentions it will be higher than the PSMP2016 electricity demand projections.

In addition, the following findings of the electricity distribution companies was taken into account:

i. 3 to 5 million new households are being supplied with electricity every month. These new connections add about 100 MW of electricity to the total demand.
ii. An additional 50 MW of electricity is being added to total demand for existing

consumers to purchase new electrical appliances.

1.3 Estimation of the daily load curve

Estimation of the daily load curve is also an important process in this IEPMP development project. In the PSMP2016, as shown in Figure 1.3.1, it was assumed that in the period 2017-2041, the daily load curve would shift from the evening peak type to the daytime peak type, which is typical for developed countries. Specifically, it was assumed that the daily load curve would shift to the Japanese summer daily load curve, and the Revisiting PSMP 2016 followed this approach.

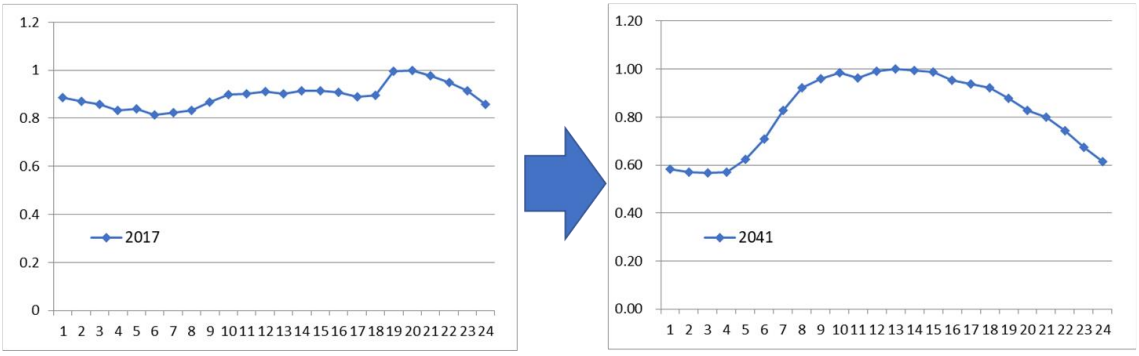


Figure 1.3-1 Estimation of Future Changes in the daily load curve at PSMP2016

The methodology for estimating the daily load curve in this IEPMP is described in a later section. There is a high probability that Bangladesh will shift to the daytime peak type if the country achieves economic development through industrialization in the future, but the idea that the country will shift to the Japan-type demand curve, where the latitude and climate are different and the difference of electricity demand between day and night and between seasons is so large that load factors are not good, was questioned during the field survey in November 2021.

Therefore, we would like to examine multiple patterns by referring to the shape of the daily load curves of major countries in Southeast Asia and South Asia. However, it is impossible to predict the exact shape of the daily load curve because it is influenced by various factors such as latitude, climate, industrial structure, lifestyle and culture, and it is not the purpose of this IEPMP to predict the exact shape. Therefore, in this IEPMP, we would like to compare the results in terms of climatic aspects, load factor, time of maximum demand generation and the impact of duck-curving by PV solar integration.

1.4 Power Development Plan

1) Outline of power development plan

As of 2016, the total installed capacity of the "existing" power sources in operation was 12,282 MW, but due to the regular decommissioning of these plants, capacity was expected to decrease to 11,946 MW in 2017, and thereafter to reach only 830 MW in 2041.

Therefore, as shown in Figures 1.4-1 and 1.4-2, a steady development of new power sources was required to meet the gap between the steadily increasing annual demand for electricity and the diminishing capacity of existing power sources.

As for new power sources, the so-called "committed" power sources that were under construction or had entered into power purchase agreements at the time of the Revisiting PSMP 2016 would not be sufficient, so it was necessary to consider "candidate" power sources as additional power sources.

Figures 1.4-1 and 1.4-2 show the breakdown of the power supply mix and the reserve margin ratio for the High Case and Low Case scenarios of electricity demand in the Revisiting PSMP 2016, respectively.

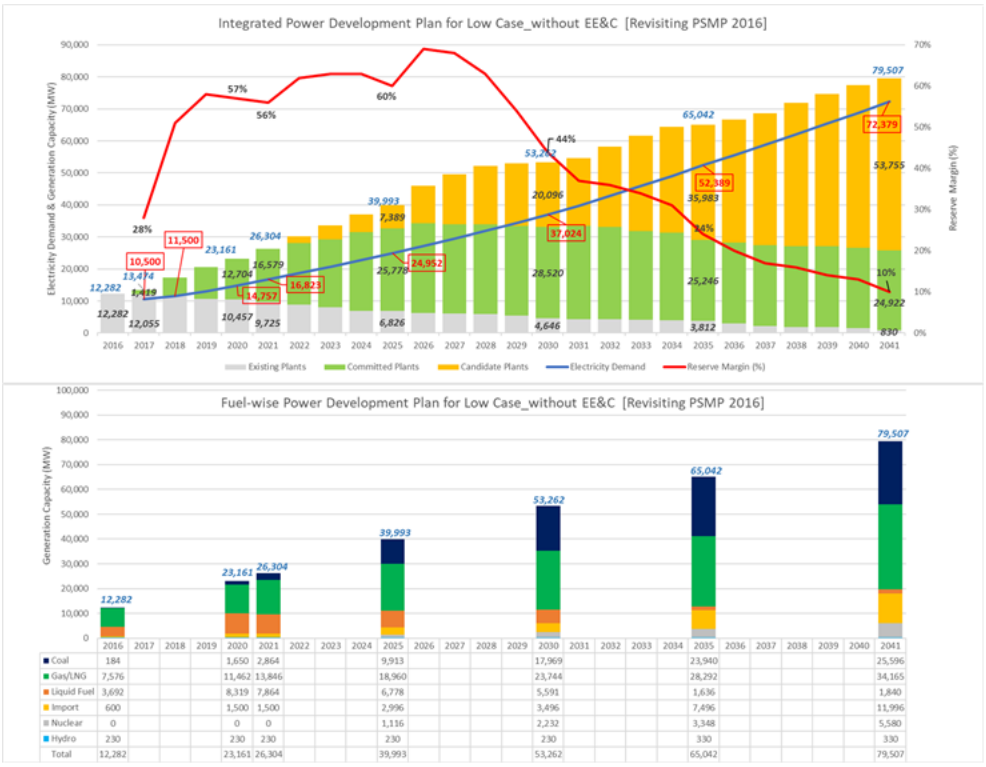
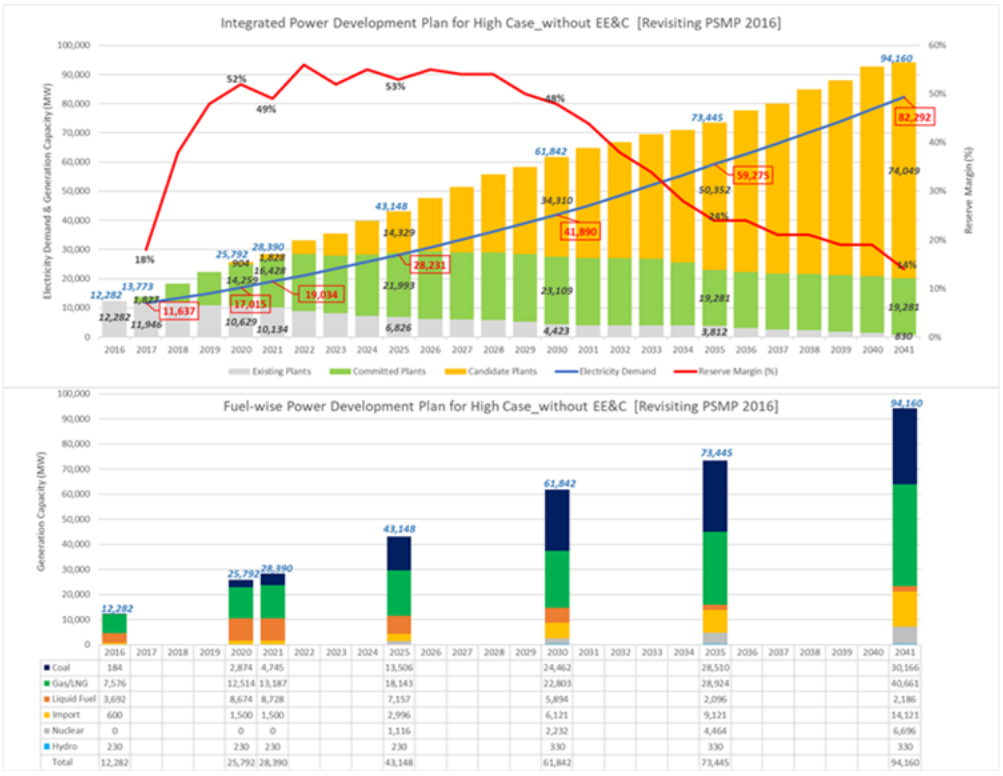


Figure 1.4-1 Overview of Power Development Plan in High Case (without EE&C)



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041
Coal	184				2,874	4,745				13,506					24,462					28,510						30,166
Gas/LNG	7,576				12,514	13,187				18,143					22,803					28,924						40,661
Liquid Fuel	3,692				8,674	8,728				7,157					5,894					2,096						2,186
Import	600				1,500	1,500				2,996					6,121					9,121						14,121
Nuclear	0				0	0				1,116					2,232					4,464						6,696
Hydro	230				230	230				230					330					330						330
Total	12,282				25,792	28,390				43,148					61,842					73,445						94,160

Figure 1.4-2 Overview of Power Development Plan in High Case (without EE&C)

2) Features of the Power Development Plan

a. Installation Capacity

1) Gas/LNG based generation capacity is projected to be higher than coal-based capacity due to the cleaner fuel.

2) The reserve margin ratio decreases from 18% (High Case) and 28% (Low Case) in 2017 to 14% (High Case) and 10% (Low Case) in 2041. Both cases are temporarily higher between 2020 and 2028, due to the construction of new coal-fired and nuclear power plants.

3) The reserve ratio is targeted at 25% for the foreseeable future up to 2025, then gradually lowered to 12% from 2036 onwards, maintained as it is until 2041 in the High Case, and 10% in the Low Case. This is because the reserve ratio is theoretically calculated to be around 20-25% when the LOLE (Loss of Load Expectation) for developing countries is set at around 1.0-1.5 days/year, so the target for the time being is to decrease gradually within that range. In the end, the target is reduced to 8-15%, which would be challenging but would be equivalent to the Japanese level of 0.3 days/year.

b. Fuel mix

The Revisiting PSMP 2016 states that the following factors have been taken into account, in addition to future declines in domestic gas reserves and fuel procurement challenges such as gas field development and domestic coal development:

1) Economic issues
2) Environmental issues
3) Constraint of transmission facilities
4) Regional balance
5) Fuel transportation
6) Cost of generation

With regard to electricity imports, both the PSMP 2016 and the Revisiting PSMP 2016 set a limit of 15% of total generation capacity and a limit of 10% per connection point (taking into account the reduction in frequency when the international interconnection line is disconnected). In general, the reliance on gas/LNG and coal is high.

c. Ratio of public to private sector in power development

Limits on the ratio of public sector to private sector generation capacity are generally set by the regulator or the government from three perspectives: to ensure healthy competition on price and efficiency, to maintain the supply-demand balance and stable supply, and to ensure national energy security.

Table 1.4-1 Yearly Change in the Ratio of Public to Private Sector in Power Development

Year	2017		2020		2021		2025		2030		2035		2041	
	MW	%	MW	%	MW	%	MW	%	MW	%	MW	%	MW	%
Public Sector	7,451	54	12,752	49	15,253	54	30,563	71	47,270	76	59,071	80	61,882	66
Private Sector	5,662	41	11,540	45	11,637	41	9,589	22	8,451	14	4,853	7	4,207	4
Imported Power	660	5	1500	6	1500	5	2996	7	6121	10	9121	12	14,121	15
Not Known	0	0	0	0	0	0	0	0	0	0	400	1	13,950	15
Grand Total Generation Capacity	13,773	100	25,792	100	28,390	100	43,148	100	61,842	100	73,445	100	94,160	100

The Revisiting PSMP 2016 states that there is no restriction on the share of generation capacity of private sector in Bangladesh, while at least 50% of the capacity should be developed by the public sector to ensure a stable supply of electricity. As shown in Table 1.4-1, 66% of the power supply is to be developed by the public sector in 2041.

On the other hand, the aforementioned PP2041 sets a target of 60% of power development from the private sector in 2041, and we believe that it is necessary to comply with this target,

but this is an issue that requires further discussion with the Bangladesh power sector.

d. Regional balance of power development

Table 1.4-2 shows the estimated supply-demand balance of electricity by zone for the period 2017 to 2041.

Table 1.4-2 Status of Power Development Plans by Zone

Year	2018			2021			2025		
Zone	Generation Capacity (MW)	Demand (33 kV) (MW)	Interchange (Not considering loss) (MW)	Generation Capacity (MW)	Demand (33 kV) (MW)	Interchange (Not considering loss) (MW)	Generation Capacity (MW)	Demand (33 kV) (MW)	Interchange (Not considering loss) (MW)
Dhaka	6,379	4,714	1,665	8,571	6,837	1,734	10,078	10,167	-89
Chattogram	1,761	1,554	207	3,624	2,235	1,389	7,387	3,419	3,968
Cumilla	2,922	968	1,954	3,594	1,448	2,146	3,059	2,033	1,026
Mymensingh	519	1,021	-502	994	1,424	-430	972	2,054	-1,082
Sylhet	1,878	730	1,148	2,405	1,034	1,371	2,165	1,555	610
Rajshahi	1,449	1,374	75	2,024	1,903	121	4,423	2,669	1,754
Rangpur	476	806	-330	810	1,145	-335	810	1,683	-873
Khulna	2,575	1,329	1,246	4,095	1,861	2,234	6,759	2,822	3,937
Barishal	360	377	-17	2,273	593	1,680	7,495	1,007	6,488
Total	18,319	12,873	5,446	28,390	18,480	9,910	43,148	27,409	15,739

Year	2030			2035			2041		
Zone	Generation Capacity (MW)	Demand (33 kV) (MW)	Interchange (Not considering loss) (MW)	Generation Capacity (MW)	Demand (33 kV) (MW)	Interchange (Not considering loss) (MW)	Generation Capacity (MW)	Demand (33 kV) (MW)	Interchange (Not considering loss) (MW)
Dhaka	10,569	14,886	-4,317	10,292	20,843	-10,551	9,437	28,070	-18,633
Chattogram	18,068	5,232	12,836	19,598	7,604	11,994	21,888	10,844	11,044
Cumilla	4,279	2,823	1,456	3,487	3,903	-416	2,770	5,273	-2,503
Mymensingh	770	3,055	-2,285	360	4,454	-4,094	360	6,284	-5,924
Sylhet	2,640	2,307	333	3,912	3,096	816	3,168	4,286	-1,118
Rajshahi	5,268	3,827	1,441	5,717	5,360	357	5,903	7,879	-1,976
Rangpur	2,435	2,544	-109	7,041	3,780	3,261	8,257	5,655	2,602
Khulna	9,103	4,161	4,942	9,593	5,702	3,891	9,338	7,640	1,698
Barishal	8,709	1,834	6,875	9,813	2,807	7,006	11,225	3,965	7,260
Total	61,842	40,669	21,173	69,813	57,549	12,264	72,346	79,896	-7,550

While the demand for electricity is expected to increase significantly in all zones, especially in Dhaka and Chattogram, the supply of electricity in 2041 is expected to be higher in Chattogram and Barishal, which are coastal areas with high potential for power generation, and in Khulna, where the international interconnection with India is underway and a nuclear power plant is being constructed. On the other hand, inland areas such as Dhaka and Mymensingh, which are expected to be the focus of future economic development, are

generally undersupplied.

It should be noted that there are more than 21,814 MW of "candidate" power plants with no fixed location. These plants need to be determined in the light of the supply-demand balance in each zone, the availability of fuel, and the coordination with the construction of transmission and substation facilities, especially the backbone networks.

e. Renewable energy generation

Targeted renewable energy generation capacity

Table 1.4.3 shows the power development plans by renewable energy type. In developing the plans, the following points have been taken into account:

1) When connecting VRE power sources such as wind and solar PV, the impact on grid stability needs the Economics of Flexible Power Systems, 2014, the target should be no more than 5-10% of the total annual electricity generation.
2) To some extent, the transmission and distribution network needs to be strengthened, but it is difficult to determine how much it will cost to expand the network in order to increase the amount of renewable energy sources (especially VREs) connected. It is said that the development of renewable energy sources should be on a feasible scale.
3) Technical regulations and standards need to be established for the development of utility-scale, high-capacity renewable energy sources.
4) The possibility of importing hydropower from South Asian countries should be considered; it is projected that around 2041, approximately 5,000 MW of hydropower could be imported, mainly from Bhutan, Nepal and north-eastern India.

Table 1.4-3 Development Plans for Renewable Energy Sources

Year	Solar(MW)	Wind(MW)	Biomass(MW)	Total(MW)	Year	Solar(MW)	Wind(MW)	Biomass(MW)	Total(MW)
2017				0	2027		50		50
2018	427	60		487	2028				0
2019	1,080	100	1	1,181	2029				0
2020	315			315	2030				0
2021	100	150		250	2031	100			100
2022	300			300	2032				0
2023				0	2033				0
2024				0	2034				0
2025				0	2035		150		150
2026				0	Total	2,322	510	1	2,833

3) Points to be considered when developing the IEPMP

a. Change of policy on the construction of coal-fired power stations

After the formulation of the Revisiting PSMP 2016, as mentioned above, the Government of Bangladesh responded quickly to the global situation towards the realization of a low and decarbonized society and froze the plans for the construction of 10 coal power plants in June 2021. This policy decision will be respected and considered in the formulation of this IEPMP.

b. Factoring renewable energy sources into supply capacity

As mentioned above, the breakdown of power sources shown in 1.4 (1) does not include renewable energy sources. This is because, for the time being, the main source of renewable energy in the future will be solar power, which cannot be expected to be available in the evenings when electricity demand peaks.

However, when the industrial structure of Bangladesh changes in the future, there is a possibility that the country will shift to a daytime peak system like Japan, Thailand and other developed countries. Therefore, it is necessary to discuss whether and how to include VRE power sources as supply capacity in the maximum power demand estimation.

c. Securing reserve margin

The target for the reserve margin ratio in the Revisiting PSMP 2016 is described in 6.1.4 (2) a., but reserve margin is usually a power source whose value is in being mainly on standby, so even if it does not generate power, it must continue to pay a fixed fee based on its installed capacity. Therefore, unplanned development of power supply may exceed the appropriate amount of reserve power, which may become an economic burden for the country. This is also an issue in Bangladesh as it is one of the negative factors to the BPDB balance of payments. Therefore, it is also mentioned that there is a need for a thorough study on the reserve ratio to maintain the reliability of supply to the customers while minimizing the reserve capacity.

In this IEPMP, the adequacy of the current reserve margin ratio will be assessed using data from the PGCB Daily Operational Reports, as described below, using a probabilistic approach to demand forecast errors and unplanned outages of generators over the past few years, and the future target of the LOLE, a supply reliability indicator, will be discussed with the power sector in Bangladesh.

1.5 Transmission system planning

1) Future transmission planning up to 2041

The topics of the plan include the following points:

a. Construction of a 765 kV transmission line

In view of the present and future decline in domestic gas production, the development of a power hub based on Matarbari, Moheskhali and Payra coal fired power plants is in progress.

Construction of 765kV transmission lines from that power hub to the load centers at Dhaka, Chattogram, etc. are planned. Specifically, two routes of 765 kV transmission lines, one from Moheskhali to Dhaka and the other from Patuakhali to Dhaka.

b. Construction of substations for 765/400kV transmission

c. The following are planned:
   1） For Dhaka, Chattogram and other load centers: 2 substations named Bhulta & Dhaka (South)
   2） 1 substation near Mirsarai for Chattogram, Greater Cumilla and Greater Noakhali

d. Construction of International Interconnection Lines and HVDC/Back-to-back facilities

There are plans to build new interconnector lines and HVDC/Back-to-back facilities for import of power through India.

In addition to the existing Bheramara HVDC/Back to Back station, there are plans to construct HVDC/Back to Back stations at Barapukuria, Cumilla, Jamalpur and Sylhet.

e. Construction of 400 kV ring transmission line around Dhaka city.

According to the demand forecast of DPDC and DESCO, the power demand in the Dhaka region supplied by these two distribution companies is expected to be about 19,000 MW by 2041, hence there is a plan to construct a 400 kV ring transmission line around Dhaka city.

f. Measures for stable operation of Rooppur Nuclear Power Plant

According to the plan at the time of preparation of Revisiting PSMP 2016, two units of 2,400 (2×1,200) MW Rooppur Nuclear Power Plant will be put into operation during 2025-2026 (latest plan is 2024-2025). In order to ensure a safe and reliable supply of electricity from the NPPs, a transmission line is planned to be constructed to ensure continued operation in the event of an N-2 failure of the power transmission line.

g. Measures to improve reliability of power supply to Economic Zones

Plans are being made for expansion of transmission lines and substations for uninterrupted supply of electricity to all the EZs being implemented by Bangladesh Economic Zones Authority (BEZA).

h. Expansion of 400 kV transmission line network

In order to strengthen the power transmission system, plans have been made to construct 400kV transmission lines in all zones of the country. Every zone of the country will be connected to Dhaka with a 400 kV transmission line.

2) Inter-regional supply and demand balance via the power grid

The power grid of Bangladesh is divided into two regions, Eastern and Western, across the delta of Ganges (Padma) and Brahmaputra (Jamuna) rivers, and further divided into two parts, North and South, South-Eastern, South-Western and North-Eastern. Currently, the eastern and western regions are interconnected by several 230 kV transmission lines.

As mentioned earlier, the PGCB plans to construct 400 kV transmission lines (765 kV in some zones) to connect the zones to the Dhaka zone, and in particular to connect the Matarbari, Moheskhali and Mirsarai power hubs to the Dhaka zone with 765 kV lines.

In zones where demand for electricity exceeds supply and transmission capacity is limited, liquid-fueled power plants are usually constructed, but at a high cost and with negative environmental impact. In order to solve this situation, the basic policy is to plan the construction of transmission lines with a capacity of at least 150% of the total generation capacity. It also states that substations should be planned to increase their capacity by the year in which they are used by more than 60% of the load. This is due to the need to provide sufficient redundancy to ensure that power supply is not disrupted for long periods in the event of cyclones and other natural disasters.

1.6 Distribution system planning

1) Technological developments in the distribution system

Distribution companies are entering an era in which the simple process of expanding distribution lines is no longer sufficient to supply high quality electricity to their customers.

Increasingly, technologies such as Distribution Management Systems (DMS), Geographic Information Systems (GIS) and Supervisory Control and Data Acquisition (SCADA) are appearing in the distribution sector community for the design, planning, maintenance and analysis of facilities. The integration of GIS into SCADA/DMS systems requires a significant investment in software development.

GIS is necessary to improve the reliability of supply by identifying, isolating and recovering from equipment faults quickly. In addition, the use of real-time SCADA data, along with the critical data managed by GIS, is expected to further improve business. Therefore, it is recommended to integrate all GIS and SCADA into a single system and exchange information in a coordinated manner.

Furthermore, it is recommended to establish a smart grid with GIS and SCADA as components in order to reduce distribution system losses, theft and leakage.

2) Distribution system planning

The requirements for distribution lines, distribution substations and distribution transformers

(pole transformers) are planned on the basis of High Case demand estimations.

1.7 Investment costs for generation, transmission and distribution facilities

a. Total investment costs

It is estimated that investment of US$216 billion will be required between 2017 and 2041 under the High Case demand estimation and US$193 billion under the Low Case demand estimation. The only difference is in the amount of investment in generation equipment, with the same amount of investment in transmission and distribution equipment estimated.

Table 1.7-1 Required Investment in Transmission and Distribution Facilities in the High Case demand

billion US$

Year	Generation	Transmission	Distribution	Total
2017-2025	56	13	12	82
2026-2030	38	5	7	50
2031-2035	27	6	7	40
2036-2041	29	6	9	44
Total(2017-41)	150	31	35	216

Table 1.7-2 Required Investment in Transmission and Distribution Facilities in the Low Case demand

billion US$

Year	Generation	Transmission	Distribution	Total
2017-2025	47	13	12	72
2026-2030	31	5	7	43
2031-2035	26	6	7	39
2036-2041	24	6	9	39
Total (2017-41)	126.6	31	35	193

b. Generation costs

The price of Bangladesh's domestic gas is much lower than the international price. However, this price will rise in the future due to the addition of LNG, which is much more expensive than domestic gas. The analysis shows that an increase in the share of coal and imported electricity will help reduce the average cost of power generation.

Table 1.7-3 Fuel-wise Generation Costs in PSMP2016 and Revisiting PSMP2016

Fuel Type	Unit	2018	2019	2020	2021	2025	2030	2035	2041
Coal	Tk./kWh	1.78	2.36	2.39	2.5	2.7	2.8	2.9	3.05
Gas	Tk./kWh	1.7	1.8	1.9	2.05	2.17	2.2	2.27	2.5
Liquid Fuel	Tk./kWh	4.21	4.25	4.26	4.29	4.39	4.69	4.95	5.25
Import	Tk./kWh	5.68	5.75	5.82	5.89	6.16	6.47	6.74	7.01
Nuclear	Tk./kWh					6.08	6.4	6.67	7.06
Hydro	Tk./kWh	1.01	1.02	1.03	1.05	1.1	1.15	1.2	1.25

2. Power Development Plan

2.1 Estimation of annual maximum electricity demand (MW)

1) Calculation procedure

The annual maximum electricity demand (MW) estimation is obtained using the electricity energy demand (GWh) estimation.

As shown in the flow in Figure 2.1-1(a), the annual final electricity energy consumption provided by TWG1 is the amount of primary energy supply allocated to electricity, plus electricity import, minus station own use and transmission & distribution losses.

TWG2 uses this annual final electricity energy consumption (GWh) to calculate the maximum electricity (MW) for each year using the following procedure:

Step 1:

Subtract from the final electricity consumption the supply from captive power and roof-top solar power, because these will not be supplied by grid-connected generators (i.e. not subject to power development planning).

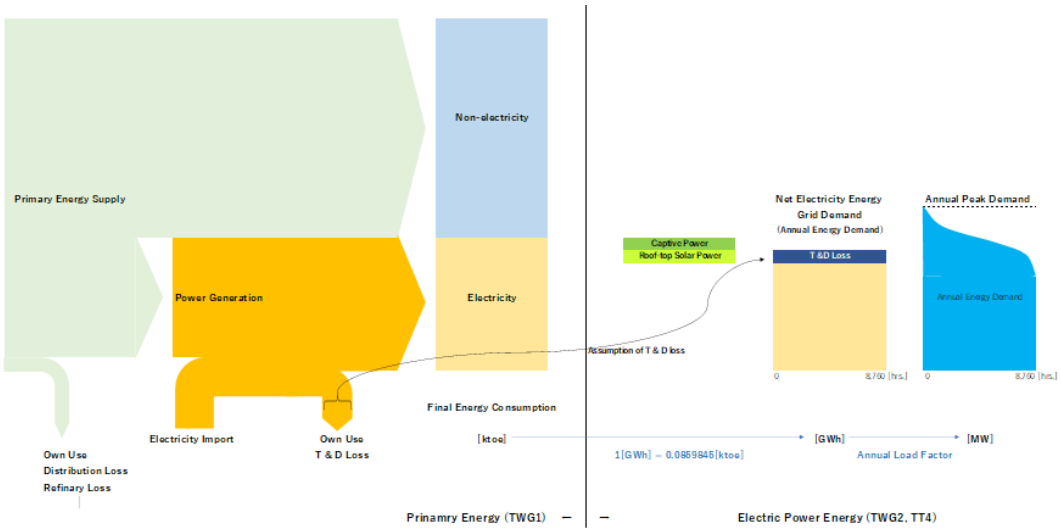
Step 2:

Next, the Net Electricity Energy Grid Demand (Annual Energy Demand) that should be annually supplied by grid-connected generators is calculated by adding the assumed transmission and distribution losses.

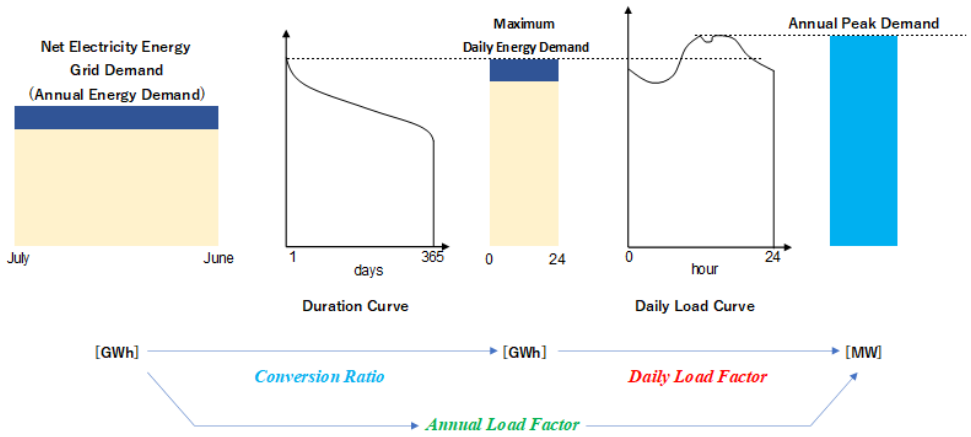
Step 3:

As shown in Figure 2.1-1(b), the maximum daily energy demand is obtained from the annual energy demand calculated in Step 2 by multiplying the conversion ratio.

This conversion ratio is calculated from the ratio of the annual energy demand to the actual maximum daily energy demand for the last three years from FY 2019 to FY 2021, and is initially set at 0.0035 for the time being.



(a) Overall Flow



$$Annual\ Peak\ Demand\ (MW) = \frac{Annual\ Energy\ Demand\ (GWh)\ \times 1{,}000}{Annual\ Load\ Factor\ \times\ 8{,}760\ (hrs.)}$$

$$Annual\ Load\ Factor = \frac{Daily\ Load\ Factor\ \times 24\ (hrs.)}{Conversion\ Ratio\ \times\ 8{,}760\ (hrs.)}$$

$Daily\ Load\ Factor \leftarrow Calculated\ from\ daily\ load\ curve\ shape\ for\ each\ year$

$Conversion\ Ratio \leftarrow Statistically\ determined$
$so\ that\ the\ annual\ load\ factor\ in\ 2050\ would\ be\ approximately$
- $64-65\%$ *in the Japan Shape case; and*
- $73-74\%$ *in the Thailand Shape case,*

which is close to the actual situation.

Methodology for assuming the Annual Load Factor and Formula for calculating the Annual Peak Demand.

Figure 2.1-1 Conversion Procedure from Electricity Energy Demand (GWh) to Maximum Electricity Demand (MW)

Step 4:

Finally, the annual load factor is calculated using the daily load factor estimated based on the assumed daily load curve and the conversion ratio assumed in Step 3. Then, the annual peak demand (MW) for each year is calculated according to the formula, shown in Figure 2.1-1(b).

The conversion ratio and annual load factor are then adjusted based on discussions with experts of the Bangladesh side to ensure that the calculated annual peak demand does not deviate from the actual situation and empirical sense.

2) Estimation of the daily load curve

a. Daily load curve model used in this study

In order to calculate the maximum hourly electricity demand (kW) from the daily electricity energy demand (kWh), it is necessary to assume the shape of the daily load curve, so the following procedure is used:

i. Modelling of the daily load curve for the first year (2021)

Hourly electricity demand data on the day of maximum demand in FY2021 (Apr. 27, 2021) and in calendar year 2020 (Sep. 5, 2020), 24 points x 2 days in total, are collected from PGCB Daily Operational Reports, and use the averaged value of the two data for each hour. The reason for using averaged value of separate days is to take into account the possible impact of the load shedding implemented in April.

Figure 2.1.2 shows the daily load curve model for 2021 used in this project. The peak demand is set at 100% and the remaining 23 demand points are normalized by that ratio, as shown in the figure.

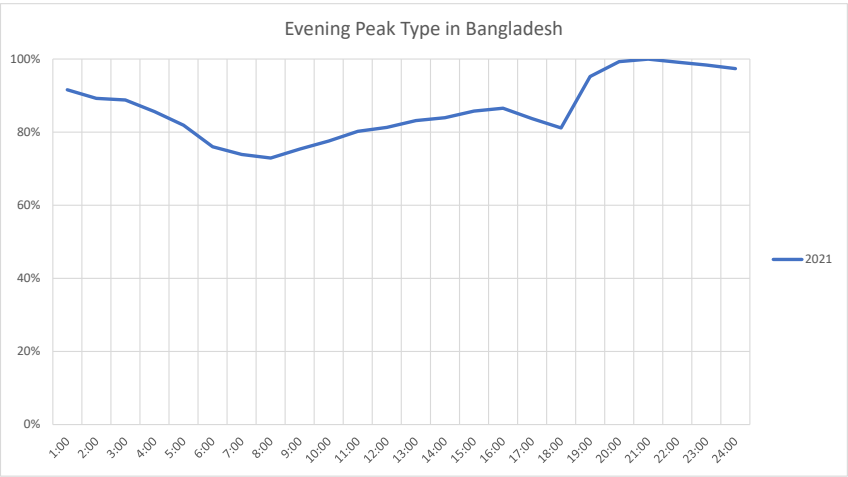


Figure 2.1-2 Daily Load Curve Model for 2021

ii. Estimation of the daily load curve model for the final year (2050)

Although it is not possible to model accurately, it is assumed that with the development of economic activities such as commerce and industry in Bangladesh, the country will gradually shift from the current evening peak type to the daytime peak type on weekdays, similar to developed countries such as Japan. The PSMP 2016 used the daily load curve for Japan's maximum electricity demand day in summer 2014, and we consider in the next section which country's demand curve should be used in this project.

Figure 2.1-3 shows the daily load curve for the maximum summer electricity demand day in Japan in 2021, normalized with peak demand at 100%.

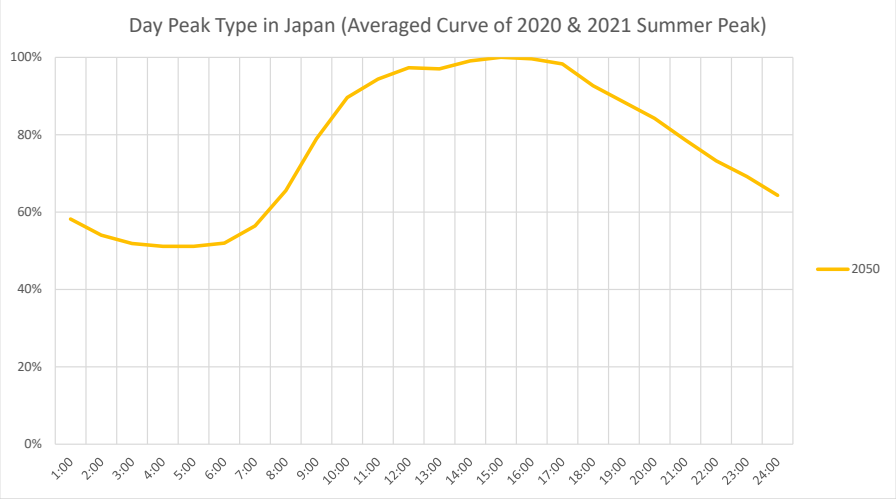


Figure 2.1-3 Daily Load Curve for Japan in Summer 2021 (one candidate for 2050 model in the IEPMP)

iii. Estimation of the daily load curve for the years leading to 2050

For the sake of simplicity, a proportional change from the first year's demand ratio to the 2050 demand ratio is used for each hourly time period. The daily load curve for each year is used in the same way, with peak demand normalized to 100%.

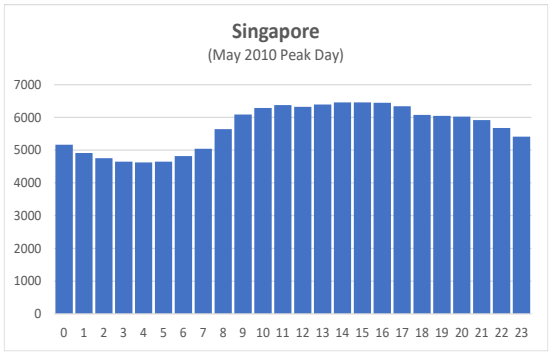
Figure 2.1-4 Image of Daily Load Curve Setting in the middle years from 2021 to 2050

b. Comparative analysis of daily load curves for Japan and major countries in Southeast and South Asia

Figure 2.1.5 shows the typical daily load curves for maximum electricity demand days for Japan and for Singapore, Thailand, Vietnam, and India as representatives of the economically developing countries of Southeast and South Asia.

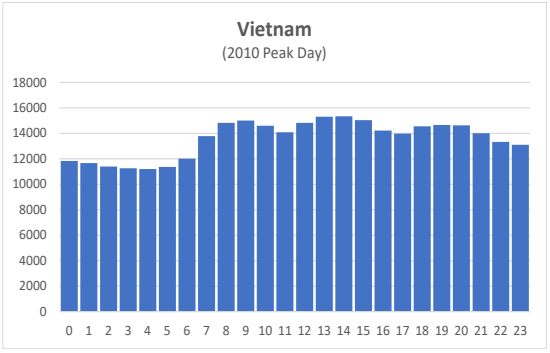
Since few countries officially publish their daily load curves (hourly electricity demand) with numerical data, the daily load curves for Singapore, Thailand and Vietnam are re-plotted from the graphs published in the source documents, using numerical data read visually with the help of free software. It is not an official value, but the study team judged it to be sufficient for an approximate study.

Although the data for the three countries are old, dating from the early 2010s, the daily load curves for the most recent years are likely to be heavily influenced by the interconnection of PV power generation to the demand side, and the demand curves are likely to be deformed in the daytime (so-called duck curves). In the following studies, it is better to use the gross daily load curve without the influence of PV, so the study team decided to use the old data.

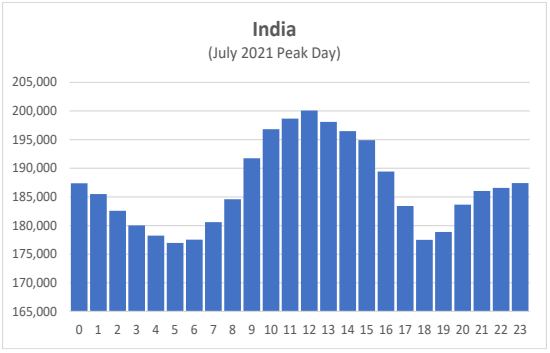


Singapore

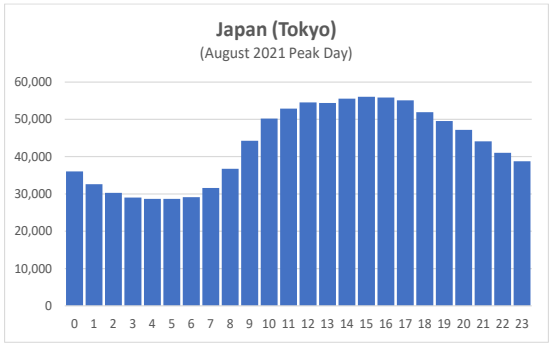
Thailand



Vietnam



India



Japan (TEPCO)

Source:

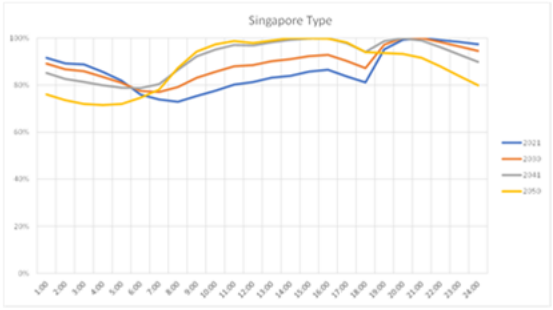
Singapore, Thailand and Vietnam: Investing in Power Grid Interconnection in East Asia, Research Project Report 2013-23, ERIA

India: Monthly Reports, Posoco

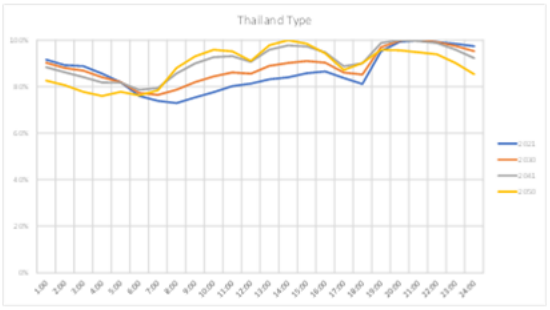
Japan (TEPCO): TEPCO illustrated, TEPCO

Figure 2.1-5 Comparison of Daily Load Curves for Japan and Major Countries in Southeast and South Asia

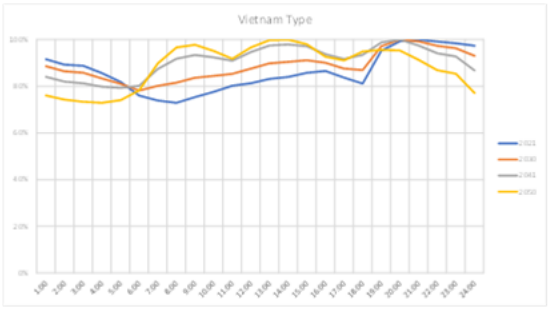
Figure 2.1-6 shows the change in the shape of the daily load curve from the Bangladesh daily load curve model in 2021 to each country's type of daily load curve model in 2050, using the data from the above five countries in the procedure described in a.



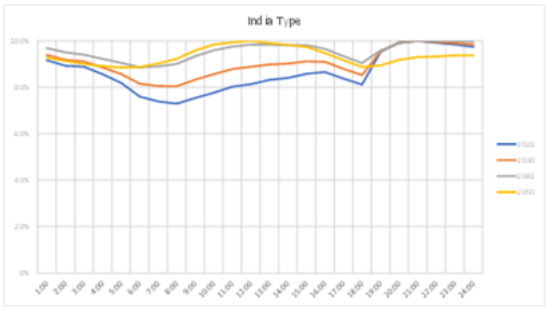
Singapore Type



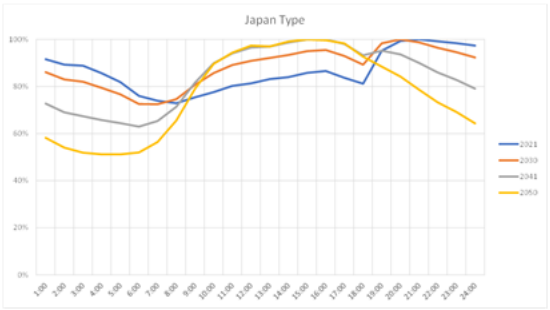
Thailand Type



Vietnam Type



India Type



Japan Type

Figure 2.1-6 Daily Load Curve for Bangladesh up to 2050 assuming Change to the Type for Japan and Major Southeast and South Asian Countries

The following is a comparative evaluation of these results. As mentioned earlier, it is impossible to predict the exact shape of the daily load curve because of the influence of various factors such as latitude, climate, industrial structure, lifestyle and culture, and it is not the purpose of this IEPMP to predict the exact shape. Therefore, in this IEPMP, considerations will be made from following three aspects: geographical aspects, daily load factor, time of maximum electricity demand (the impact of duck-curve phenomenon by PV generation).

iv. Geographical considerations

Japan is located at a higher latitude than Bangladesh, and most of the country, including Tokyo, has a temperate humid climate. The high temperature and humidity, especially during the daytime in summer, induces an increase in the demand for air-conditioning. As a result, the difference between day and night is relatively large and the load factor is not good. In Bangladesh, which has a tropical monsoon climate, the average temperature is higher than in Japan, but the change in electricity demand between day and night is relatively low.

Singapore and Thailand, on the other hand, are located at lower latitudes than Bangladesh and have higher average temperatures than Bangladesh. Singapore has a tropical rainforest climate, while Thailand has a tropical savanna climate, with seasonal differences in dry and rainy seasons, similar to Bangladesh.

Vietnam is long and narrow from north to south, and Hanoi in the north is relatively close in latitude to Dhaka in Bangladesh, but has a temperate climate, while Ho Chi Minh City in the south has a tropical climate. Overall, the differences in climate are so great that it is difficult to make a uniform assessment.

Similarly difficult to assess uniformly is the neighboring country of India. With half an hour time difference between Bangladesh and India, there are differences in sunrise and sunset times according to longitude. Therefore, there is concern that the difference between day and night is low in general, and that the load factor may be too favorable when applied to Bangladesh.

From the above discussion, it seems reasonable to target the daily load curve of Thailand for the year 2050 from the point of view that although Thailand is at a lower latitude and has a higher average temperature than Bangladesh, there is no significant difference in temperature during the high temperature season and the climate is similar to that of tropical Savannah.

v. Consideration by comparison of daily load factors

Table 2.1.1(a) shows the load factors of the daily load curve for each year set up by the procedure described in (1) of this section.

As mentioned earlier, the assumption of a Japan-type daily load curve in 2050 leads to a lower load factor in each year compared with the assumption by the other four developed countries in the low latitude zone.

If the lower load factor is adopted, the maximum electricity demand (kW) is calculated larger, which is a conservative assumption, but also leads to excessive power development.

Therefore, the Thai daily load curve model (or at least South-East Asian model) is recommended in this respect.

Table 2.1-1 Characteristics of the Daily Load Curve Model for Asian Countries

	Japan	Thailand	Vietnam	Singapore	India
2021	86.19%	86.19%	86.19%	86.19%	86.19%
2022	86.49%	86.43%	86.51%	86.49%	86.63%
2023	86.80%	86.68%	86.84%	86.80%	87.07%
2024	87.12%	86.92%	87.18%	87.11%	87.52%
2025	87.31%	87.17%	87.51%	87.42%	87.97%
2026	87.44%	87.42%	87.77%	87.73%	88.42%
2027	87.58%	87.67%	87.96%	88.05%	88.87%
2028	87.72%	87.92%	88.16%	88.37%	89.32%
2029	87.85%	88.17%	88.36%	88.68%	89.78%
2030	87.99%	88.42%	88.56%	89.00%	90.24%
2031	88.13%	88.67%	88.76%	89.25%	90.70%
2032	88.28%	88.93%	88.96%	89.50%	91.16%
2033	88.42%	89.18%	89.16%	89.76%	91.63%
2034	88.57%	89.44%	89.36%	90.01%	92.10%
2035	88.32%	89.66%	89.56%	90.27%	92.57%
2036	87.57%	89.87%	89.77%	90.52%	93.04%
2037	86.83%	90.08%	89.97%	90.78%	93.51%
2038	86.10%	90.29%	90.17%	91.04%	93.99%
2039	85.37%	90.50%	90.38%	91.30%	94.47%
2040	84.66%	90.71%	90.58%	91.56%	94.95%
2041	83.94%	90.92%	90.79%	91.70%	95.43%
2042	83.23%	91.14%	90.99%	91.35%	95.92%
2043	82.50%	91.35%	91.20%	91.00%	96.24%
2044	81.78%	91.56%	91.40%	90.65%	95.86%
2045	81.06%	91.38%	90.99%	90.31%	95.49%
2046	80.35%	90.97%	90.57%	89.93%	95.12%
2047	79.64%	90.57%	90.15%	89.56%	94.76%
2048	78.94%	90.18%	89.75%	89.20%	94.40%
2049	78.25%	89.79%	89.34%	88.84%	94.05%
2050	76.89%	89.02%	88.54%	88.12%	93.36%

(a) Load factor

	Japan	Thailand	Vietnam	Singapore	India
2021	21	21	21	21	21
2022	21	21	21	21	21
2023	21	21	21	21	21
2024	21	21	21	21	21
2025	20	21	21	21	21
2026	20	21	20	21	21
2027	20	21	20	21	21
2028	20	21	20	21	21
2029	20	21	20	21	21
2030	20	21	20	20	21
2031	20	21	20	20	21
2032	20	21	20	20	21
2033	20	21	20	20	21
2034	20	21	20	20	21
2035	16	20	20	20	21
2036	16	20	20	20	21
2037	16	20	20	20	21
2038	16	20	20	20	21
2039	16	20	20	20	21
2040	16	20	20	20	21
2041	16	20	20	16	21
2042	15	20	20	16	23
2043	15	20	20	16	12
2044	15	20	20	16	12
2045	15	14	14	15	12
2046	15	14	14	15	12
2047	15	14	14	15	12
2048	15	14	14	15	12
2049	15	14	14	15	12
2050	15	14	14	14	12

(b) Time of maximum electricity demand

vi. Consideration of time of maximum electricity demand (the impact of duck-curve phenomenon by PV generation)

Table 2.1-1 (b) shows the annual trends in the time of maximum demand.

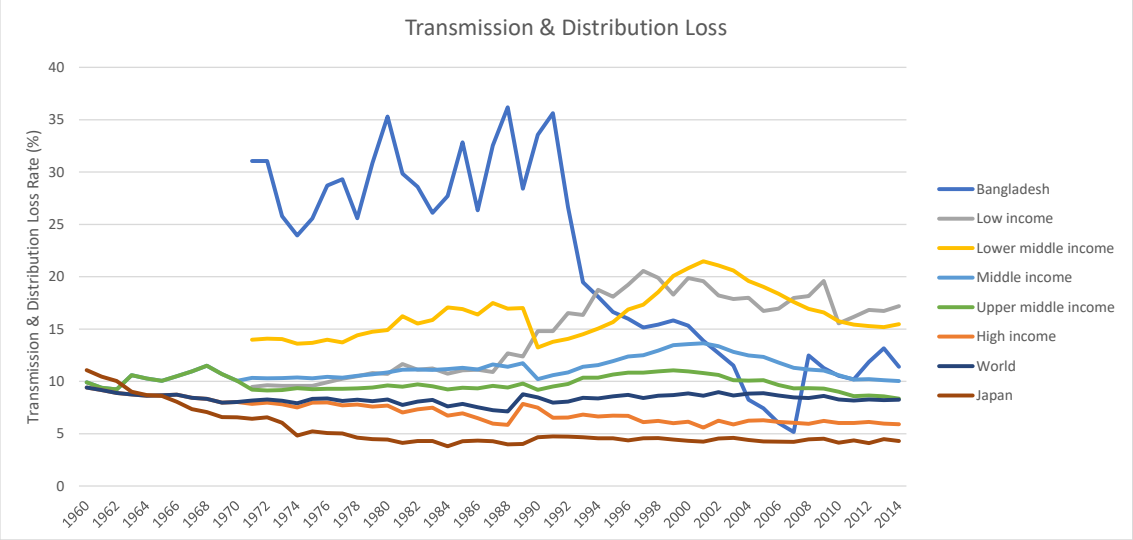
The daily load curve models used in this study for each country are those of which are unaffected by the apparent decline in daytime electricity demand associated with increased PV output (the so-called duck curve phenomenon of the daily load curve). Therefore, in this study, the JICA study team assumes that the daily load curve will gradually shift to a daytime peak type curve after 2035 in the case using the Japanese-type model and in the 2041 in the case using the other four country-type models. However, if the duck curve phenomenon progresses, the actual daily load curve may continue with peak demand in the evening after the output from PV power generation has decreased. In such a case, one approach is to consider assuming that the time of maximum electricity demand is in the evening for all years leading up to 2050.

However, because there is a potential risk that the maximum electricity demand will occur during the daytime due to bad weather conditions, the JICA Study Team decided that, when considering the power supply development plan, the daily load curves should not be corrected to take the duck-curve phenomenon into account.

3) Transmission and Distribution Losses (kWh)

Figure 2.1-7 shows the yearly trend of the transmission and distribution loss ratio in Bangladesh and a comparison with other countries obtained from the World Bank's World Development Indicator.

In Bangladesh, the transmission and distribution loss ratio fluctuated around 30% before the 1990s, but it has improved significantly since then and has been reduced to around 10% by around 2014. Although not shown in the graph, the BPDB's Annual Report shows that, in 2020-21, the transmission loss rate was 3.07% and the distribution loss rate was 8.50%, making a total transmission loss rate of 11.11%.



Source: World Bank: World Development Indicators

Figure 2.1-7 Annual Trends in Transmission and Distribution Loss Ratio

2.2 Supply reliability and reserve capacity

As mentioned in the Revisiting PSMP 2016, the adequacy of reserve power and regulating power is an important issue to ensure both stability and affordability of the electricity supply.

In order to ensure a stable supply of electricity, it is necessary to secure reserve capacity so that electricity is not cut off as much as possible in the event of unpredictable and abnormal events, such as unplanned outages of generators or errors in demand forecasts.

Larger reserves will increase supply reliability, but if they become excessive, there is a risk that utilities will not be able to recover their investment and O&M costs, putting pressure on their finances. Ultimately, they will have to recover these costs through higher electricity prices, which will be a financial burden on electricity consumers. Therefore, it is necessary that the necessary amount of reserve power should be calculated through a proper and transparent process.

1) Methodology for calculating Supply Reserve Capacity

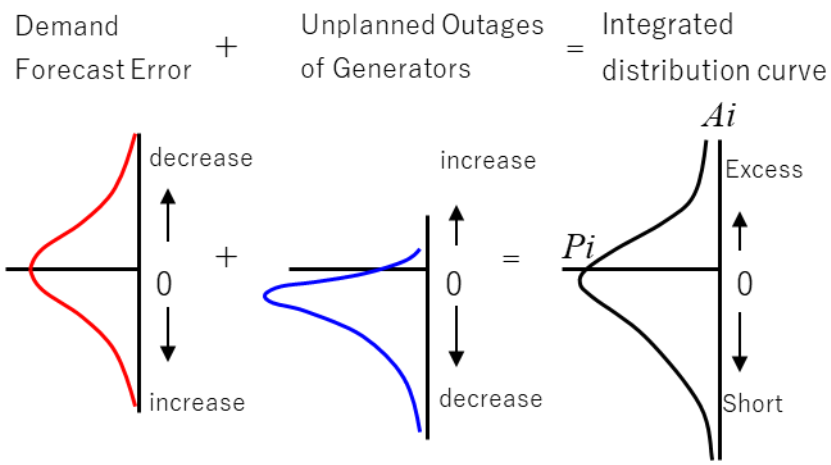
Step 1:

The following items are considered stochastic variables in the calculation of reserve capacity in Bangladesh and their probability distributions are obtained from the data in the Daily Operational Reports of the PGCB:

1) Demand fluctuation (Demand forecast error)
2) Supply fluctuation (Unplanned outage rate of generators)

Step 2:

Integrate the above three probability distributions to obtain the overall power supply shortage: Ai (kW) and its probability distribution (Integrated probability distribution of power supply shortage): Pi(Ai) (%).

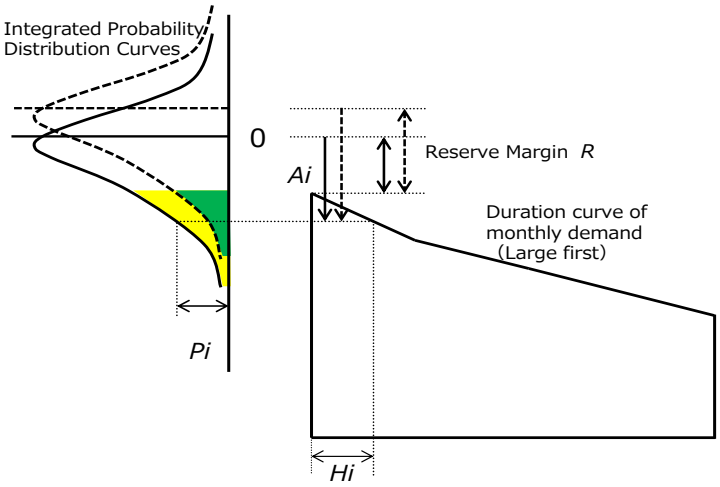


Step 3:

Aggregate the maximum daily electricity demand from the PGCB Daily Operational Reports and create a duration curve (a curve with the maximum daily electricity demand arranged from left to right in descending order with the horizontal axis being the number of days or hours).

Step 4:

Using the Integrated probability distribution of power supply shortage created in Step 2 and the maximum daily electricity demand duration curve created in Step 3, the number of days or hours: *Hi* (days or hours), that the supply power will be insufficient when the total supply capacity (kW) including the reserve capacity: *R* (kW) is reduced by *Ai* (kW) accidentally, and obtain the so-called LOLE (Loss of Load Expectation) = $\Sigma Hi * Pi(Ai)$. This gives the relationship between LOLE and the reserve capacity *R*(kW).



Step 5:

From the acceptable LOLE, the required reserve capacity *R*(kW) can be determined. For example, LOLE = 2.4 hours/year in Japan, 17.5 hours/year in India, and 24 hours/year in Vietnam and Sri Lanka are used respectively as the basis for calculating the required reserve capacity.

Based on a meeting with BPDB System Planning in November 2021, the JICA study team has decided, for the time being, to assume the following LOLE to calculate the appropriate reserve capacity ratio:

Present – 2030	LOLE=24 hours/yr.
2031-2041	LOLE=12 hours/yr.
2041-2050	LOLE= 6 hours/yr.

2) Study results

a. Demand forecasting error (Step 1)

i. Analysis method in Japan

In Japan, as a result of collecting and statistically analyzing the error data between the day-ahead forecasting of maximum electricity demand and the actual maximum demand of the day over the past several years, the probability density distribution of the demand forecasting error rate followed an approximate normal distribution, and as shown in Figure 2.2-1, the demand forecasting error rate with a cumulative probability of 99% was approximately -6%. As a result, the probability distribution of the demand forecasting error rate is still assumed to be a normally distributed curve with a cumulative probability of 49% from the mean to -6%.

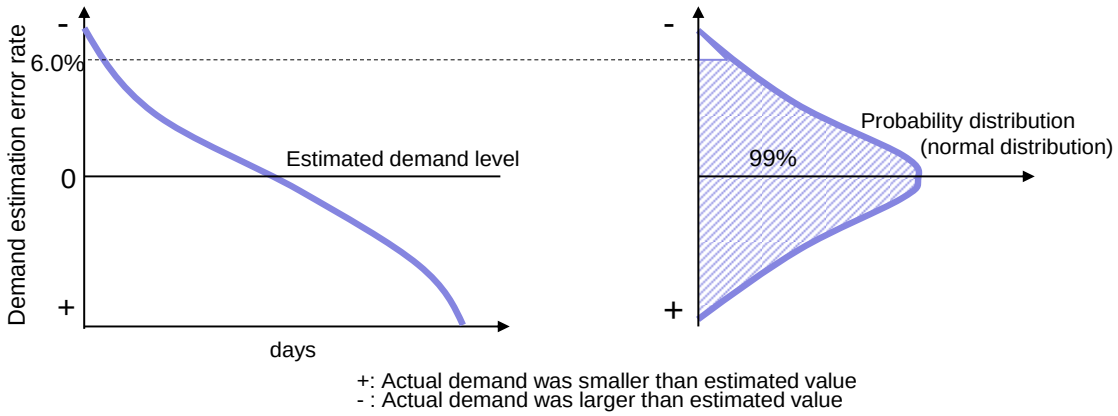


Figure 2.2-1 Concept of the Probability Distribution Curve for Demand Forecasting Error in Japan

ii. Result of the probability distribution analysis of demand forecasting error in Bangladesh

Figure 2.2-2 shows the calculated probability distribution of error between the forecasted and actual maximum daily electricity demand in Bangladesh, using data from the Daily Operation Report of the PGCB.

The results are for the four-year period from January 2018 to 31 December 2021 and analysis is currently in the process.

Horizontal axis: Demand Estimation Error Rate (%) = $\frac{Forecasted\ Demand - Actual\ Demand}{Actual\ Demand}$

Vertical axis: Probability Distribution (%) = $\frac{Frequency\ that\ Error\ Rate\ falls\ within\ each\ range}{Total\ number\ of\ data}$

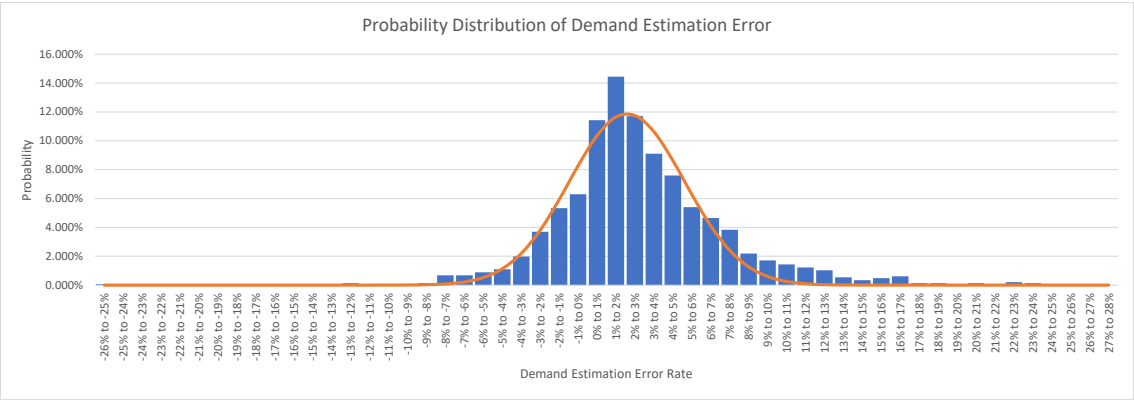


Figure 2.2-2 Probability Distribution of Maximum Electricity Demand Forecasting Error in Bangladesh

The blue bar graph is the frequency of each error rate interval on the horizontal axis divided by the total number of data, and it shows the actual probability distribution of demand forecasting errors. The orange line graph shows the curve estimated using the least-squares method, assuming that the actual probability distribution follows a normal distribution. The main parameters are as follows:

1) Maximum value (a) = 11.86%
2) Mean value (μ) = 2.082%
3) Standard deviation (σ) = 3.034
4) Assumed demand error rate at which the cumulative probability from the right-hand side reaches 99% is approximately -4.5%

It is still difficult to judge from the figure whether the demand forecasting error rate follows a normal distribution, but since the number of data and the setting of the interval width of the horizontal axis also affect the result, the JICA study team will continue to aggregate data and analyze.

The reason why the average value is shifted to the positive side instead of 0% is thought to be that system operators tend to make conservative (large) estimations when they judge maximum demand of the day. The error rate at which the cumulative probability reaches 99% is -4.5%, but considering the shift in the mean value, the distribution curve is equivalent to the -6.7% error rate case, which means that the trend is the same as in Japan.

iii. Probability distribution formula used in the analysis

This study is still in the process of being compiled and analyzed, but for the time being the JICA study team will assume that the demand forecasting error rate follows an orange normal distribution. In other words, the following formula is used:

$$Probability\ Distribution\ (\%) = 11.86 \times \exp\left(-\frac{(Error\ Rate - 2.082)^2}{2 \times 3.034^2}\right)$$

b. Unplanned outage probability of generator units (Step 2)

i. How to calculate the probability of unplanned outage for each generator unit

The Daily Operational Report of PGCB contains the operation records of all existing generators. In order to simplify the calculation, it was assumed that the generator units that were stopped or reduced in output due to fuel constraints or breakdowns during the evening peak demand period remained in the same state for the entire day, so the data is compiled on a daily basis.

The following simple equation was therefore defined as the unplanned outage probability for each unit and calculated for all generator units:

$$Unplanned\ outage\ probability\ of\ generator = \frac{O}{R+O}$$

Where,

O: number of days of unplanned outage, *R*: operating hours

Note that in this calculation, all units are calculated with R+O as 365 days (366 days in leap years), but this may include cases of planned outages for generator maintenance or planned output curtailment to prepare for primary response, such as FGMO, and the number of days in such a state should normally be excluded from the denominator, but this is not taken into account due to unknown data.

ii. How to calculate the probability distribution of unplanned outage of generators

The distribution of unplanned generator outage probabilities is obtained statistically using the probabilities of each generator unit obtained in the previous section.

However, as the process is very complex, the details are omitted here, but the basic idea is based on the following concept:

If there are *n* generators and the probability of an unplanned outage of each generator is uniformly *p*, then the probability *P(r)* of an unplanned outage of *r* out of *n* units follow binominal distribution as follows:

$$\mathrm{P(r)} = nCr \cdot p^r \cdot (1-p)^{n-r}$$

Therefore, if all generator units have the same rated capacity (*A* [MW]) and there are only two states: either they stop with the same probability of *p* or operate at rated output with a probability of *1 - p*, the unplanned outage probability distribution can be obtained quite simply as *A * r* [MW] on the horizontal axis and *P(r)* above on the vertical axis.

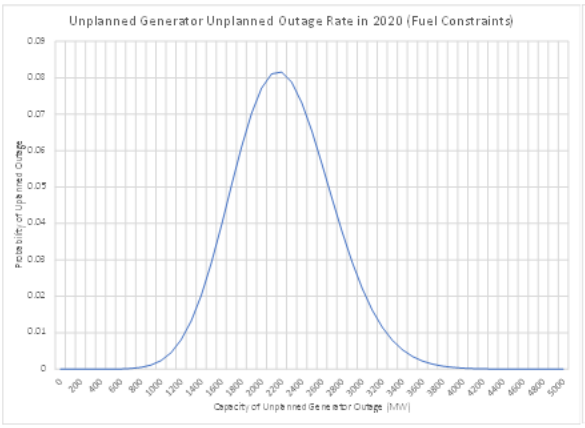
In practice, however, the unplanned outage probability of each generator unit is not uniform. In addition, the capacity (MW) of unplanned outage or output reduction is also different for each unit. It is not practical to calculate the probability distribution taking all these conditions into account accurately, because it requires a huge amount of time even with the large computers currently available.

Therefore, in this study, each generator unit was classified into several groups by collecting generators of similar rated output and fuel type. Furthermore, within the same group, the unplanned outage probability of each generator unit was uniformly taken as their average value, and the amount of outages and curtailments were rounded to the nearest 100 MW.

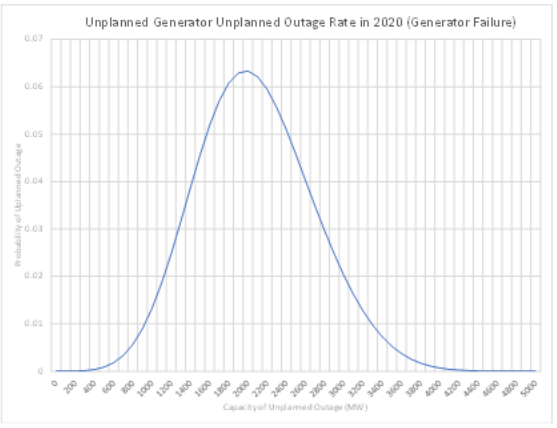
The unplanned outage probability distributions for each group were integrated by the method of convolution to calculate the overall unplanned outage probability distribution.

As the above calculations under rather bold standardized conditions require a very large amount of calculation time, the calculations were first carried out only for the operational results of the generators for the period January-December 2020.

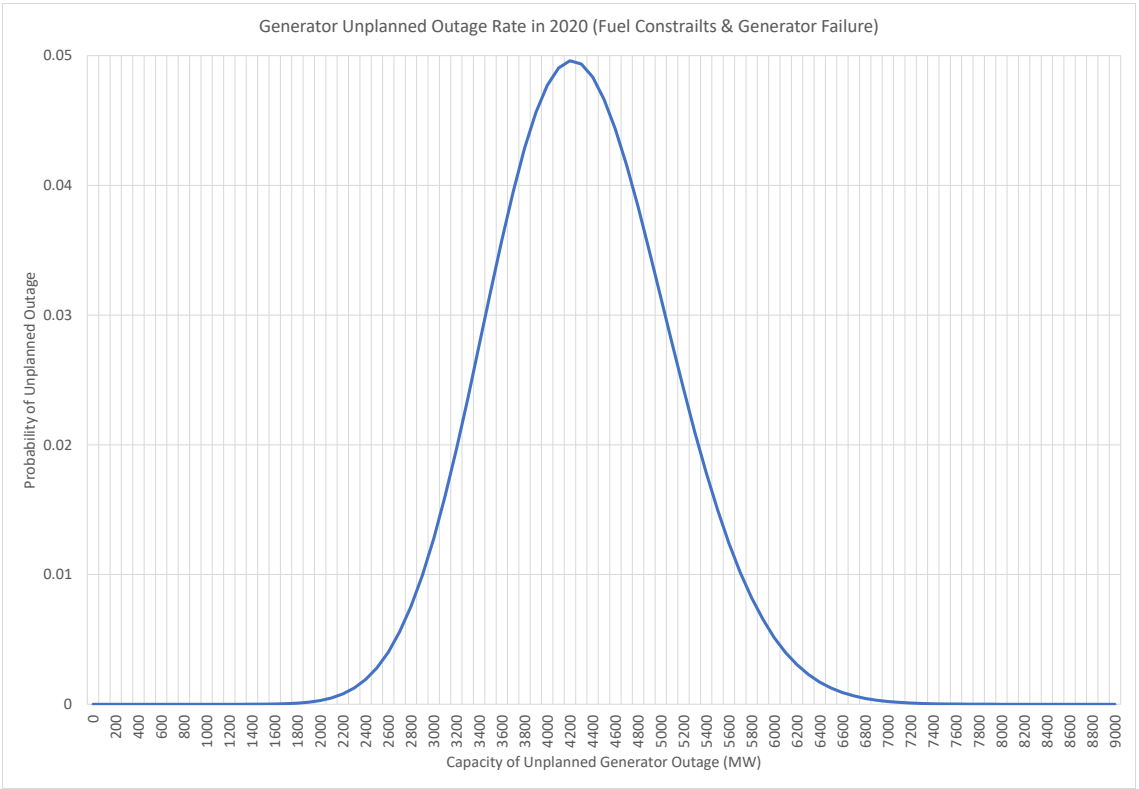
The results are shown in the graph in Figure 2.2-3:



(a) Fuel constraint case



(b) Generator failure case



(c) Integrated probability distribution of generator unplanned outage

Figure 2.2-3 Probability Distribution of Generator Unplanned Outage (2020)

As shown in Figure 2.2-3, generator output of around 2,200 MW and 2,000 MW on average, cannot be expected every day due to fuel constraints, breakdowns and other factors, respectively.

In total, about 4,200 MW on average is unplanned outage every day, and the amount of outage fluctuates in a wide range from 2,000 MW to 7,000 MW.

Generally, 'supply capacity' is defined as the amount of electricity that can be expected to be generated at an individual power station with a probability of 90% or more. In thermal and biomass power plants, if the generating facilities are normal and there are no disruptions to the fuel supply, they can always provide 100% of their output. The supply power in such cases is therefore equal to the net capacity, excluding on-site power consumption.

However, among renewable energy sources, the amount of electricity generated by solar and wind power depends on natural conditions, and if no function is added to store the energy generated, the amount of electricity generated that can be expected as supply power will significantly decrease.

v. Photovoltaic solar power

i-1). Concept of supply capacity

Solar energy can only be expected during the daytime when solar radiation is present, so in cases where electricity demand peaks in the evening, such as in Bangladesh, it cannot be considered supply capacity in the power development plan unless a storage function for electrical energy is added.

However, as the daily load curve of electricity demand is expected to shift from an evening peak type to a daytime peak type in the future, it is necessary to accumulate actual results and determine at an early stage to what extent PV solar generation can be expected as a supply power source for maximum electricity demand.

As of the end of FY2021 (end-June 2021), the following seven PV solar powers have been connected to the electricity grid and records of their output can be obtained from the PGCB Daily Operational Reports.

1) Spectra Solar Plant Ltd (35 MW)
2) Teknaf 20MW PP (Solartech)
3) Kaptai 7 MW Solar PP
4) Sarishabari 3 MW Solar Plant
5) Sutiakhali 50 MW Solar PP
6) Sirajgonj 6.55 MW Solar
7) Sympa Solar Power 8MW

The hourly output data (24 points) of these generators are aggregated to obtain the maximum, average and 90% probability expected output rate for each hour, using the rated output as 100%.

Table 2.2-1 and Figure 2.2-4 show the results of the calculations for the seven power

plants, weighted and averaged by rated output of each generator.

The following issues are identified during the current data aggregation work and analysis:

1) Only 5-6 years have passed since PV solar power generations were connected to the grid and the number of data is small, and more peculiar data can be found in power plants that have not started generating power for a long time.
2) In addition, data that appear to be clearly incorrect (e.g. values above the rated output, large discrepancies between the daily electricity energy output (GWh) records and the sum of 24 hourly output (MW) data, etc.) are also found.

Therefore, as a countermeasure to (1), in calculating the average power output of the seven power plants, a weighted average was also taken for the number of operating days. In addition, all 24 data points were excluded for days with data such as (2).

Table 2.2-1 Averaged Output Data

	Max.	Ave.	Prob.90%
1	0.0%	0.0%	0.0%
2	0.0%	0.0%	0.0%
3	0.0%	0.0%	0.0%
4	0.0%	0.0%	0.0%
5	0.8%	0.0%	0.0%
6	11.6%	1.2%	0.0%
7	33.7%	9.5%	0.1%
8	62.1%	25.6%	3.3%
9	89.3%	42.8%	7.5%
10	95.5%	55.8%	13.1%
11	99.0%	64.1%	16.7%
12	99.9%	67.2%	20.8%
13	98.7%	64.6%	19.0%
14	97.1%	57.0%	17.0%
15	88.3%	43.5%	12.8%
16	73.3%	25.6%	5.5%
17	34.4%	8.7%	0.6%
18	13.3%	1.0%	0.0%
19	0.1%	0.0%	0.0%
20	0.0%	0.0%	0.0%
21	0.0%	0.0%	0.0%
22	0.0%	0.0%	0.0%
23	0.0%	0.0%	0.0%
24	0.0%	0.0%	0.0%

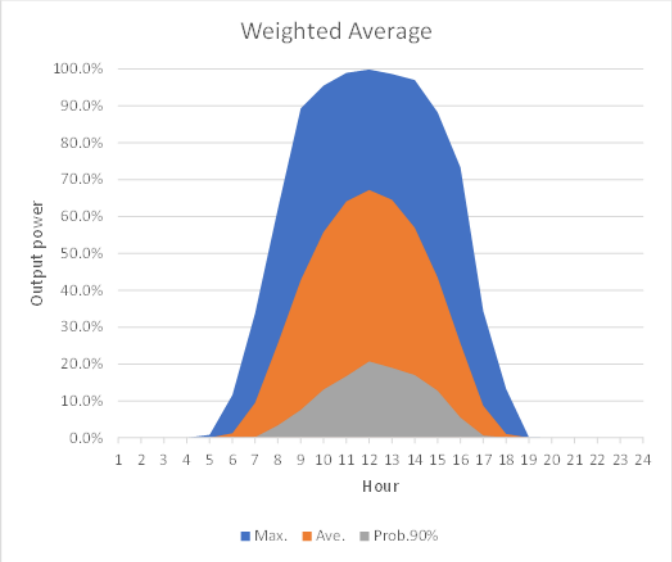


Figure 2.2-4 Averaged Output Graph

It is clear from Table 2.2-1 and Figure 2.2-4 that the output at 18:00 and 19:00, which are currently the peak hours for electricity demand, is less than 1% and cannot be considered supply capacity.

In the future, however, as shown in Table 2.1.1(b), the daily load curve for electricity demand is expected to shift to a daytime peak type, with peak electricity demand occurring between 14:00 and 16:00 from 2035 onwards for the Japanese type, and from 2041 onwards for the other Southeast and South Asian countries type. (12:00 for the Indian model).

In this case, if the supply capacity of solar power is the output that can be expected with a 90% probability as defined, it is only 20% of rated output at most, based on Table 2.2-1.

However, the average output is more than three times that amount, and the simple sum of the output of individual power plants may be underestimated, as the overall output will be smoothed out as the amount of PV power installed increases and becomes more geographically dispersed in the future.

On the other hand, as mentioned above, the current number of data is not sufficient for a statistical assessment, and in order to improve accuracy in the future, a 10-20 year track record is required, so data should be accumulated and regularly updated after this Master Plan.

In addition, the PGCB's Daily Operational Report only records hourly output data, which is too rough for monitoring output fluctuations. (This may, however, become less of a problem in the future due to the smoothing effect of the output.)

Taking into account the above pros and cons, the JICA study team would like to propose that in this Master Plan, the 'supply capacity' is the total installed capacity of PV solar powers

multiplied by the rate listed in the "Prob. 90%" column of the Table 2.2-1 according to the timing of electricity peak demand.

i-2) Output fluctuation probability distribution and its impact on the required reserve capacity

Next, the unplanned outage probability distribution of generators calculated in 6.2.2.(2) b. should essentially be corrected in the reserve power study, as there is at least a 10% probability of output shortfall due to occasional weather changes and equipment failures relative to the supply power estimated in 2.2 (2) c. i.

In this respect, as mentioned above, the daily load curve of future electricity demand will shift to the daytime peak type from 2035 onwards when assuming the Japanese type, and from 2041 onwards when assuming the other Southeast and South Asian countries type. By then, it is expected to have a smoothing effect on the overall output fluctuations of PV power generation, and the spread of energy storage facilities is also expected. Therefore, although only 20% of the rated output is assumed as supply capacity at this time, a higher rate of output can be expected as stable supply capacity in the future.

In view of the above, in order to avoid underestimating the ability of PV power generation as a supply source and securing unnecessary reserve margin, the calculation of the required reserve margin should be carried out without considering the probability of fluctuations in the output of PV power generation.

vi. Wind power

Unlike solar energy, wind energy can be expected to be used day and night, so it can be supply capacity even in cases where electricity demand peaks in the evening, such as in Bangladesh. In addition, if a power energy storage function is added, it can be expected to provide a more reliable supply.

However, there are currently no utility size power plants like wind firm in Bangladesh, and there are no records of power generation, so it is not possible to statistically estimate how much power can be generated and how much the output will fluctuate.

Therefore, in this Master Plan, the JICA study team would like to propose to use 20% of the rated output as the 'supply capacity' for wind power, regardless of the hour of day, in accordance with the supply power at 12:00, when solar power is at its rated output.

As with PV generation, the calculation of the required reserve margin should be carried out without considering the probability of output fluctuations, in anticipation of a smoothing effect on the overall output of wind power and the spread of energy storage facilities in the future.

c. Integrated Probability Distribution of Supply-Demand Fluctuation (Step 2)

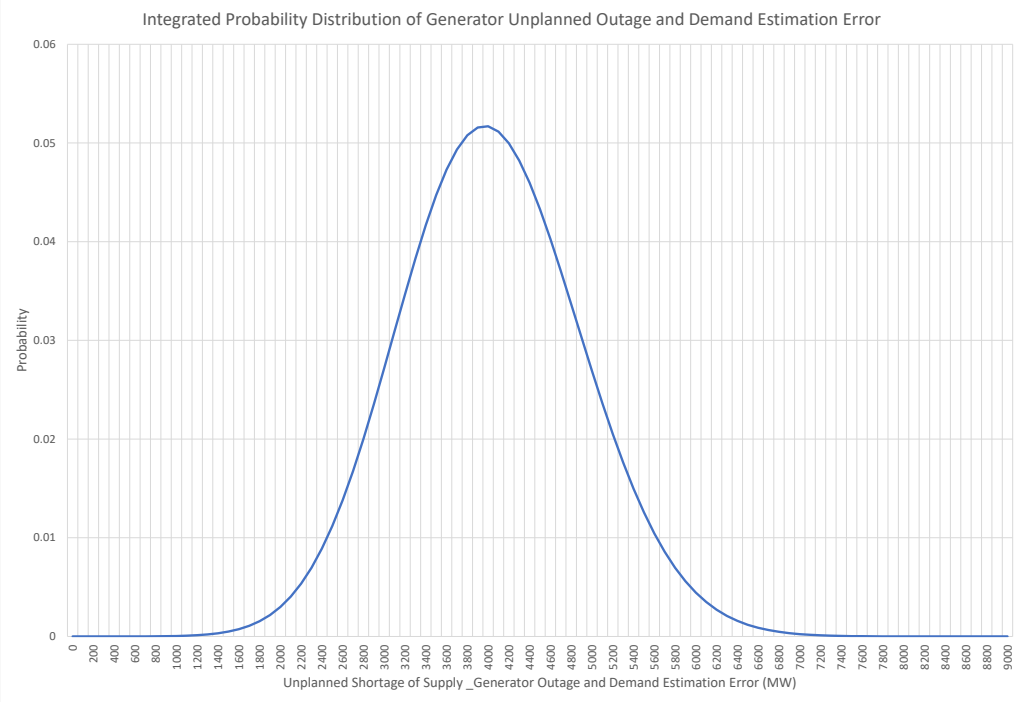


Figure 2.2-5 Integrated Probability Distribution of Supply-demand Change (2020)

Figure 2.2-5 shows the integrated probability distribution of supply-demand change, which can be obtained by convolution of the probability distributions of electricity demand forecasting errors and supply capacity fluctuations due to unplanned outages of generators, as discussed in 6.2.2 (2) a. and b. The graph shows that there is always an average of about 4,000 MW of supply capacity reduction, with a wide range of fluctuation from 1,200 MW to 7,000 MW.

c. Maximum electricity demand duration curve (Step 3)

Figure 2.2-6 shows the duration curve of daily maximum electricity demand for the year 2020. Usually, the rate of increase becomes steeper as it approaches the annual maximum electricity demand on the left-hand side, but in the case of Bangladesh, the trend is lower and can be calculated using a linear approximation. However, when the portion of the maximum 30-day duration curve is enlarged as shown in Figure 2.2-7, the absolute value of the slope increases. The following formula is used in the subsequent calculations:

Maximum daily electricity demand (y) = -23.357 × (days (x) - 1) + 12,827

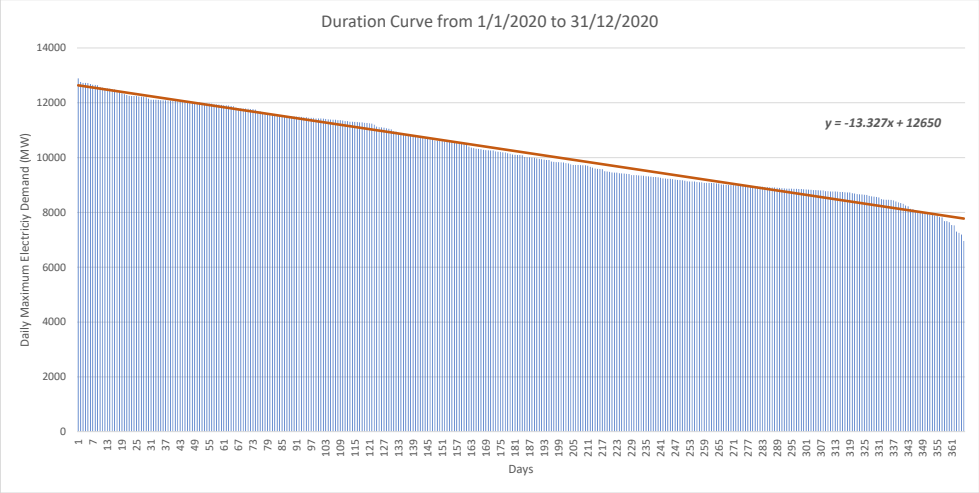


Figure 2.2-6 Duration Curve of Maximum Daily Electricity Demand in 2020 (sorted in order of maximum)

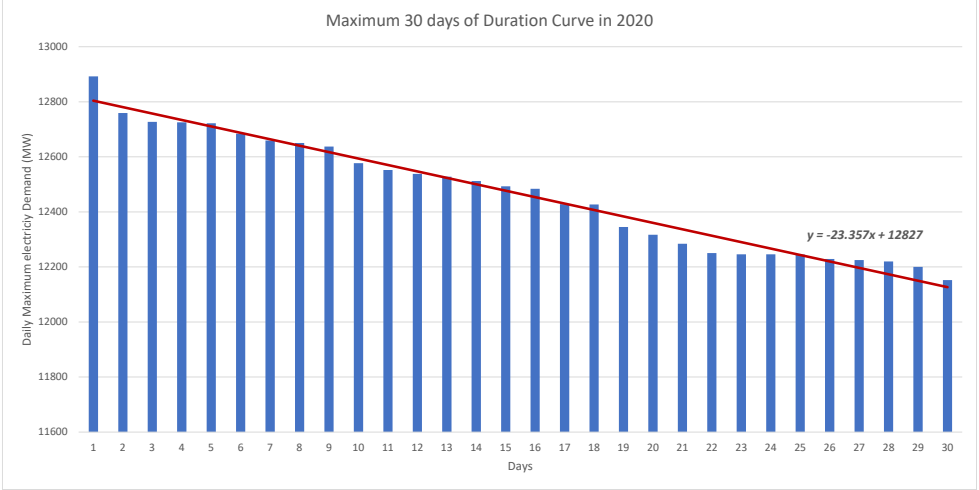


Figure 2.2-7 Duration Curve of Maximum Daily Electricity Demand for Maximum 30 days in 2020

d. Relationship between LOLE and reserve capacity under the current reliability of generator operation. (Step4, Step5)

Based on the results of the calculations in d. and e., the relationship between the reserve margin and LOLE can be obtained using the concept of Step 4 in Section 6.2.2.1. As shown in Figure 2.2-8, LOLE decreases monotonically as the reserve capacity increases. The graph indicates that, in the ultimate case without reserve capacity, there would be a shortage of electricity for about 190 days or so per year.

Figure 2.2-9 shows an enlarged graph of the range where the LOLE falls below 1 day/year. According to this, the reserve capacity ratio to achieve the LOLE targets, described in Step 5 of Section 6.2.2.1, is roughly as follows:

Target year Target	LOLE	Required reserve capacity ratio
Present-2030	24 hours/yr.	approx. 42% min.
2031-2041	12 hours/yr.	approx. 44% min.
2041-2050	6 hours/yr.	approx. 46% min.

As shown in Figure 2.2.2-5 in Section 2.2.2 (2), at present the installed capacity of the generators has a reserve margin of more than 50%, even taking into account the lower reserve capacity ratio and lower generating capacity due to the derated capacity during high demand periods. However, in the real time operation phase, the capacity that can be expected as a reserve margin may be less than 10%, in which case the LOLE will decrease to a significant low reliability level of about 130 days/yr. (this means that, if the same reliability level continued for a year, power shortage would last for about 4 months).

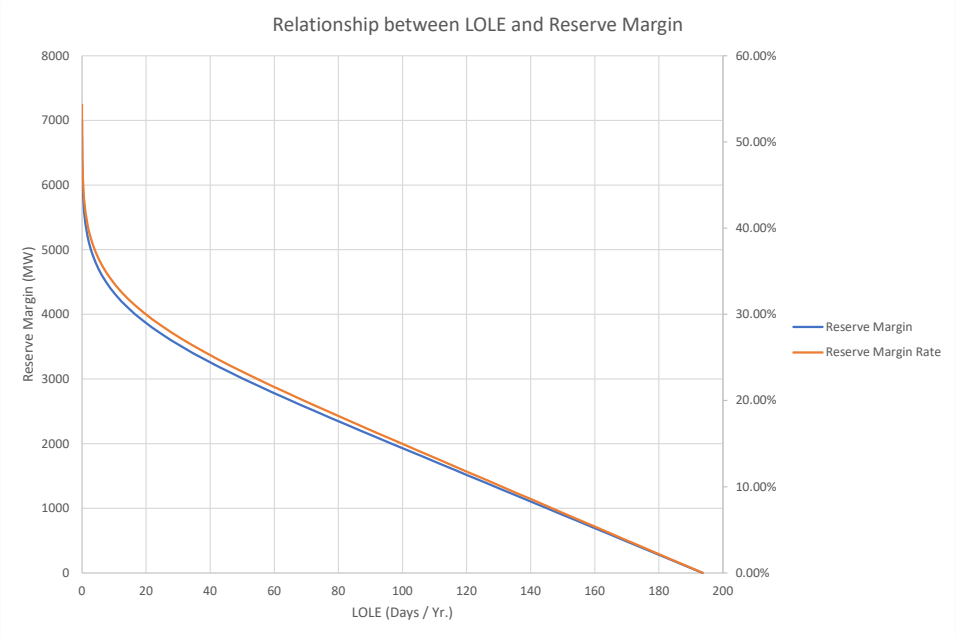


Figure 2.2-8 Relationship between LOLE and Reserve Margin (overall diagram)

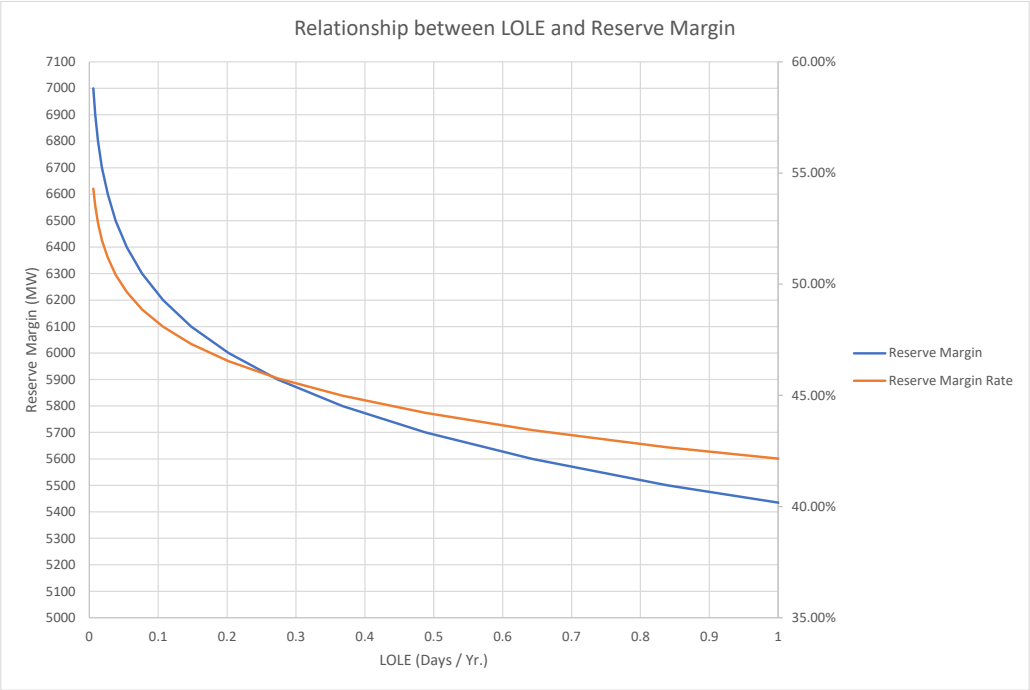


Figure 2.2-9 Relationship between LOLE and Reserve Margin (Enlarged view of LOLE < 1 day /yr.)

In order to remedy the situation described above and maintain supply reliability within the LOLE target, it is not desirable to build up new reserves, but rather to reduce the probability of unplanned outages of generators and thus reduce the required reserve margin ratio to achieve the LOLE target.

Target value of reserve margin and improvement measures

Figure 2.2-10 shows the current state of the integrated supply-demand fluctuation probability distribution in Bangladesh, the case where unplanned outages of generators due to fuel supply constraints were supposed to be eliminated, and a typical example of the distribution in Japan.

As mentioned above, the current probability distribution in Bangladesh, as shown in the blue curve, is somewhat unusual in that it has a bell-shaped peak at about 4,000 MW (just over 18% of the total installed generation capacity of 22,031 MW at the end of June 2021), with an almost 0% probability of no unplanned fluctuation (0 MW). In order to reduce the excess reserve margin ratio in the future, the probability distribution should be shifted as far to the left as possible, as shown in the distribution curve for Japan in orange, i.e. the average of unplanned outages should be significantly lowered to around 200 MW (around 0.9% of the total installed generation capacity of 22,031 MW at the end of June 2021) and the probability of unplanned fluctuations (0 MW) also needs to be increased.

The distribution curve shown in grey represents one process of moving from the current

situation in Bangladesh to a distribution curve equivalent to that in Japan, for example, when unplanned outages of generators due to fuel supply constraints are eliminated. In other words, if the average of unplanned outages is reduced to about 1,800 MW, which is just over half of the current level (about 8% of the total installed generation capacity of 22,031 MW at the end of June 2021), the distribution curve will look like this grey curve.

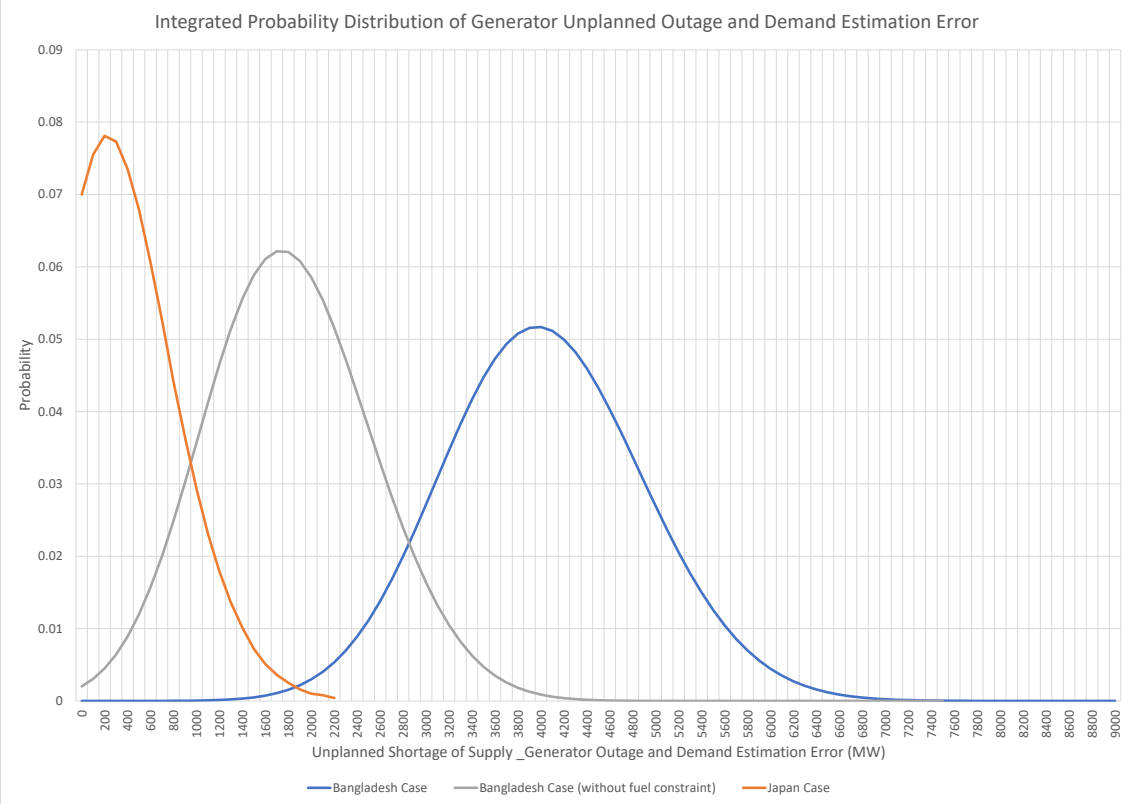


Figure 2.2-10 Comparison of Integrated Probability Distributions of Supply-demand Fluctuation in Bangladesh and Japan

Figure 2.2-11 and Figure 2.2-12 show the relationship between LOLE and reserve ratio when the generator unplanned outage probability distribution improves to the grey distribution curve (fuel supply constraints on generators are resolved) and when the distribution improves to the orange distribution curve (generator unplanned outage probability distribution in Japan), respectively.

According to the results, if the LOLE is improved to the grey colored curve, the LOLE target of 6 hours/yr. to 24 hours/yr. can be achieved by securing a reserve margin of approximately 22% to 25% or more, and if it is improved to the orange-colored curve, the LOLE target can be achieved by securing a reserve margin of approximately only 8% to 11% or more.

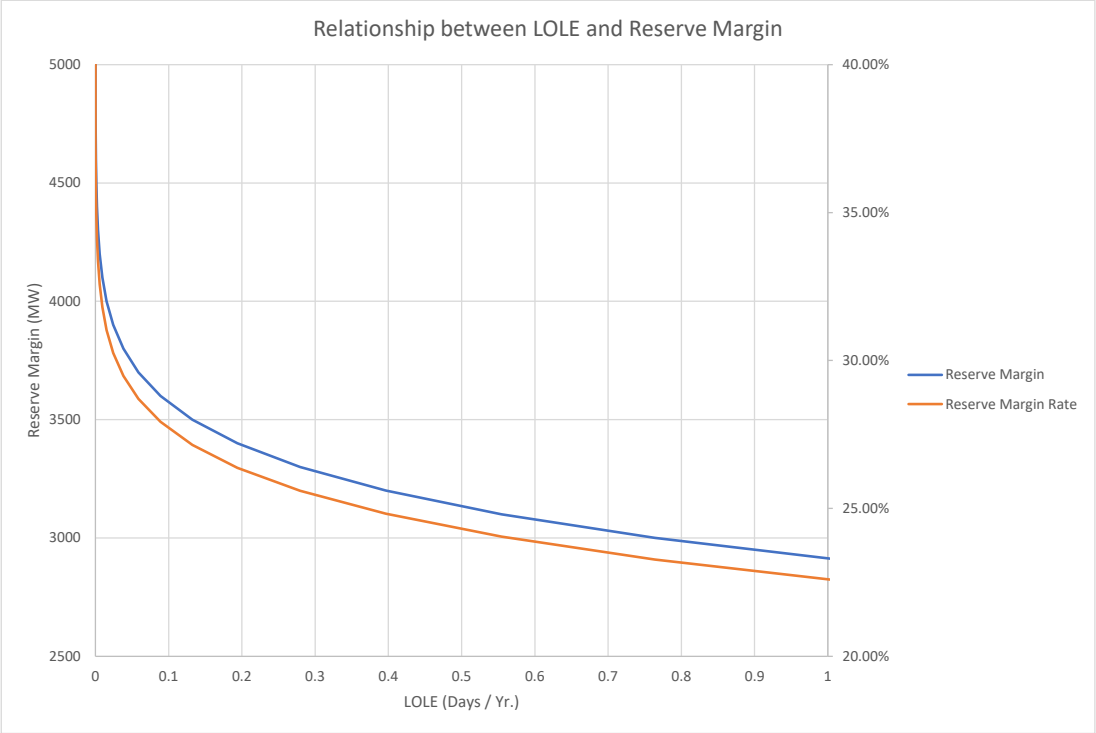


Figure 2.2-11 Relationship between LOLE and Reserve Margin when unplanned generator outages due to fuel constraints are eliminated

Figure 2.2-12 Relationship between LOLE and Reserve Margin when improved to the level of the Japanese supply-demand fluctuation probability distribution

As noted above, the Revisiting PSMP 2016 sets the reserve margin target at 25% for the foreseeable future until 2025, then gradually lowered to 12% from 2036 onwards, with the High Case remaining unchanged until 2041, and the Low Case at 10%.

This challenging target is to be followed in this project, and the study team will propose the reserve margin targets as shown in Table 2.2-2.

Table 2.2-2 Targets for Reducing the Unplanned Outage Rate of Generators to achieve both the Target Reserve Margin and the Target LOLE

FY	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Minimum Requirement in IEPMP	**36.0%**	**25.0%**	**25.0%**	**25.0%**	**25.0%**	**24.4%**	**23.8%**	**23.2%**	**22.6%**	**22.0%**	**20.6%**	**19.2%**	**17.8%**	**16.4%**
Concept of setting values	30 Jun. 2021	the same values in Rev.PSMP2016				gradually decreased until 2030				new target	gradually decreased until 2035			
Min. Requirement in Rev.-PSMP2016 (Low Case)	25%	25%	25%	25%	25%	25%	23.3%	21.7%	20%	17.5%	15%	15%	15%	15%
Min. Requirement in Rev.-PSMP2016 (High Case)	25%	25%	25%	25%	25%	23.8%	22.5%	21.3%	20%	17.5%	15%	15%	15%	15%
Minimum Requirement from LOLE Target										22%				
LOLE (hours/yr.)	132									24				
Key assumptions	Unplanned outages of generators due to **fuel supply constraints** should be resolved **by 2030**													
	Unplanned outages due to **generator failures** should be improved to the same level as in Japan (Annually averaged outage rate: 2-3% or less) **by 2050**													

FY	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Minimum Requirement in IEPMP	**15.0%**	**12.0%**	**12.0%**	**12.0%**	**12.0%**	**12.0%**	**12.0%**	**11.0%**	**11.0%**	**11.0%**	**11.0%**	**11.0%**	**11.0%**	**11.0%**	**11.0%**	**11.0%**
Concept of setting values	the same values in Rev.PSMP2016							new target until 2050								
Min. Requirement in Rev.-PSMP2016 (Low Case)	15%	12%	12%	12%	12%	12%	10%									
Min. Requirement in Rev.-PSMP2016 (High Case)	15%	12%	12%	12%	12%	12%	12%									
Minimum Requirement from LOLE Target							9%									11%
LOLE (hours/yr.)							12									6
Key assumptions																
	Unplanned outages due to **generator failures** should be improved to the same level as in Japan (Annually averaged outage rate: 1% or less) **by 2050**															

The key fiscal years for setting targets in this table are 2030 and 2050.

- **By FY2030**, the annual average of the unplanned outage rate of generators should be improved to no more than about 8% of the total installed capacity of generators, at least through measures such as eliminating unplanned outages of generators due to fuel constraints. Subject to this achievement, the minimum reserve ratio to achieve the target LOLE = 24 hours/year shall be set at 22%.
- **By FY2050**, unplanned outages due to generator failures should also be reduced and the annual average of the unplanned outage rate of generators should be improved to less than or equal to 1% of the total installed capacity of generators. Subject to this achievement, the minimum reserve ratio to achieve the target LOLE = 6 hours/year is set at 11%.

For transitional years other than the above two years, the target is either identical to the target set in the Revisiting PSMP 2016, or interpolated to ensure that the target is not too stringent.

2.3 Power development plan

(1) Current (2021) generation capacity portfolio and progress of power development plans in the PSMP 2016

Table 2.3-1 shows the capacity portfolio and actual power development at the end of FY2021 (30 June 2021) as envisaged at the time of the PSMP 2016.

Table 2.3-1 Assumptions of Generation Capacity Portfolio for FY2021 in the PSMP2016 and Actual Status of Power Development

	Assumption in PSMP2016 (MW)		Actual power development by 30.Jun.2021 (MW)	
	Existing	Committed	Planned	Unplanned
Coal	182	5,691	1,661	
Gas	4,268	5,126	10,785	95
Oil	1,460	2,245	3,055	3,918
Import	500	600	1,160	
Hydro	230	0	230	
Nuclear	0	0	0	
	6,640	**13,661**	**16,891**	**4,013**
	20,301		**20,904**	

At the time of formulation of the PSMP 2016, the power mix envisaged at the end of FY2021 was to increase the total installed capacity of coal-fired power to around 5,900 MW, in addition to the existing Barapukuria power plant (with a derated capacity of 182 MW), but, in reality, the total capacity of only just under 1,700MW is in operation.

The shortfall is being met by gas-fired power, oil-fired power and international procurement. In particular, oil-fired power shows that more “unplanned” power sources than the total capacity of “planned” power plants, which were positioned as Existing or Committed sources in the PSMP 2016, urgently meet the shortfall of supply capacity. This situation is not favorable from the perspective of best mix of power sources, as it is likely to lead to higher generation costs and increased environmental impact.

It should be noted that, according to the latest information, development of coal-fired power plants, which were not planned at the time of the PSMP 2016, is progressing, albeit with some delay. Table 2.3-2 provides an overview. However, as new coal-fired power plant development is expected to be difficult in the global trend to realize a low-carbon and decarbonized society, future treatment of coal-fired power plants under construction and consideration of alternative power sources will be carried out in the future.

Table 2.3-2 Coal-fired Power Plant Development (as of 29 November 2021)

Name of the Power Plant	Installed Capacity (MW)	Net Capacity (MW)	Ownership	COD (PSMP2016)	Expected COD (Revised)	Status
Barapukuria 250 MW (1st & 2nd Unit) (BPDB SBU)	250	170	BPDB			Existing
Barapukuria 275 MW (3rd Unit) (BPDB)	274	247	BPDB			Existing
Payra, Potuakhali 1320 Coal Fired Power Plant (1st Phase)	1,320	1,244	BCPCL (NWPGCL)			Existing
Sub-total		**1,661**				
Rampal Coal Fired PP (BIFPCL)	1,320	1,234	BIFPCL	2020	2022	Committed
Chittagong 2 x 612 MW Coal Fired Power Project (S.Alam Group)	1,224	1,224	IPP	2020	2023	Committed
Borisal 307 MW Coal Fired Power Plant	307	307	IPP		2023	Committed
Payra, Potuakhali 1320 Coal Fired Power Plant (2nd Phase)	1,320	1,244	BCPCL (NWPGCL)		2024	Committed
Patuakhali 1320 (2x660) MW USCPP (Phase-1)	1,320	1,244	RNPL		1st unit: 2024 2nd unit: 2025	Committed
Matarbari 1200 MW USCPP (Phase 1: Unit 1&2)	1,200	1,128	CPGCBL	2023	1st unit: 2024 2nd unit: 2025	Committed
Dhaka 635MW Coal Fired PP (Orion)	635	635	IPP	2020	2027	Committed
Sub-total		**7,016**				
Mirshorai 1,320 MW Coal Fired PP (Hangzhou Group)	1,240	1,240	IPP			Cancelled
Khulna, 630MW Coal Fired PP (Orion)	630	630	IPP	2020		Cancelled
Maowa, Munshiganj 522MW Coal Fired PP (Orion)	522	522	IPP	2020		Cancelled

1) Power development plans in the BPDB (excluding renewable energy) (as of 29 November 2021)

Table 2.3-13 shows the installed capacity for each year based on the development and decommissioning plans for "Existing" power plants and "Committed" power plants.

Table 2.3-13 Year-wise Supply Capacity of "Existing" and "Committed" Power Plants

		Existing	Up to Jun 2022	Up to Jun 2023	Up to Jun 2024	Up to Jun 2025	Up to Jun 2026	Up to Jun 2027	Up to Jun 2028	Up to Jun 2029	Up to Jun 2030	Up to Jun 2031	Up to Jun 2032	Up to Jun 2033	Up to Jun 2034	Up to Jun 2035
Existing	Gas	11,178	10,946	11,000	10,125	9,939	9,394	8,731	8,644	8,463	7,958	7,958	7,792	7,792	7,582	7,467
	Coal	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666	1,666
	Oil	7,268	7,118	6,499	5,392	5,242	5,242	5,242	5,242	5,038	4,827	4,607	4,349	3,717	2,170	1,349
	Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Import	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160
	Hydro	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230
	Sub Total	21,503	21,121	20,555	18,574	18,237	17,692	17,029	16,942	16,557	15,841	15,621	15,197	14,565	12,808	11,872
Committed	Gas	0	0	983	2,857	4,493	5,993	7,728	7,728	7,878	7,878	7,878	7,878	7,878	7,878	7,878
	Coal	0	0	1,541	3,951	5,759	6,381	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016
	Oil	0	285	789	950	614	616	616	621	621	621	621	621	624	624	624
	Nuclear	0	0	0	1,030	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060
	Import	0	0	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,996	1,996	1,996	1,996	1,996	1,996
	Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sub Total		285	4,809	10,284	14,422	16,546	18,916	18,921	19,071	19,571	19,571	19,571	19,574	19,574	19,574
Grand Total		21,503	21,406	25,364	28,858	32,659	34,238	35,945	35,863	35,628	35,412	35,192	34,768	34,139	32,382	31,446

		Up to Jun 2036	Up to Jun 2037	Up to Jun 2038	Up to Jun 2039	Up to Jun 2040	Up to Jun 2041	Up to Jun 2042	Up to Jun 2043	Up to Jun 2044	Up to Jun 2045	Up to Jun 2046	Up to Jun 2047	Up to Jun 2048	Up to Jun 2049	Up to Jun 2050
Existing	Gas	7,250	6,705	6,008	5,366	4,573	3,619	2,564	2,125	1,430	799	416	416	0	0	0
	Coal	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496	1,496
	Oil	695	193	102	102	102	102	102	0	0	0	0	0	0	0	0
	Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Import	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160
	Hydro	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230
	Sub Total	10,832	9,785	8,996	8,354	7,561	6,607	5,552	5,011	4,316	3,685	3,302	3,302	2,886	2,886	2,886
Committed	Gas	7,878	7,878	7,715	7,715	7,715	7,715	7,715	7,715	7,715	6,732	5,180	3,655	2,069	400	400
	Coal	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016	7,016
	Oil	624	339	324	324	324	324	324	324	0	0	0	0	0	0	0
	Nuclear	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060	2,060
	Import	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996	1,996
	Hydro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sub Total	19,574	19,289	19,111	19,111	19,111	19,111	19,111	19,111	18,787	17,804	16,252	14,727	13,141	11,472	11,472
Grand Total		30,406	29,074	28,107	27,465	26,672	25,718	24,663	24,122	23,103	21,489	19,554	18,029	16,027	14,358	14,358

The total amount of current “Existing” power plants is 21,503MW, which will drop to 2,886MW as it is decommissioned by 2050.

For “Committed” power plants, there are currently plans that are expected to be commissioned by early 2030. First, it is important that these plants are developed as planned. In particular, Roopure nuclear power, which is planned to start operation in 2024 and 2025, will play an important role in the stable supply of electricity as a CO2-free base load power, so it is important to improve supply reliability while linking it with the transmission system plan.

“Committed” power plants will peak in FY2029, after which the amount of development will gradually decline, and the gap with the assumed electricity demand in the very long term will rapidly widen, as shown in Figures 2.3-1 and 2.3-2. Therefore, additional supply capacity will be considered in the future, while ensuring adequate supply reserves and being aware of the need to achieve a low-carbon and decarbonized society.

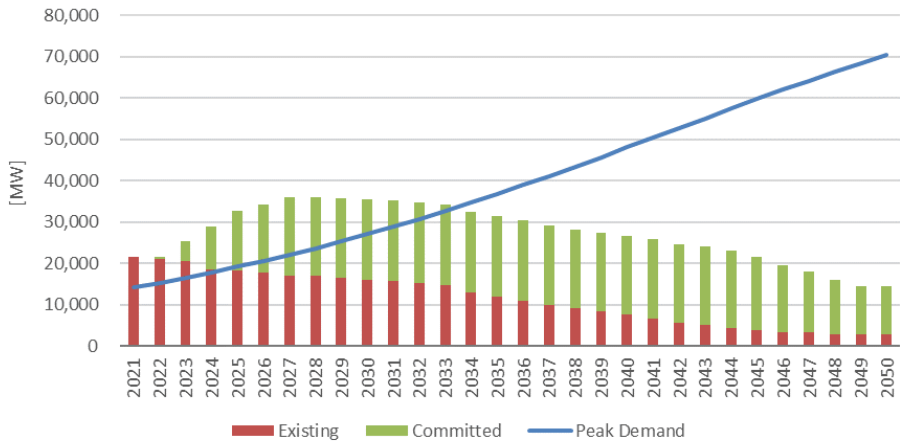


Figure 2.3-1 Gaps between Future Peak Demand and Existing & Committed Capacity

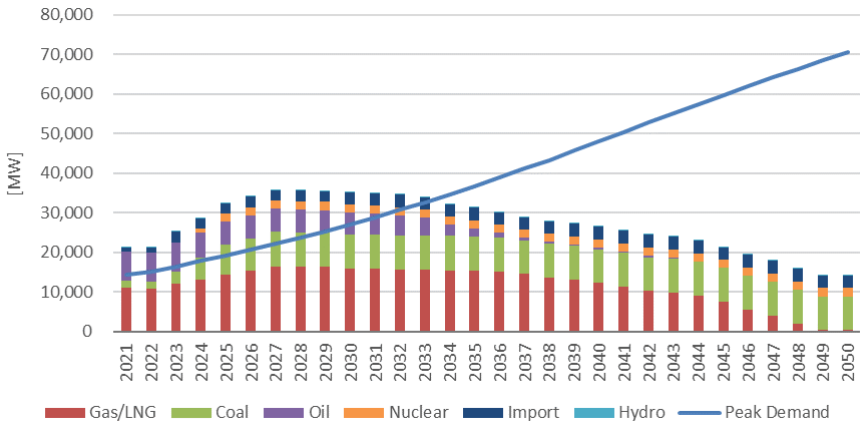
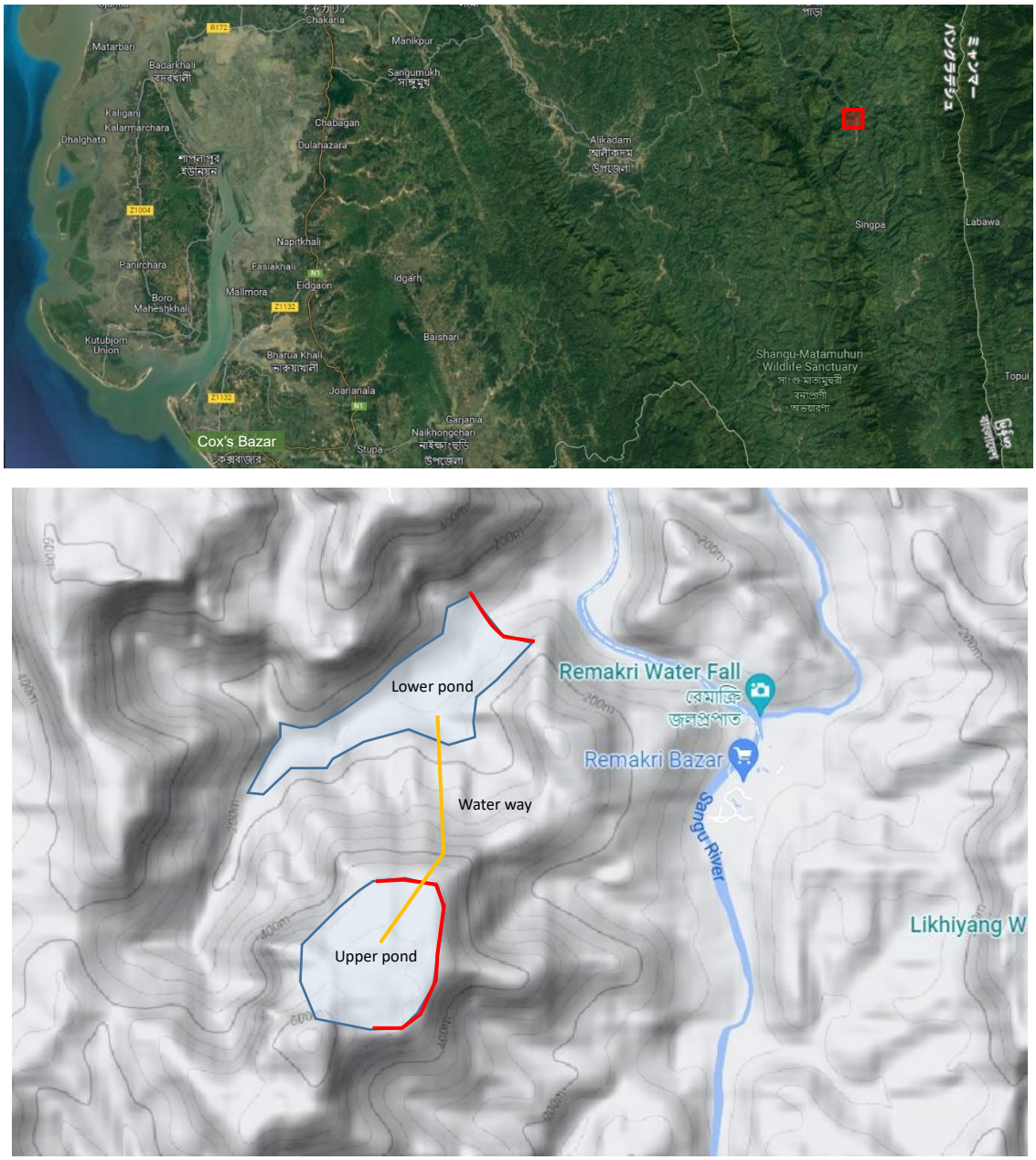


Figure 2.3-2 Gaps between Future Peak Demand and Fuel-wise Capacity

(2) Possibility of PSPP in Bangladesh

No.17 site is proposed as the most promising site in PSMP2016. The results of a very rough desk study of this site are as follows.

a. Location



Source: Study Team

Figure 2.3-4 Location and Rough Image of PSPP Site

This site is located in Thanchi Upazila, Bandarban District, near Remaki waterfall.

b. Salient feature

If both the upper and lower ponds have enough storage capacity to operate continuously for 6 hours at maximum output, it is possible to construct a maximum of 900MW of PSPP (pumped-storage power plant) in consideration of the local topography.

Table 2.3-34 Salient Features

	No.17 PSPP
Installed capacity	900 MW
Maximum plant discharge	289 m^3/s
Effective head	361.0 m
Upper Dam height	40 m
Upper Dam crest length	1,570 m
U/D Asphalt Concrete Area	25 ha
Lower Dam height	70 m
Lower Dam crest length	430 m
U/D Concrete volume	0.4 million m^3
Effective storage capacity	6.2 million m^3 (6.0 hrs)
Horizontal Waterway Length	1,520 m
L / H	4.0

Item	Upper dam	Lower dam
Dam type	Artificial Excavated Asphalt Full Facing	Concrete gravity
Seismic coefficient	0.15	0.15
Dam height	40 m	70 m
Dam Top EL	EL.523.0	EL.151.0
Crest Length	1570 m	480 m
Full Reservoir Level	EL.520.0	EL.146.0
	Waterway	
Horizontal Waterway Length	1,520 m	
Gross Head	384 m	
L / H	4.0	

Source: Study Team

c. Rough cost estimate

The rough cost estimate is shown below.

Table 2.3-35 Rough Cost Estimate

(Unit: million USD)

	N0.17 PSPP
Upper Dam (Artificial Asphalt Facing Pond)	120
Lower Dam	70
Waterway (Headrace & Tailrace)	60
Powerhouse Switchyard	70
Hydromechanical Equipment	90
Electromechanical Equipment	240
Others (Contingency, Engineering, IDC,)	142
Transmission Line and Switchgear	0
Construction Cost	792
Unit Construction Cost (USD/kW)	880

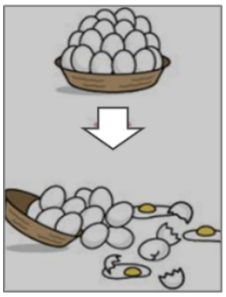
Source: Study Team

When constructing a capacity of 900MW, the construction unit price will be USL considered economical because it is within USD 1,000/kW, which is generally considered an economical site

2.4 Power Generation System

2.4.1 Energy security needs to be a focus

Figure 2.4-1 shows that Energy security needs to be a focus. As shown in Figure 2.4-1, Energy security is extremely important in Japan, a country that does not have its own energy supply.



"Don't put all eggs in one basket !

This is a famous proverb.

In order for the energy composition

- **Risk hedging**
- **Hazard diversification**
- **Negotiation options**

need to be considered.

(Reference)
Japan's energy policy of the resources poor country is LNG 30%, Coal 30% and Nuclear 30%.

Source: JICA study team

Figure 2.4-1 Energy Security Needs to be a focus

Figure 2.4-2 shows the LNG tank in JERA Futtsu thermal power station. The Futtsu thermal power station is one of the largest LNG-fired thermal power stations in Japan, with a total capacity

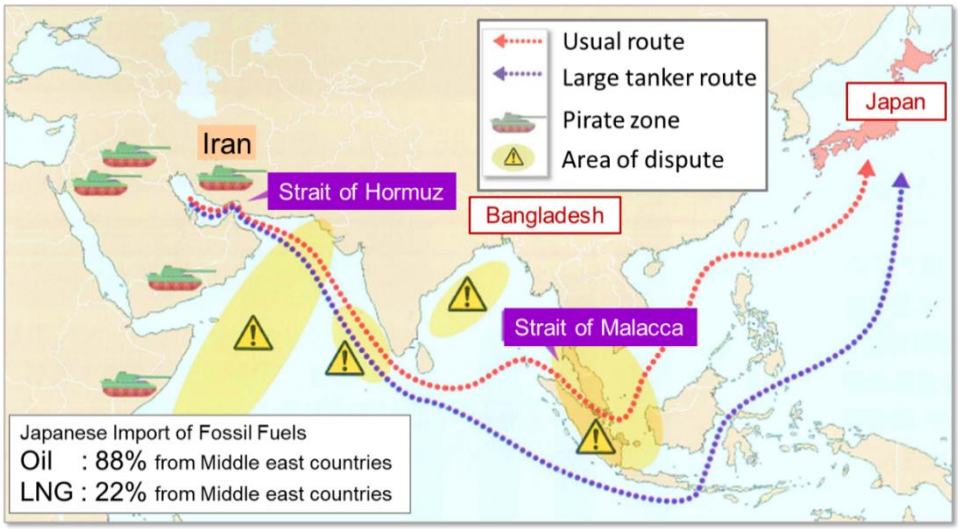
of 5,160 MW.

The map on the upper right of the figure shows thermal power plants that have been installed in Tokyo Bay, with a total output of 31,146 MW (around 30GW). Most of the fuel used here is imported from Middle Eastern countries. The 30 GW is about the same as gas-fired power in Bangladesh in 2041.

Source: TEPSCO

Figure 2.4-2 LNG Tank in JERA Futtsu Thermal Power Station

Figure 2.4-3 shows Energy Reserves in Japan. The LNG reserves equate to 14 days' worth, Oil reserves 294 days' worth and Coal reserves 35 days' worth in Japan.

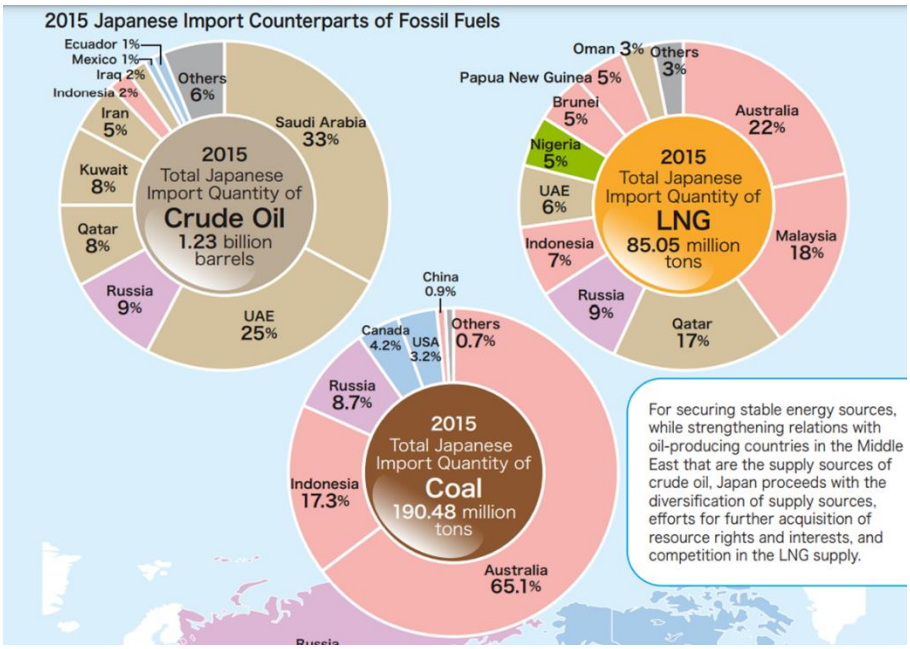


Source: The Institute of Energy Economics, Japan (IEEJ)

Figure 2.4-3 Reserves in Japan

Figure 2.4-4 shows Japanese Import Counterparts of Fossil Fuels. Japanese Import of Fossil Fuels are as below. Oil is 88% from Middle east countries. LNG is 22% from Middle east

countries.

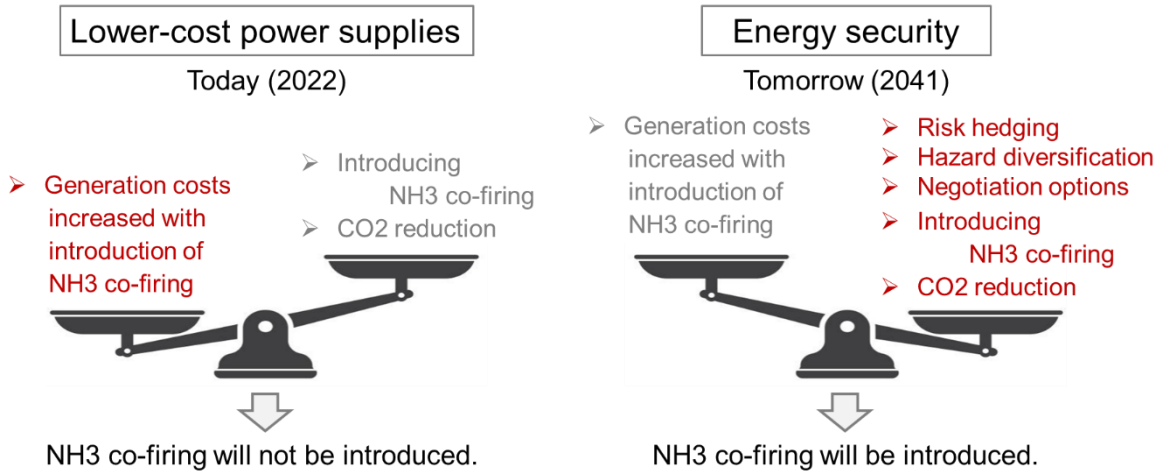


Source: METI Japan

Figure 2.4-4 Japanese Import Counterparts of Fossil Fuels

2.4.2 Value Changes, Today and Tomorrow in Bangladesh

Figure 2.4-5 shows Value Changes, Today and Tomorrow in Bangladesh. In Bangladesh, the current value proposition for power generation systems is low generation costs. However, energy security will be an important value in 2041 in the clean energy expanding era.



Source: JICA study team

Figure 2.4-5 Value Changes, Today and Tomorrow in Bangladesh

2.4.3 Ratio of various thermal power generation systems and fuel consumption

Figure 2.4-6 shows the ratios and fuel consumption of various thermal power systems. Fuel consumption was calculated here for gas-fueled GTCC, simple cycle GT, gas and oil fired engines, and coal-fired USC, respectively.

Model	Gas ratio	H2 ratio	Coal ratio	NH3 ratio	Oil ratio	Capacity/unit	Efficiency	Gas Calo. Vul.	H2 Calo. Vul.	Coal Calo. Vul.	NH3 Calo. Vul.	Oil Calo. Vul.	Load factor	Number	Total capacity	Gas consumption		H2 consumption		Coal consumption		NH3 consumption	
	%	%	%	%	%	MW	%(LHV)	kcal/kg	kcal/kg	kcal/kg	kcal/kg	kcal/kg	%		MW	t/h	t/y	t/h	t/y	t/h	t/y	t/h	t/y
Gas GTCC	100	0	-	-	-	840	61	10,753	33,890	5,000	5,377	10,278	80	38	31,920	4,185.1	36,661,139	0.0	0	-	-	-	-
	50	50	-	-	-	840	61	10,753	33,890	5,000	5,377	10,278	80	0	0	0.0	0	0.0	0	-	-	-	-
	0	100	-	-	-	840	61	10,753	33,890	5,000	5,377	10,278	80	6	5,040	0.0	0	209.7	1,836,672	-	-	-	-
USC	-	-	100	0	-	600	41	10,753	33,890	5,000	5,377	10,278	70	16	9,600	-	-	-	-	4,027.3	35,279,298	0.0	0
	-	-	50	50	-	600	41	10,753	33,890	5,000	5,377	10,278	70	6	3,600	-	-	-	-	755.1	6,614,868	702.2	6,151,077
	-	-	0	100	-	600	41	10,753	33,890	5,000	5,377	10,278	70	0	0	-	-	-	-	0.0	0	0.0	0
Total fuel consumption (t/y)														66	50,160	4,185.1	36,661,139.5	209.7	1,836,672.4	4,782.4	41,894,165.9	702.2	6,151,077.1

Source: Gas Turbine World

Figure 2.4-6 the ratios and fuel consumption of various thermal power systems

2.4.4 Load flexibility capability of Gas Turbine

There are a large number of wind and solar power installations in the area near Astoria Station, and these sources fluctuate with weather conditions. Astoria Station has a 245 MW simple-cycle GT installed, which plays a role in absorbing the load fluctuations of the wind and solar power generation.

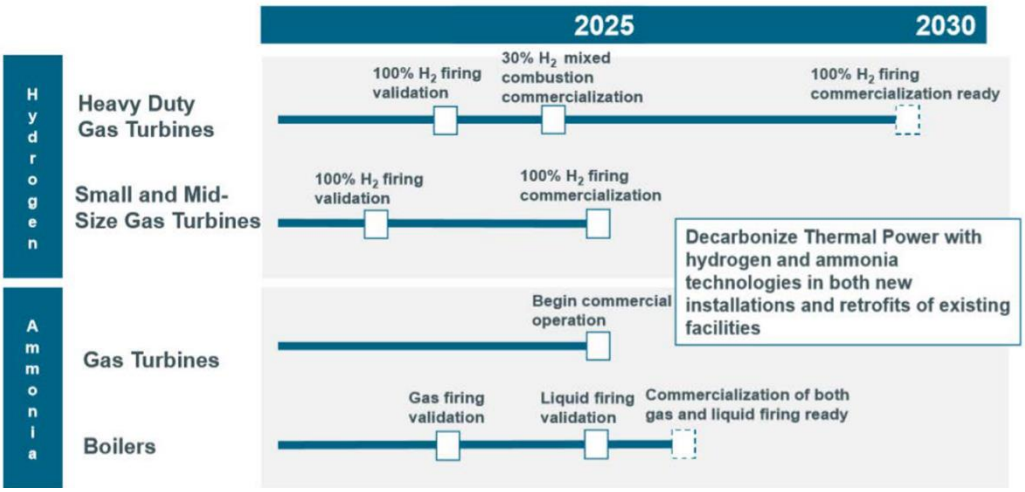
The three major gas turbine manufacturers in the world today are Mitsubishi Heavy Industries (MHI), GE, and Siemens, and these three companies are competing with each other in technological development. MHI's technological development history is summarized here as a representative of these three companies.

The figure above shows the main specifications of the state-of-the-art JAC gas turbine, which is a 50 Hz simple cycle GT with GTCC output of 547 MW and 840 MW with GTCC. And the overall efficiency will be 64% (LHV).

The lower left figure shows the gas turbine inlet temperature °C and efficiency % (LHV): the M701DA model had a gas turbine inlet temperature of 1250°C and an efficiency of about 51%, but the gas turbine inlet temperature has since increased to 1650°C and the efficiency to 64%.

The figure on the lower right also shows the relationship between gas turbine model and power levels. For the small gas turbine H25 type, 41 MW for simple cycle and 60 MW for GTCC; for the large 701DA type, 144 MW for simple cycle and 213 MW for GTCC are shown.

2) Carbon Free Combustion Development Plan (MHI)



Source: MHI Feb. 7, 2022

Figure 2.4-7 Carbon Free Combustion Development Plan (MHI)

Figure 2.4-7 shows the Carbon Free Combustion Development Plan (MHI). Here, MHI's carbon-free combustion development plan is presented as a representative of the world's three major gas turbine manufacturers.

Regarding hydrogen (H2) combustion, MHI is ahead in the development of small gas turbines and is conducting demonstration tests on 100% H2 combustion. The plan is to have a commercial H2 combustion system available by 2025.

On the other hand, the development of large gas turbines is planned to conduct demonstration tests of 30% H2 mixed combustion by 2025, and to apply 100% H2 combustion to commercial equipment by 2030.

2.4.5 Manufacturer of 600MW-class USC in Japan

Table 2.4-1 shows the list of coal-fired SC/USC plants in Japan. This is a list of SC or USC plants in Japan constructed since 1981, listed in order of year of operation. The following information is provided: year of operation, Type, boiler manufacturer, Generator output (MW), Main Steam Pressure (MPa), Main Steam Temperature (°C), Reheat Steam Temperature (°C), turbine manufacturer, and generator manufacturer.

The following is a summary of understandings from this list.

＜Understanding from the list＞

- There are 50 units here.
- J-POWER Matsushima Thermal Power Unit 1, which opened in 1981, is still in operation.

- The other units are also in operation, indicating that the life of the plant in Japan is more than 40 years.
- In the list of domestic coal-fired SC/USC plants, the first USC units with improved steam conditions are as follows

In 1998, Chugoku Electric Power Co. Misumi Unit 1, Main Steam Temperature 600°C, Reheat Steam Temperature 600°C

In 2000, J-POWER Shin-Isoko Unit 1, Main Steam Temperature: 600°C, Reheat Steam Temperature: 610°C

In 2009, J-POWER Shin-Isogo Unit 2, Main Steam Temperature: 600°C, Reheat Steam Temperature: 620°C

In 2020, J-POWER Shin Takehara Unit 1.t Main Steam Temperature: 600°C Reheat Steam Temperature is 630°C

- As of 2022, MHI and IHI are the two USC boiler manufacturers in Japan.

Table 2.4-1 List of Coal Fired SC/USC Plants in Japan

Company	Power station	COD (Year)	Type	Boiler manufacturer	Capacity (MW)	Pressure (MPa)	MST (℃)	RST (℃)	Turbine manufacturer	Generator manufacturer
J-Power	Matusima 1	1981	SC	MHI	500	24.1	538	538	Hitachi	Hitachi
J-Power	Matusima 2	1981	SC	MHI	500	24.1	538	538	Toshiba	Toshiba
Joban	Nakoso 8	1983	SC	MHI	600	24.1	538	566	Hitachi	Hitachi
J-Power	Takehara 3	1983	SC	BHK	700	24.1	538	538	Hitachi	Hitachi
Joban	Nakoso 9	1983	SC	IHI	600	24.1	538	566	Toshiba	Toshiba
Hokkaido	Tomatoatsuma 2	1985	SC	IHI	600	24.1	538	566	Hitachi	Hitachi
Chugoku	Shinonoda 1,2	1986	SC	IHI	500	24.1	538	566	Toshiba	Toshiba
Kyusyu	Matsuura 1	1989	SC	MHI	700	24.1	538	566	Hitachi	Hitachi
J-Power	Matsuura 1	1990	SC	BHK	1000	24.1	538	566	MHI	MELCO
JERA	Hekinan 1	1991	SC	MHI	700	24.1	538	566	Toshiba	Toshiba
Hokuriku	Tsuruga 1	1991	SC	MHI	500	24.1	566	566	Toshiba	Toshiba
JERA	Hekinan 2	1992	SC	BHK	700	24.1	538	566	Hitachi	Hitachi
Tohoku	Noshiro 1	1993	SC	BHK	600	24.5	538	566	Fuji	Fuji
JERA	Hekinan 3	1993	USC	IHI	700	24.1	538	593	MHI	MELCO
Soma	Shinchi 1	1994	SC	BHK	1000	24.1	538	566	Hitachi	Hitachi
Tohoku	Noshiro 2	1994	USC	IHI	600	24.1	566	593	Toshiba	Toshiba

Company	Power station	COD (Year)	Type	Boiler manufacturer	Capacity (MW)	Pressure (MPa)	MST (℃)	RST (℃)	Turbine manufacturer	Generator manufacturer
Soma	Shinchi 2	1995	SC	MHI	1000	24.1	538	566	Toshiba	Toshiba
Hokuriku	Nanaoohta 1	1995	USC	BHK	500	24.1	566	593	MHI	MELCO
Kyusyu	Reihoku 1	1995	SC	IHI	700	24.1	566	566	Toshiba	Toshiba
Tohoku	Haramachi 1	1997	USC	MHI	1000	24.52	566	593	Toshiba	Toshiba
J-Power	Matsuura 2	1997	USC	BHK	1000	24.1	593	593	MHI	MELCO
Chugoku	Misumi 1	1998	USC	MHI	1000	24.5	600	600	MHI	MELCO
Tohoku	Haramachi 2	1998	USC	BHK	1000	24.52	600	600	Hitachi	Hitachi
Hokuriku	Nanaoohta 2	1998	USC	IHI	700	24.1	593	593	Toshiba	Toshiba
Hokuriku	Tsuruga 2	2000	USC	MHI	700	24.1	593	593	Toshiba	Toshiba
Shikoku	Tachibanawan 1	2000	USC	Hitachi	700	24.1	566	593	Toshiba	Toshiba
J-Power	Tachibanawan 2	2000	USC	Hitachi	1050	25	600	610	MHI	MELCO
J-Power	Tacibanawan 1	2000	USC	IHI	1050	25	600	610	Toshiba	GE
JERA	Hekinan 4、5	2001	USC	IHI	1000	24.1	566	593	Toshiba	Toshiba
Hkkkaido	Tamatoatsuma 4	2002	USC	IHI	700	25	600	600	Hitachi	Hitachi
J-Power	Isogoshin 1	2002	USC	IHI	600	25	600	610	Fuji	Fuji
Kyusyu	Reihoku 2	2003	USC	MHI	700	24.1	593	593	Toshiba	Toshiba
JERA	Hitachinaka 1	2003	USC	BHK	1000	24.5	600	600	Hitachi	Hitachi
JERA	Hirono 5	2004	USC	MHI	600	24.5	600	600	MHI	MELCO
Kansai	Maizuru 1	2004	USC	MHI	900	24.5	595	595	MHI	MELCO
J-Power	Isogoshin 2	2009	USC	IHI	600	25	600	620	Hitachi	Hitachi
Kansai	Maizuru 2	2010	USC	IHI	900	24.5	595	595	Toshiba	Toshiba
JERA	Hirono 6	2013	USC	MHI	600	24.5	600	600	MHI	MELCO
JERA	Hitachinaka 2	2013	USC	BHK	1000	24.5	600	600	Hitachi	Hitachi
Kyusyu	Matsuura 2	2019	USC	MHPS	1000	24.5	600	600	Toshiba	Toshiba
Tohoku	Nochiro 3	2020	USC	MHPS	600	24.5	600	600	Toshiba	Toshiba
J-Power	Takehara 1	2020	USC	IHI	600	27	600	630	Toshiba	Toshiba
Hitachinaka Gerenation	Hitachinakakyodo 1	2021	USC	Mitsubishi	650	24.5	600	600	Mitsubishi	MELCO
KOBELCO Kobe	Kobe 3	2021	USC	IHI	650	25.1	600	620	Toshiba	Toshiba
JERA Power Taketoyo	Taketoyo 5	2022	USC	Mitsubishi	1070	24.5	600	600	Mitsubishi	MELCO
Chugoku	Misumi 2	2022	USC	Mitsubishi	1000	24.5	600	600	Mitsubishi	MELCO
KOBELCO Kobe	Kobe 4	2022	USC	IHI	650	25.1	600	620	Toshiba	Toshiba
JERA Power Yokosuka	Yokosuka 1	2023	USC	Mitsubishi	650	24.5	600	600	Mitsubishi	MELCO
Shikoku	Saijyo 1	2023	USC	Mitsubishi	500	24.5	600	600	Mitsubishi	MELCO
JERA Power Yokosuka	Yokosuka 2	2024	USC	Mitsubishi	650	24.5	600	600	Mitsubishi	MELCO

Source: TEPSCO

2.4.6 USC plants lists regarding Steam conditions in ASEAN countries

Table 2.4-2 shows major USC delivered plants in ASEAN countries. As shown in Table 2.4-2 the plants that are scheduled to be put into operation in ASEAN countries are planned to have steam conditions such as 610℃ and 620℃ for Reheat Steam Temperature in order to achieve higher efficiency.

The Main Steam Pressure (MSP) of DONGFANG and DOOSAN plants are 26.25 MPa and 27.5 MPa, respectively, which are higher than the 241.1 MPa and 24.5 MPa of Mitsubishi Power and Toshiba & IHI plants in Japan.

Table 2.4-2 USC Plants Lists regarding Steam Sonditions in ASEAN Countries

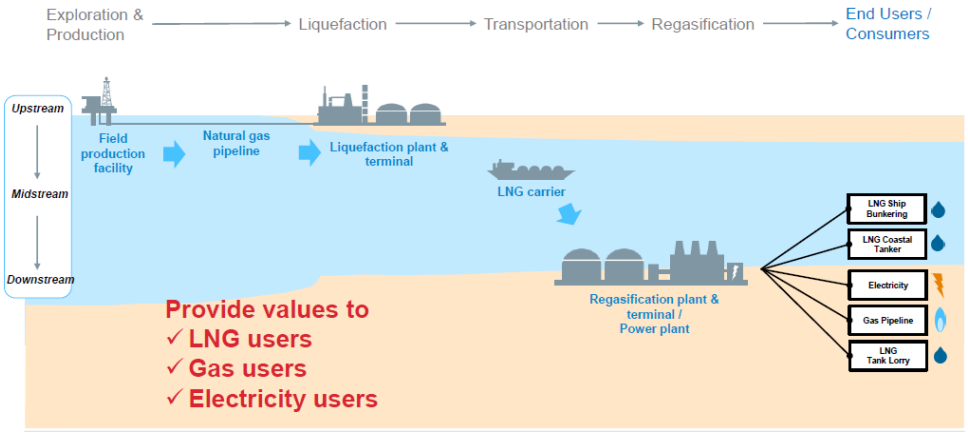
No.	Manufacturer (Steam Turbine)	Manufacturer (Boiler)	Plant Owner	Plant		Country	Steam Condition	Unit Capacity	COD (YY/MM/DD)	Steam Conditions (MSP/MST/RST)
1	SHANGHAI TURBINE CO.	DONGFANG BOILER CO.	BANGLADESH CHINA PR CO LTD (BCPCL-CMC, NWPGCL)	DHANKHALI 1, PATHUAKHALI, PAYRA	Payra 1	BANGLADESH	USC	660	2020/12/1	26.25/600/610
2	SHANGHAI TURBINE CO.	DONGFANG BOILER CO.	BANGLADESH CHINA PR CO LTD (BCPCL-CMC, NWPGCL)	DHANKHALI 2, PATHUAKHALI, PAYRA	Payra 2	BANGLADESH	USC	660	2020/4/1	26.25/600/610
3	SIEMENS CO.	DOOSAN HEAVY INDUSTRIES CO.	PT INDO RAYA TENAGA	JAWA THERMAL POWER	Java 9	INDONESIA	USC	1000	2024/7/1	26.0/600/620
4	SIEMENS CO.	DOOSAN HEAVY INDUSTRIES CO.	PT INDO RAYA TENAGA	JAWA THERMAL POWER	Java 10	INDONESIA	USC	1000	2024/12/1	26.0/600/620
5	TOSHIBA	DOOSAN HEAVY INDUSTRIES CO.	VAPCO	Vung Ang2	1	VIETNAM	USC	600	2025/3/31	27.5/600/610
6	TOSHIBA	DOOSAN HEAVY INDUSTRIES CO.	VAPCO	Vung Ang2	2	VIETNAM	USC	600	2025/7/31	27.5/600/610
7	TOSHIBA	IHI	CPGCBL	Matarbari Power Station	1	BANGLADESH	USC	600	2024/1/1	24.5/600/600
8	TOSHIBA	IHI	CPGCBL	Matarbari Power Station	2	BANGLADESH	USC	600	2024/7/1	24.5/600/600
9	Mitsubishi Power	DOOSAN HEAVY INDUSTRIES CO.	NS2PC	Nghi Son2	1	VIETNAM	SC	600	2021/12/1	24.2/566/566
10	Mitsubishi Power	DooSAN HEAVY INDUSTRIES CO.	NS2PC	Nghi Son2	2	VIETNAM	SC	600	2022/6/1	24.2/566/566

MSP: Main Steam Pressure
MST: Main Steam Temperature
RSP: Reheater Steam Temperature

Source: TEPSCO

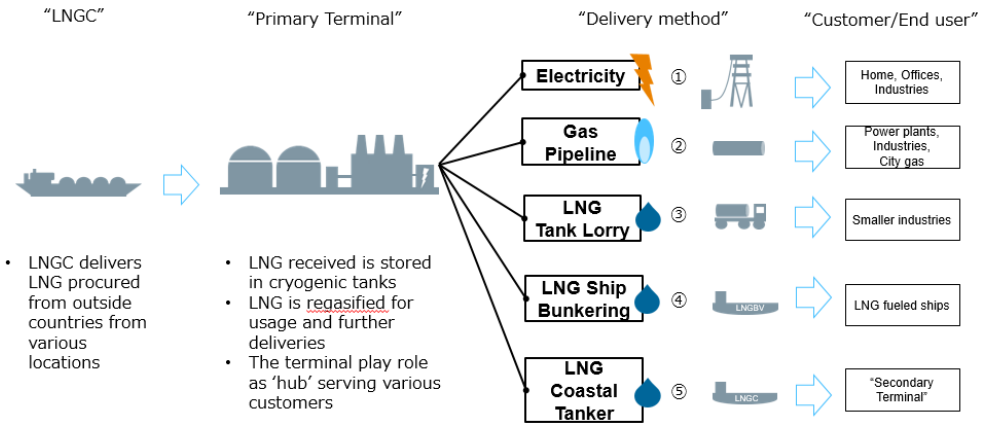
2.4.7 LNG to Power Structure

As an example of optimal operation of onshore LNG terminals and large-scale GTCC thermal power plants, LNG to Power structure is shown in Figure 2.4-8. In the LNG value chain (from the production of LNG on Upstream to the supply of vaporized gas on Downstream), it is a business structure in which the same company conducts regasification at onshore LNG terminals and power generation at adjacent GTCC thermal power plants, which is common in mature LNG importing countries such as Japan. As shown in Figure 2.4-9, LNG to Power projects enables Customer/End Users to receive various services from operation companies. At the same time, by creating a competitive environment among private companies, LNG procurement costs are expected to be restrained to the maximum extent possible, and the governments introducing the projects to its country can obtain and enjoy the LNG import know-how in such private companies, which will enable them to procure LNG on favorable terms considering various aspects such as supply stability, economy, and elasticity.



Source: JICA Study Team

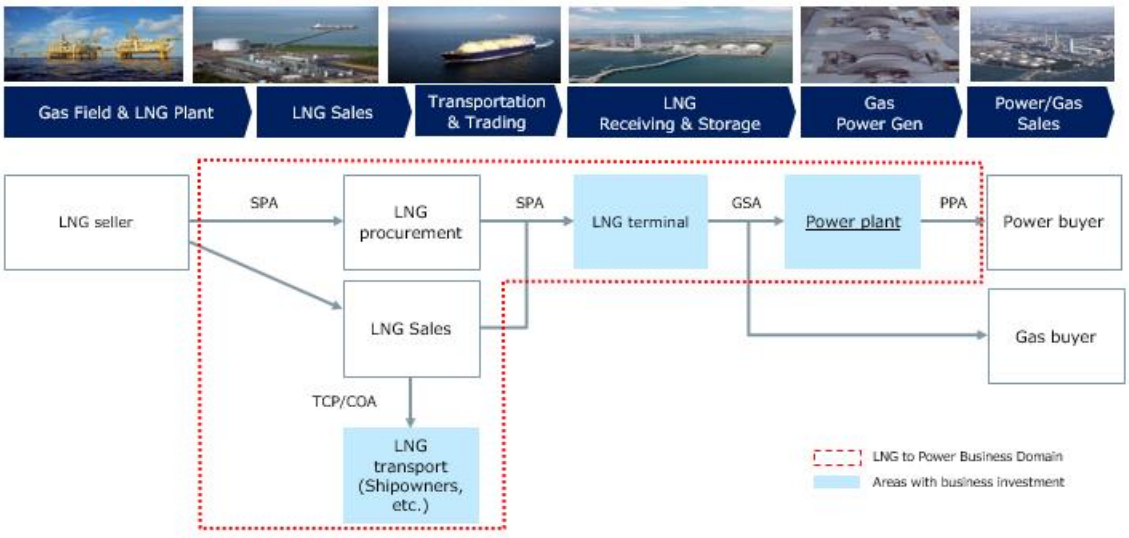
Figure 2.4-8 LNG to Power Structure in the LNG Value Chain



Source: JICA Study Team

Figure 2.4-9 Overview of the Various Services Available through LNG to Power

To introduce the LNG to Power project, it is necessary to establish a scheme in which private companies import LNG, receive, store and vaporize it at LNG receiving terminals, and generate electricity at power plants and sell it to the government. In order to establish this scheme in Bangladesh, it is essential to develop a legal system and implement policy measures with reference to the cases of the preceding countries. A typical contract structure for LNG to Power projects is shown in Figure 2.4-10.



Source: JICA Study Team

Figure 2.4-10 Typical Contract Structure of the LNG to Power Project

The private companies operating the LNG to Power project will purchase LNG on their own from sellers such as IOCs and NOCs under the Sale and Purchase Agreement ("SPA"). If a private company holds some shares in LNG upstream projects and can offtake LNG, it is possible to direct such LNG to an onshore LNG terminal that it operates.

Private companies receive LNG at onshore LNG terminals and store it in LNG tanks. The LNG is then re-gasified ("Re-gasified Liquefied Natural Gas"; RLNG) and sent out under the Gas Supply Agreement ("GSA") to supply gas to the adjacent GTCC thermal power plant.

Power Buyer buys the electricity generated by the GTCC thermal power plant under Power Purchase Agreement ("PPA"), and the private company receives payment.

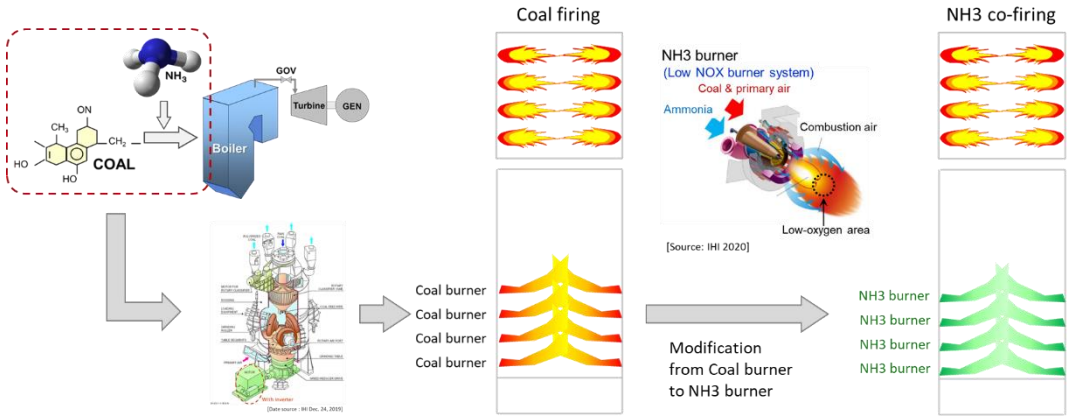
In addition, private companies can sell RLNG to Gas Buyer through a separate GSA or supply LNG by LNG Tank Lorry to customers geographically distant from the gas pipeline.

The SPA includes provisions for determining the amount and timing of annual LNG delivery, as well as conditions specific to the LNG industry, such as take-or-pay payments for not to take back a certain amount of the contract. It should be kept in mind that when a private company sells electricity on the basis of LNG, it is desirable that the cost associated with SPA is basically pass-through to PPA in order to maintain the financial health of the private company.

2.4.8 NH3 co-firing modification procedure in coal-fired thermal power plant

Modification of burners is needed for NH3 co-firing in coal-fired thermal power plants. The need for modification of the de-NOX and de-SOX systems should be studied in detail. For long-term operation of NH3 co-firing, additional berths and ancillary facilities such as NH_3 tanks are needed.

2.4.9 NH3 co-firing can be achieved by coal burner modification

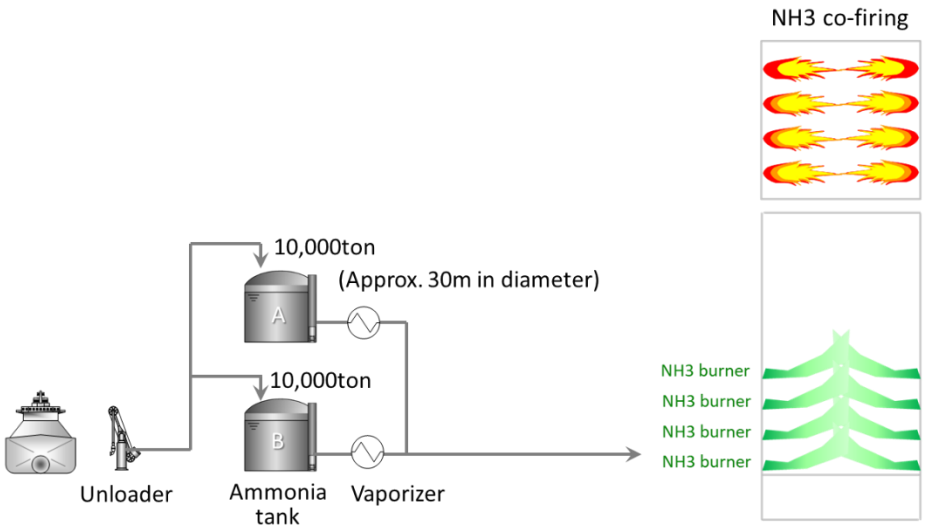


Source: JICA Study team

Figure 2.4-11 NH3 Co-firing can be achieved by Coal Burner Modification

Figure 2.4-11 shows NH3 co-firing can be achieved by coal burner modification. The center of the figure shows the combustion state in the case of coal combustion. In this case, pulverized coal is fed to the coal burner for combustion. To convert this to NH3 co-fired combustion, the coal burner can be converted to an NH3 burner that burns a mixture of pulverized coal and gasified NH3 fuel, as shown on the right side of the figure.

2.4.10 NH3 consumption for NH3 co-firing



Source: JICA Study team

Figure 2.4-12 NH3 Consumption for NH3 Co-firing

Figure 2.4-12 shows NH3 consumption for NH3 co-firing. The NH3 consumption for a 600 MW coal-fired thermal power plant with 20% NH3 co-firing is approximately as follows.

- The approximate NH3 consumption of 120 MW equivalent per unit is about 30 ton/h.

- The daily NH3 consumption of one unit is 30 ton/h x 24h = 720 ton/day.
- NH3 consumption for one unit for two weeks is 1,080ton. (Approx. 1,000ton)

2.4.11 Comparison of gas NH3 and liquefied NH3

Table 2.4-3 Comparison of Gas NH3 and Liquefied NH3

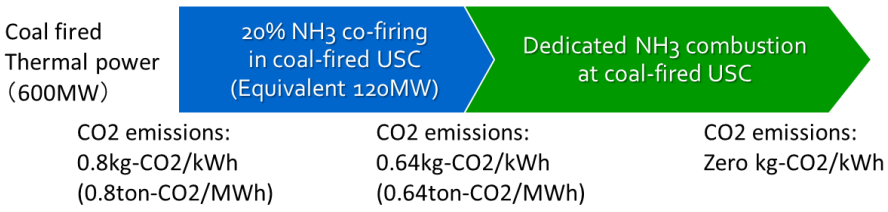
Hekinan P.S.

	Liquid NH3 burner	Gas NH3 burner
Transport	NH3 is liquefied and transported. So **it can be used directly in the burner.**	NH3 is transported in liquid form. Liquid NH3 is vaporized and fed to gas NH3 burner.
NH3 pipe line installation costs	**Liquid NH3 pipelines are thin.** Therefore installation costs is not so expensive.	Gas NH3 pipelines are thick. Therefore installation costs is expensive.
Boiler modification costs	**Liquid NH3 burners can be realized by modifying just oil burners.** The costs of this modification is much cheaper than that of a gas NH3 burner.	Modification costs are more expensive than liquid NH3 burner. Because of the need to install a new coal and NH3 co-firing burner.
Combustion capability	**In the case of an integrated flame with multiple burners, there is no significant difference between gas NH3 combustion and liquid NH3 combustion** because there is enough space for combustion.	**In the case of a single flame with individual burners, combustion with gas NH3 is superior** to combustion with liquid NH3 with heat of vaporization.

Source: JICA Study team

Table 2.4-3 shows Comparison of gas NH3 and liquefied NH3. As shown in the comparison table, gas NH3 and liquefied NH3 have their advantages and disadvantages, but liquefied NH3 is superior in terms of modification cost if sufficient stable combustion with liquefied NH3 is confirmed.

2.4.12 CO2 reduction by NH3 co-firing



Source: JICA Study team

Figure 2.4-13 CO2 Reduction by NH3 Co-firing

Figure 2.4-13 shows CO2 reduction by NH3 co-firing in coal fired thermal power plants with 600MW.

- The CO2 emission intensity for a coal-fired power plant is 0.8 kg-CO2/MWh.
- By co-firing 20% NH3, the CO2 emissions intensity of the co-firing unit is 0.8 kg-CO2/MWh x 0.8 = 0.64 kg-CO2/MWh.
- The specific CO2 reductions can be calculated here as follows.

The CO2 reduction of 20% NH3 co-firing in coal-fired thermal power plant is
600MW x (0.8-0.64)ton-CO2/MWh = 96ton-CO2/h

- The CO2 reduction per year is

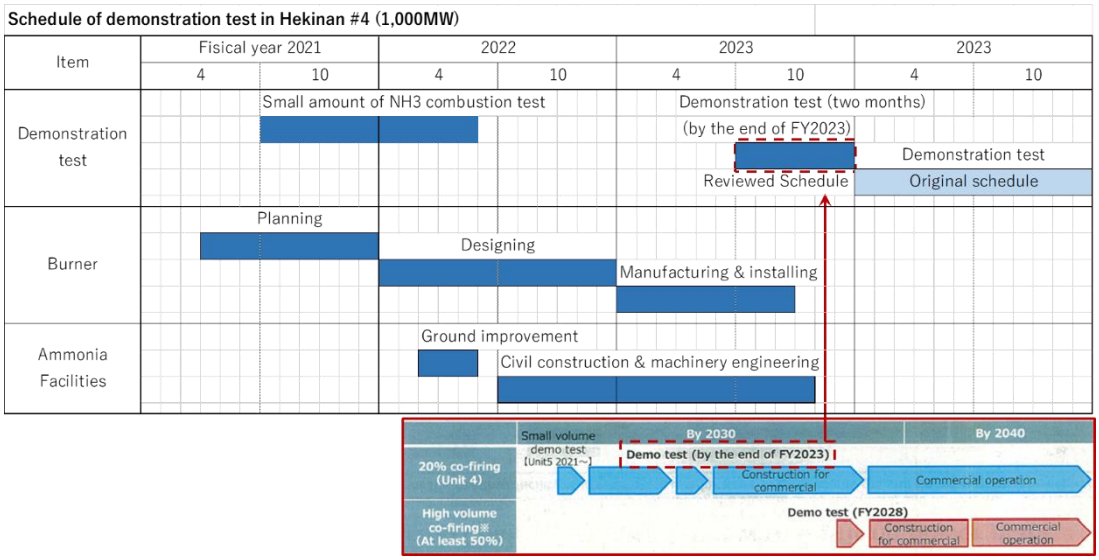
96ton-CO2/h x 8,760h = 840,960ton-CO2 ≈ 0.84million ton-CO2/year

- Assuming an annual load factor of 50%.

0.84millionton-CO2/year x 0.5 ≈ 0.42millionton-CO2/year

2.4.13 Demonstration test process of NH_3 co-firing at Hekinan Thermal Power Station

1) Demonstration Schedule



Source: Data provided by JERA Jul. 2022, content added by JICA study team

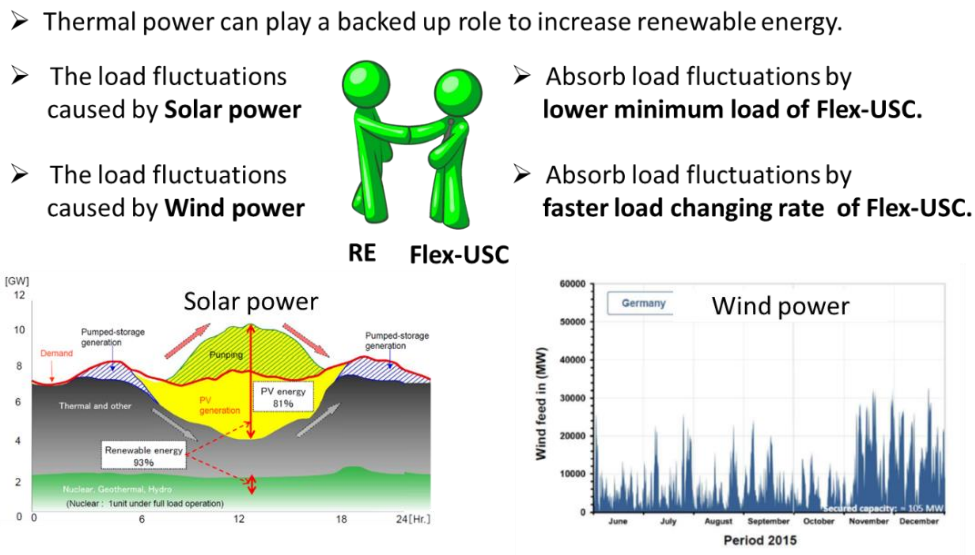
Figure 2.4-14 Demonstration Test Process of NH3 Co-firing at Hekinan Thermal Power Station

Figure 2.4-14 shows the Demonstration test process of NH3 co-firing at Hekinan Thermal Power Station. As shown in the figure, as of July 2022, the test, which was originally scheduled to be conducted at the end of 2023 under the original process, is now being conducted, nearly one year ahead of schedule.

2) Demonstration test data

Although NOX was expected to increase due to the combustion of NH3 during the NH3 planning phase, the NOX value was kept lower than expected, as shown in the actual data on the right side of the figure.

2.4.14 Renewable energy and thermal power are mutually complementary



Source: JICA Study team

Figure 2.4-15 Renewable Energy and Thermal Power are mutually complementary

Figure 2.4-15 shows Renewable energy and thermal power are mutually complementary. Thermal power plants with excellent flexibility capability can absorb the fluctuations of renewable energy in the Renewable Energy expanding era, which is a discontinuous source of power.

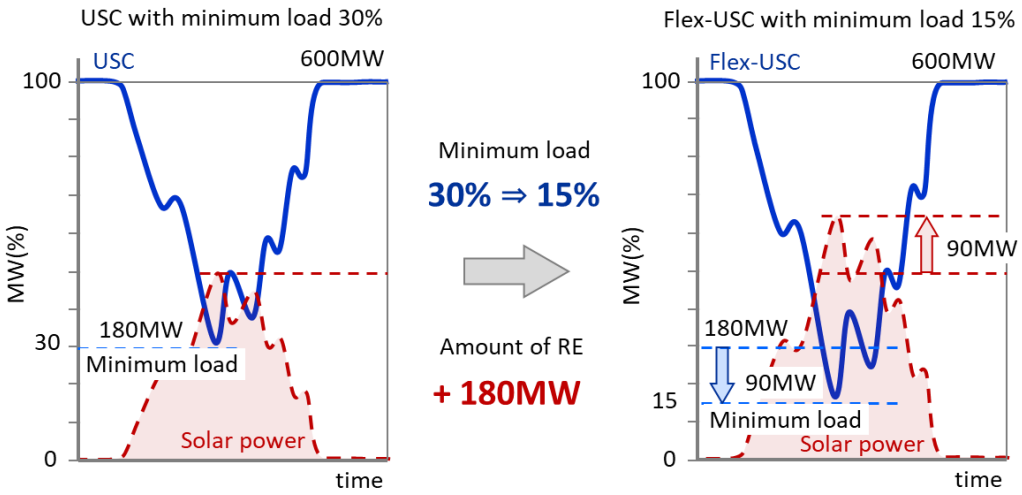
The left side of the figure shows a 24-hour load curve. In good daytime weather, solar power, shown in yellow, is large, and thermal power, shown in gray, is reduced to the minimum load, but the excess power demand, shown by the red line, is used as nighttime power through pumped-storage power. Such large load fluctuations due to solar power can be absorbed by lowering the minimum load for thermal power.

The right side of the figure shows the variation in wind power from June to December. As the figure shows, load fluctuations due to wind power are large and the load changing rate is high. Such rapid load changes caused by wind power can be absorbed by increasing the load changing rate of thermal power.

2.4.15 Amount of renewable energy that can be increased by applying Flex-USC

Flex-USC is defined as a coal-fired power plant that has a reduced minimum load and a faster load changing rate compared to a coal-fired power plant operating at conventional baseload. Specifically, coal-fired thermal power with load flexibility capability with a minimum load of 15% and a load changing rate of 5%/minute.

- By reducing the minimum load of the 600 MW plant from 30% to 15%, the amount of RE can be increased by 90 MW.
- Therefore, by applying the Flex-USC in Matarbari #3 / #4 , 180 MW of RE can be installed.



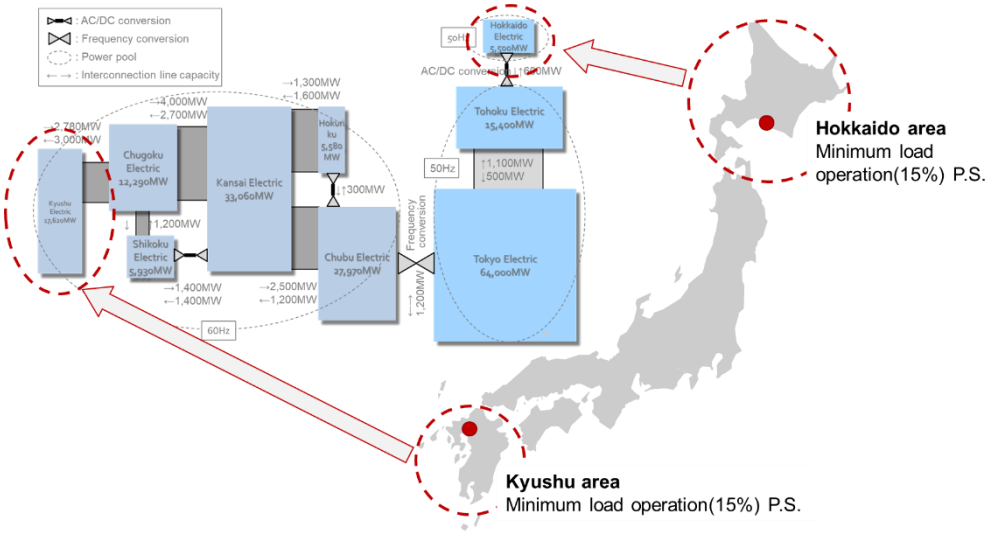
Source: JICA Study team

Figure 2.4-16 Amount of Renewable Energy that can be increased by applying Flex-USC

Figure 2.4-16 shows the Amount of renewable energy that can be increased by applying Flex-USC. The figure compares a USC with an output of 600 MW and a minimum load of 30% (180 MW) with a Flex-USC with a minimum load of 15% (90 MW) to determine how much more renewable energy can be increased by lowering the minimum load.

The left figure shows the case of 30% minimum load and the right figure shows the case of 15% minimum load. As can be seen in the figure on the right, the minimum load can be reduced from 30% (180 MW) to 15% (90 MW) with coal-fired power (Flex-USC), which corresponds to an increase of 90 MW of renewable energy. These are the effects of increasing renewable energy when the minimum load is lowered, which is one function of Flex-USC.

2.4.16 Load flexibility Capability of Coal-Fired thermal Power in Japan



Source: JICA Study team

Figure 2.4-17 Load flexibility Capability of Coal-Fired thermal Power in Japan

Figure 2.4-17 shows the Load flexibility Capability of Coal-Fired thermal Power in Japan. The figure shows a map of Japan and a schematic diagram of the power system showing the grid interconnections of Japan's major power companies. The map also shows units operating at 15% minimum load in the Hokkaido area and units operating at 15% minimum load in the Kyushu area.

Japan's power system operates at 50 Hz in eastern Japan, represented in blue, and at 60 Hz in western Japan, represented in gray. East and west Japan are connected to the grid through frequency converters. In addition, both East and West Japan power companies are interconnected to the grid, and load adjustments are made in each company's area to reduce load adjustments on interconnection lines.

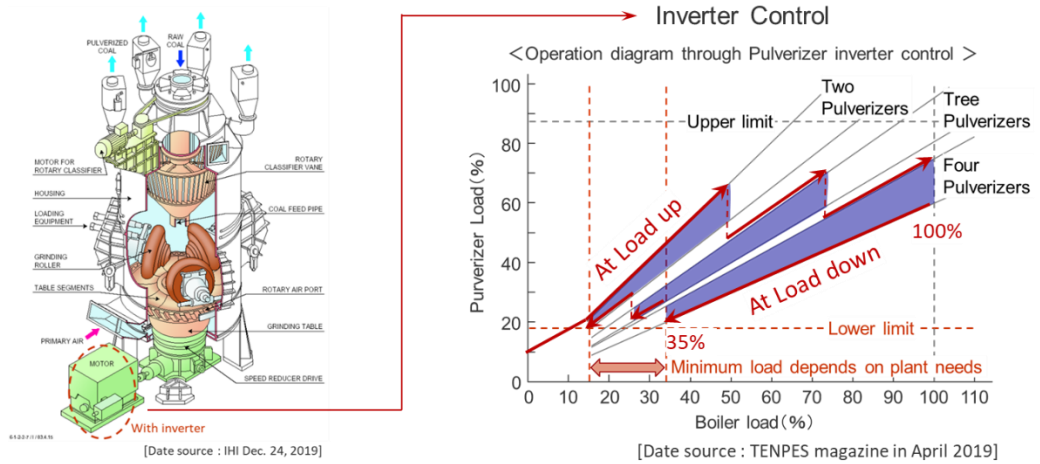
In Japan, which is composed of such grids, both the Kyushu and Hokkaido areas have a high need for load regulation capability for coal-fired thermal power. For this reason, both areas are operating with a 15% minimum load reduction for coal-fired thermal power.

Table 2.4-4 Minimum Load Operation Results

No.	Country	Plant	MW	Press.	MST	MW	Minimum load	COD
			(MW)	(Mpa)	(dgree C)	(dgree C)	(%)	(year)
1	Japan	A	700	25.0	566	566	15	1995
2	Japan	B	700	24.1	600	600	15	2002
3	Japan	C	1,000	24.5	600	600	15	2019

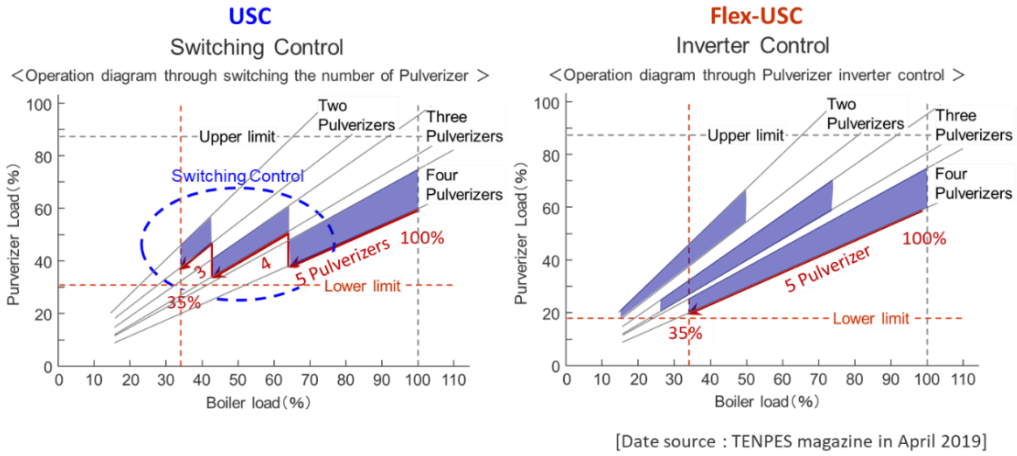
Source: JICA Study team

2.4.17 Load operation through coal fired thermal Power in Japan



Source: JICA Study team

Figure 2.4-18 Load Operation through Coal Fired Thermal Power in Japan



(Source) JICA Study team

Figure 2.4-19 Comparison of Number Control of Pulverizer and Speed Control by Inverter

Figure 2.4-18 shows the Load operation through coal fired thermal Power in Japan, and Figure 2.4-19 shows Comparison of number control of pulverizers and speed control by inverter.

An inverter controls the speed of the mill motor shown in Figure 2.4-18. Here we show an example of operation with four pulverizers in regular use at 100% load, but it is common to provide one spare pulverizer in consideration of pulverizer maintenance.

1) Load operation with pulverizer motor speed control

Figure 2.4-19 shows an example of load operation pattern by a pulverizer with an inverter. The application of the inverter widens the turndown of the pulverizer.

Figure 2.4-18 shows that four pulverizers can be operated continuously from 100% load to 35% load. To further reduce the load, the minimum load can be reduced to 15% by reducing the number of pulverizers.

2) Load operation through the number of pulverizers

Figure 2.4-19 shows the Comparison of number control of pulverizer and speed control by inverter.

The left figure in 2.4-19 shows the number control of pulverizer by a conventional way. The turndown of a conventional pulverizer without an inverter is narrower than that with an inverter.

Therefore, when the load lowers from 100% load to 35%, it is necessary to hold the load at 65% and switch the number of pulverizers from 4 to 3, and at 40% load, hold the load and switch from 3 to 2.

Thus, by applying the pulverizer with inverter, a wide range of load changes can be performed in continuous operation without load holding.

Table 2.4-5 shows the delivery record of pulverizer with inverters in Japan.

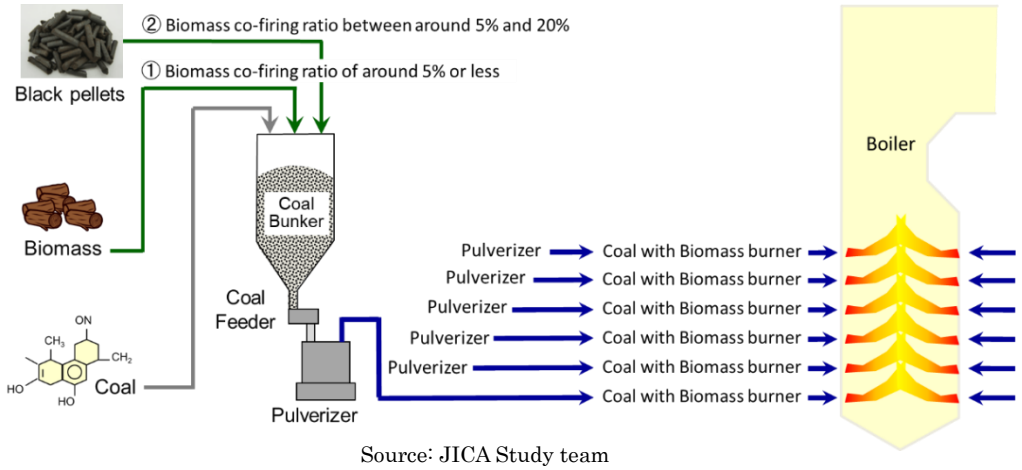
Table 2.4-5 Delivery Record of Pulverizers with Inverters in Japan

No.	Country	Plant	MW	Pulverizer (Numbers)	Manufacture	COD (year)
1	Japan	A plant	600	5	IHI	2002
2	Japan	B Plant	156	3	MHI	2004

Source: JICA Study team

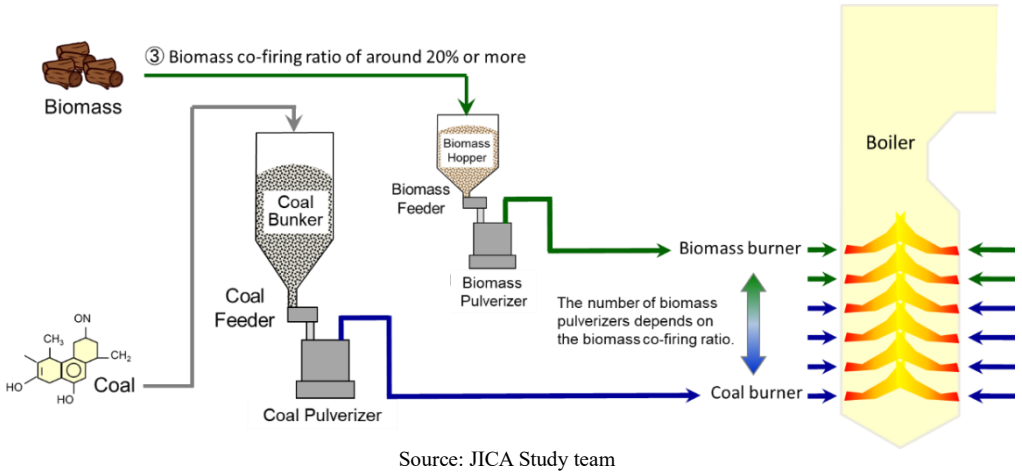
2.4.18 Biomass co-firing in coal fired power plants

Figure 2.4-20 shows the configuration of a biomass co-firing system (co-firing ratio less than 20%) and Figure 2.4-21 shows the configuration of a biomass co-firing system (co-firing ratio greater than 20%.



Source: JICA Study team

Figure 2.4-20 Configuration of a Biomass Co-firing System (co-firing ratio less than 20%)



Source: JICA Study team

Figure 2.4-21 Configuration of a Biomass Co-firing System (co-firing ratio greater than 20%)

As shown in ① in the figure, if the biomass co-firing ratio is 5% or less, the biomass can be mixed and co-fired in a coal bunker.

As shown in ② in the figure, when the biomass co-firing ratio is 5% to 20%, the biomass needs to be processed. As an example, black pellets can be used for co-firing with coal.

As shown in ③ in the figure, if the biomass co-firing ratio is 20% or more, a dedicated biomass pulverizer should be installed.

As described above, there are three levels of implementation for biomass co-firing, but the most economical way to reduce CO2 emissions is the three-stage mixing of 20% NH3 co-firing with 5% biomass (so-called hybrid co-firing).

Black pellets are wood that has been crushed, dried, roasted, and semi-carbonized. Compared to conventional white pellets, black pellets have superior water resistance and crushability, and

can be handled like coal. Therefore, the use of coal can be reduced, and the use of renewable energy (black pellets) can be increased without modifying existing facilities.

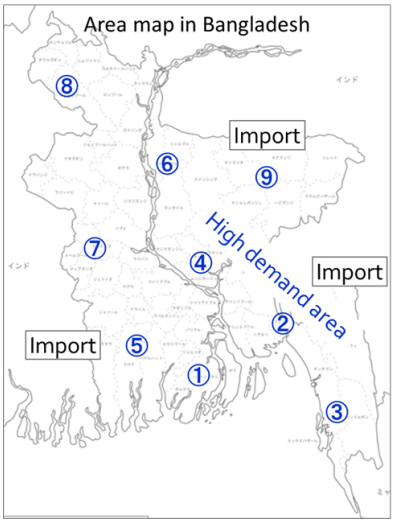
As of 2022, the amount of black pellets in circulation is small, and the unit cost of fuel is high because existing biomass is processed. However, as the distribution volume increases in the future, the unit cost of fuel is expected to decrease. The calorific value of black pellets (4,300-5,500 kcal/kg) is about twice that of woodchips (1,600-2,500 kcal/kg), which is equivalent to that of coal.

Table 2.4-6 Comparison of NH3 Co-firing and Biomass Co-firing in Coal-fired Thermal Power Plants

	Biomass co-firing	NH_3 co-firing
Boiler modification	➢ 6% biomass co-firing can be achieved without boiler modification. ➢ For biomass co-firing of 20% or more, it is necessary to add a dedicated biomass pulverizers.	➢ 20% NH_3 co-firing can be achieved by simply converting one burner stage from a coal burner to an NH_3 burner. ➢ In the future, 100% dedicated NH_3 firing can also be achieved by basically only modifying the burner section.
Fuel supply facilities	➢ No new facilities are needed for biomass storage because the coal area can be used.	➢ NH_3 storage tanks need to be added.
Fuel procurement	➢ The world's forest resources are limited, making it difficult to procure biomass on a long-term and stable basis.	➢ There are two types of NH_3: blue NH_3 and green NH_3. Blue NH_3 is produced from fossil fuels and can be expected to be stably procured.
Economy	➢ Initial cost: The cost of the dedicated biomass pulverizers are about the same as the cost of the NH_3 combustion burner section. ➢ Running cost (unit cost of power generation) Dedicated biomass burning: 100% increase over coal (Source: CRIEPI Research Report M13009, 2015)	➢ Initial cost: The cost of modifying the NH_3 combustion burner is almost the same as the cost of a dedicated biomass pulverizers. Additional cost for NH_3 storage tank is also required. ➢ Running cost (unit cost of power generation) NH_3 20% co-firing: 20% increase compare to coal NH_3 100% firing: 110% increase compared to coal (Source: Ministry of Economy, Trade and Industry, Public-Private Council for Fuel NH_3 Introduction, 2020)
CO_2 reduction	➢ 20% biomass co-firing is realistic and can be expected to reduce CO_2 emissions by about 20%.	➢ In the future, 100% dedicated NH_3 firing is possible, and zero-emission thermal power can be realized.
Overall evaluation	➢ If biomass co-firing of about 6% is carried out, no equipment modification costs are required and a 6% reduction in CO_2 emissions can be expected. ➢ In order to realize zero-emission thermal power in the future, difficulties in fuel procurement will be involved. ➢ Therefore, it is not a desirable choice from the viewpoint of zero-emission thermal power.	➢ In order to achieve zero-emission thermal power in the future, NH_3 is the preferred choice as an alternative fuel to coal, as it is expected to provide a stable supply of fuel.

Source: JICA Study team

2.4.19 Engine



	2021		2041	
	Gas engine (Less than 100MW)			
	H2	Gas	H2	Gas
⑨Sylhet	0	277	0	⇨
⑧Rangpur	0	0	0	⇨
⑦Rajshahi	0	43	0	⇨
⑥Mymensing	0	22	0	⇨
⑤Khulna	0	0	0	⇨
④Dhaka	0	354	0	⇨
③Chatitogham	0	45+22	0	⇨
②Cumilla	0	392	0	⇨
①Barishal	0	95	0	⇨
Total	0	1,250	0	⇨

Source: JICA Study team

Figure 2.4-22 The Number of Existing Engines in Bangladesh by Area

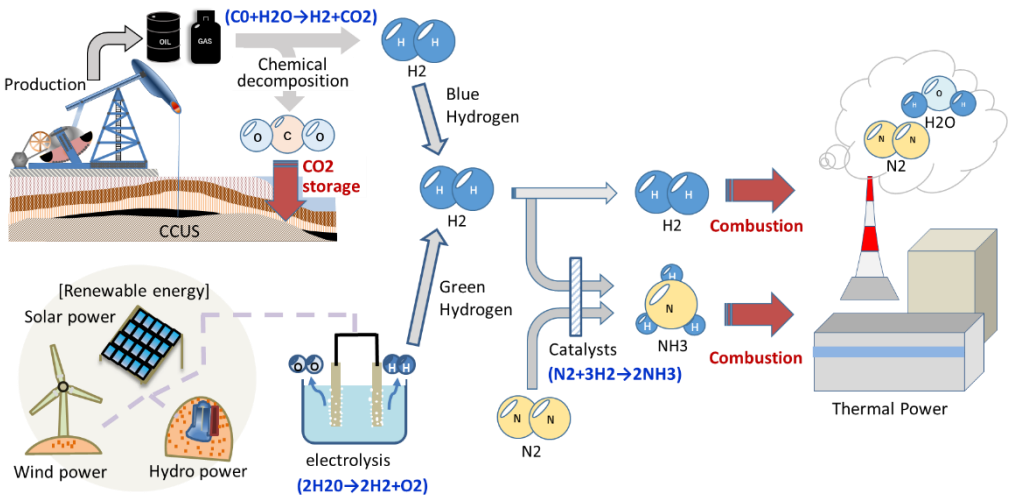
Figure 2.4-22 shows the number of existing engines in Bangladesh by area. Since these engines will continue to be a necessary source of power in each area, they are basically assumed to be maintained at their current levels in 2041.

- Comparing an engine and a small GT with the same output, the engine is more efficient.
- Basically, engines with higher efficiency are suitable for small output (demand).
- On the other hand, the efficiency of a gas turbine increases as the output increases, so a gas turbine is suitable for a size exceeding 30 MW.
- Also, comparing inspection intervals, engines can be inspected for 4,000 hours, while GTs can be inspected for 2 years.

Based on an understanding of these characteristics, engines and small GTs should be placed in the right places.

2.4.20 H2 and NH3 production method

(1) Hydrogen (H2) and ammonia (NH3) production method



Source: JICA Study team

Figure 2.4-23 H2 and NH3 Production Method

Figure 2.4-23 shows H_2 and NH_3 production method. NH_3 is generally produced by synthesizing hydrogen (H_2), the raw material, and nitrogen (N_2) from the atmosphere using the Haber-Bosch (HB) method. The following two methods are commonly used to produce H2, the raw material for ammonia (NH_3).

(1) Hydrogen is obtained by reforming natural gas or coal using the steam reforming method.

(2) Hydrogen is obtained by electrolyzing water with renewable electricity.

NH_3 made from fossil fuels by process (1)s called "Gray NH_3," and most of the NH_3 distributed in the world today falls into the "Gray" category.

Blue NH_3 is produced through the process (1), which is called "Blue NH_3" when CO_2 emitted in the manufacturing process (2) is captured and stored deep underground or used in chemical products (CCS).

"Green NH_3" is produced without CO_2 emissions in the process in the (2) process.

A demonstration project for carbon-free hydrogen production using inexpensive lignite coal as a feedstock is also underway. In the future, relatively inexpensive blue NH_3 derived from lignite coal may be distributed.

(2) Types of ammonia

	Name	Definition	Notes
	Green	・Made by renewable energy	・Expensive at present
	Blue	・Made from fossil fuel with CCUS	
	Gray	・Made from fossil fuel	・Not regarded as carbon-neutral
	Turquois	・Synthesis from methane	
	Yellow	・Co-production from RE and fossil	
	Red	・Made by nuclear	
	White	・Made from natural hydrogen underground	

Source: Dr. Shozo Kaneko, the University of Tokyo

Figure 2.4-24 Types of NH_3

Figure 2.4-24 shows the types of NH3. As shown in the figure, NH_3 is produced through various manufacturing processes.

The NH3 commonly used today is gray NH_3, but in the future, blue NH3, in which CO_2 is removed by using CCS in the manufacturing process, and green NH_3, which is made from renewable energy, are expected to become available.

(3) Ensuring safety in the handling of fuel NH_3

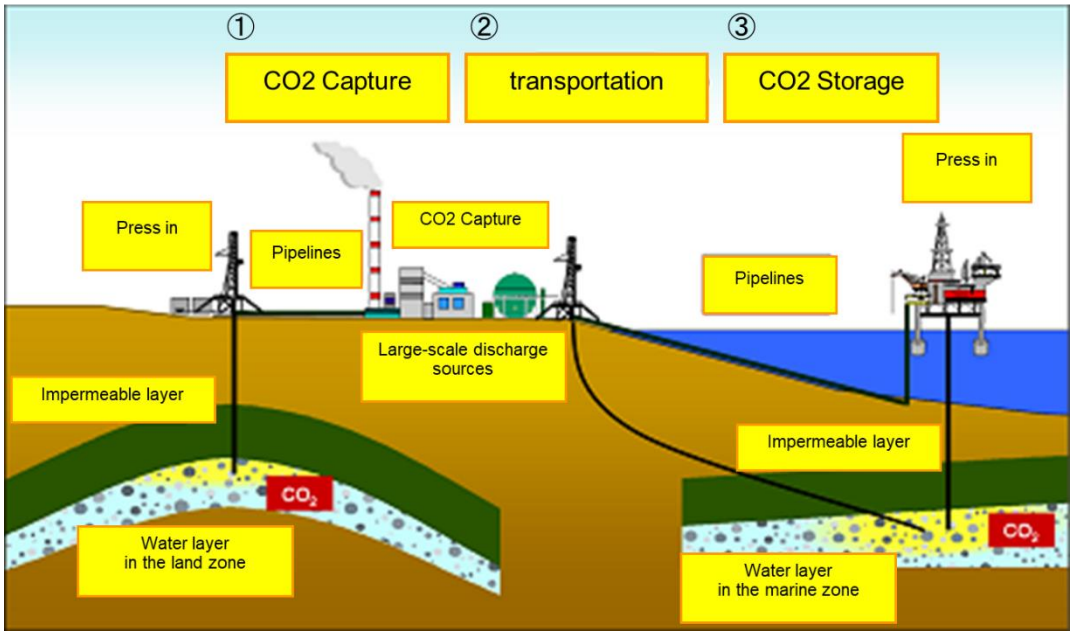
In Japan, technical standards for NH_3 facilities for denitration have been established, but these do not assume the use of large amounts of NH_3 in boilers. Revisions to the technical standards are being implemented to ensure the safety of NH_3 co-firing thermal facilities. The main items to be considered are as follows:

- Selection of appropriate materials based on the characteristics of NH_3.
- Measures to prevent gas leakage from piping, joints, etc. (safety valves, detoxification devices, double pipes, gas detection, etc.)
- Separation distances (NH_3 containers and storage tanks)

Therefore, it is desirable to conduct FS of NH_3 storage facilities and piping prior to the demonstration project to fully examine safety aspects.

2.4.21 CCS (Carbon dioxide Capture and Storage)

1) CO_2 Capture and Storage Methods



Source: RITE (Research Institute of Innovative Technology for the Earth)

Figure 2.4-25 CO2 Capture and Storage Methods

Figure 2.4-25 shows the CO2 capture and storage method.

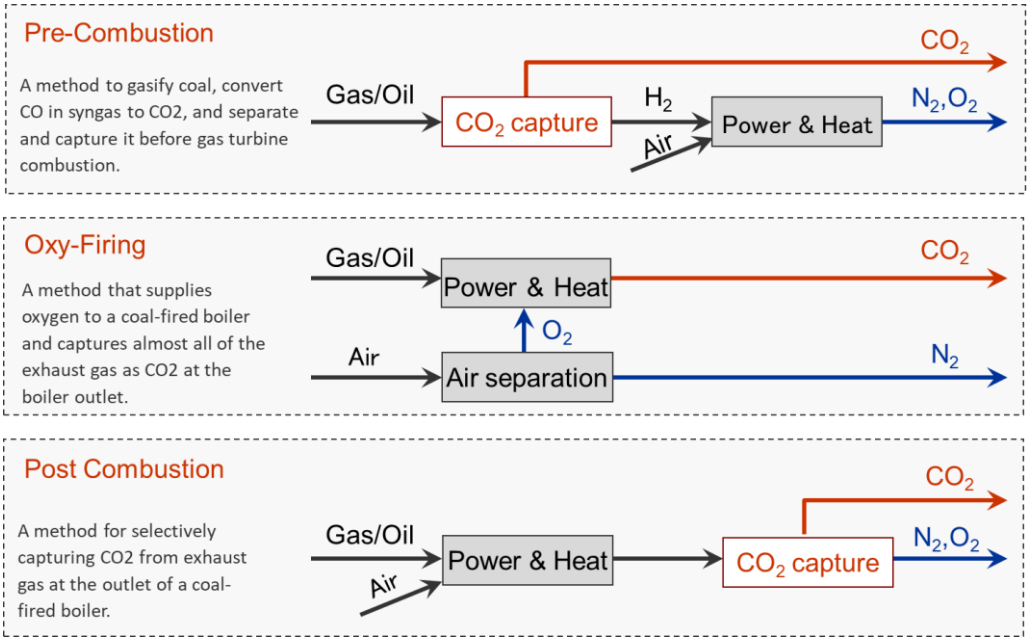
CO2 is pressurized to approximately 20 MPa and stored in a water layer that is shielded by an impermeable layer. There are several layers of this aquifer at depths of approximately 1 km to 3 km below the earth's surface and seafloor.

For long-term storage, a capped and shielded aquifer like the one shown on the left side of the figure is preferred.

To apply CCS to thermal power plants, it is necessary to overcome the issues (1) to (3) shown in the figure.

(1) CO2 Capture : Improve the efficiency of CO_2 capture technology.
(2) Transportation : How to transport the captured CO_2 to the storage site
(3) CO2 Storage : Where should the captured CO_2 be stored?

2) CO_2 Capture Methods



Source: JICA Study team

Figure 2.4-26 CO2 Capture Methods

Figure 2.4-26 shows CO2 capture method from thermal power plants.

- CO2 recovery before combustion (Pre-Combustion)

  This is a technology used in IGCC systems, in which coal is gasified and the CO in the syngas is converted to CO2, which is then separated and recovered prior to gas turbine combustion.

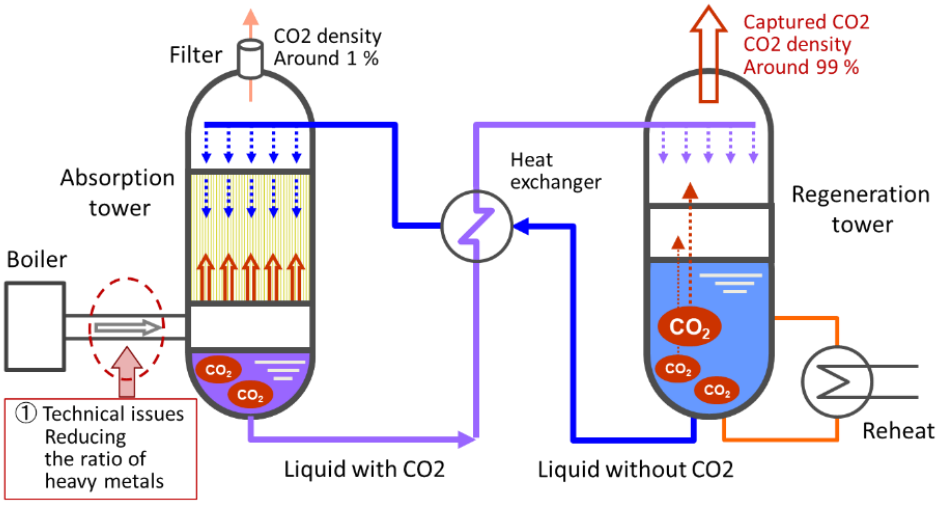
- Oxygen combustion (Oxy-Firing)

  Oxy-firing is a technology currently under development that supplies oxygen to a coal-fired boiler and recovers almost all of the CO2 in the exhaust gas at the boiler outlet.

- Post Combustion (Post-Combustion)

  This technology is used to recover CO2 in USC boilers, and is a method of selectively recovering CO2 from the exhaust gas at the outlet of a coal-fired boiler.

CO2 capture technology (amine chemical absorption method)



Source: JICA Study team

Figure 2.4-27 CO2 Capture Technology (amine chemical absorption method)

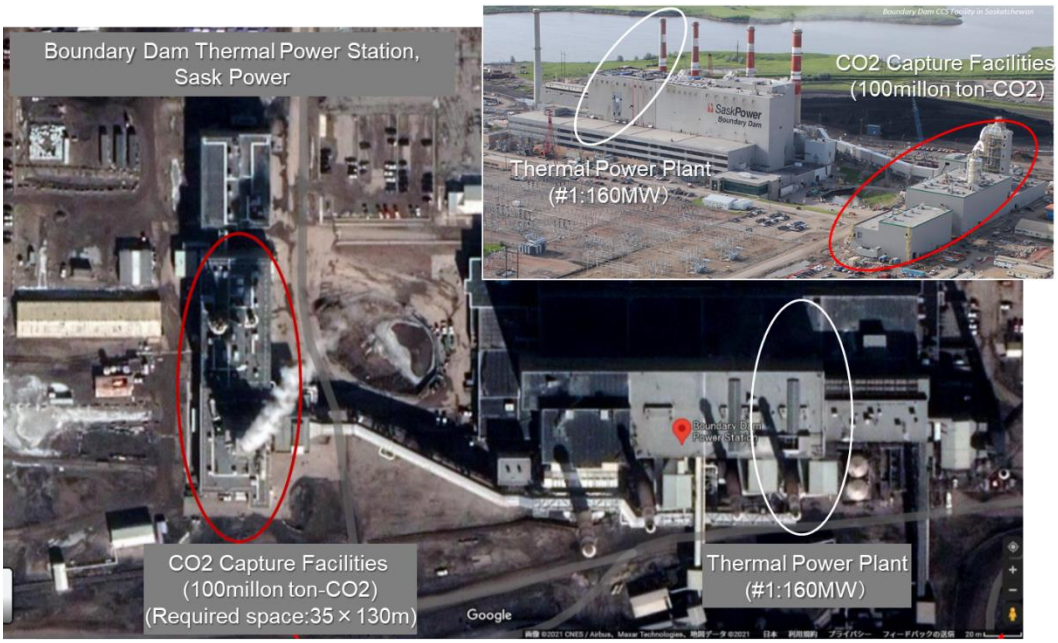
Figure 2.4-27 shows the CO_2 recovery technology (amine chemical absorption method). After absorbing CO_2 in the "absorption tower" on the left side of the figure, the absorbed solution is sent from the bottom of the absorption tower to the "regeneration tower," where it is heated by steam to release CO_2, and the regenerated absorption solution is returned to the "absorption tower" for reuse. This figure shows the case where the exhaust gas from the boiler does not contain many impurities, and the final CO_2 recovery rate is 99%.

However, the actual boiler exhaust gas contains heavy metals. In practical application tests, it has been found that when gas containing such heavy metals enters the CO_2 recovery tower, amines react with these heavy metals, reducing the reaction to CO_2, which was originally intended to be absorbed.

Therefore, improving the CO_2 recovery rate is an issue to be addressed in the future.

(4) Example of CO2 Capture System Installation (Sask Power in Canada)

Figure 2.4-28 shows the space required for the installation of a CO2 capture system. The photo in the figure shows a CO2 capture system installed at Sask Power's Boundary Dam Power Plant Unit 3 (160 MW at the generating end/150 MW at the transmission end) in Canada, using the "amine chemical absorption method". The CO2 recovered here is sold for EOR (at a depth of about 1.4 km), and some of it is injected into a deep saltwater formation (at a depth of 3.2 km).



Source: JICA Study team

Figure 2.4-28 Space Required for Installation of CO2 Capture System

EOR: Enhanced Oil Recovery

- CO2 Recovery Capacity of CO2 Recovery System

  The CO2 recovery system has a capacity of approximately 1 million tons-CO2/year, and recovers all CO2 emitted from Unit 3, which is 160 MW at the generation end and 150 MW at the transmission end.

- In-house power required for the CO2 recovery system

  The power required for the CO2 capture system with a capture capacity of 1 million ton-CO2 /year is about 30 MW, which is about 20% of the power required for the 150 MW unit at the transmission end.

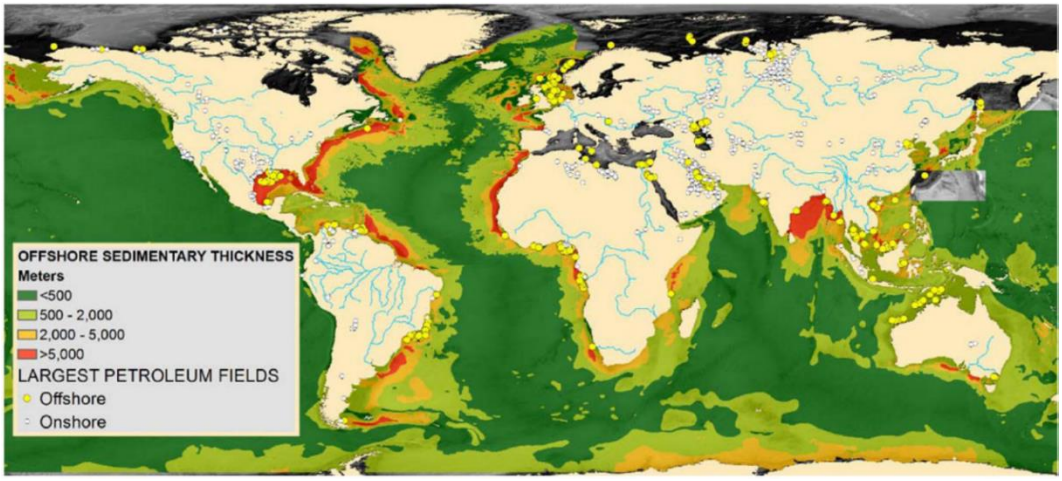
- Installation space required for CO2 capture system

  For a 160 MW power generation facility, a CO2 capture system with a capacity of approximately 1 million ton-CO2 /year is required, and the required space for the capture system is 35 x 130 m ≈ 4,500 m2.

- Cost of the CO2 capture system.

  When installed in 2015, the cost of a 160 MW power generation facility is 1, the cost of a CO2 recovery system is approximately 1.4 times the cost of a 160 MW power generation facility. Therefore, the overall cost including the power generation facility and the CO2 capture equipment is 2.4 times that of the power generation facility alone.

(5) CO2 reservoirs on the seafloor (Gton class)

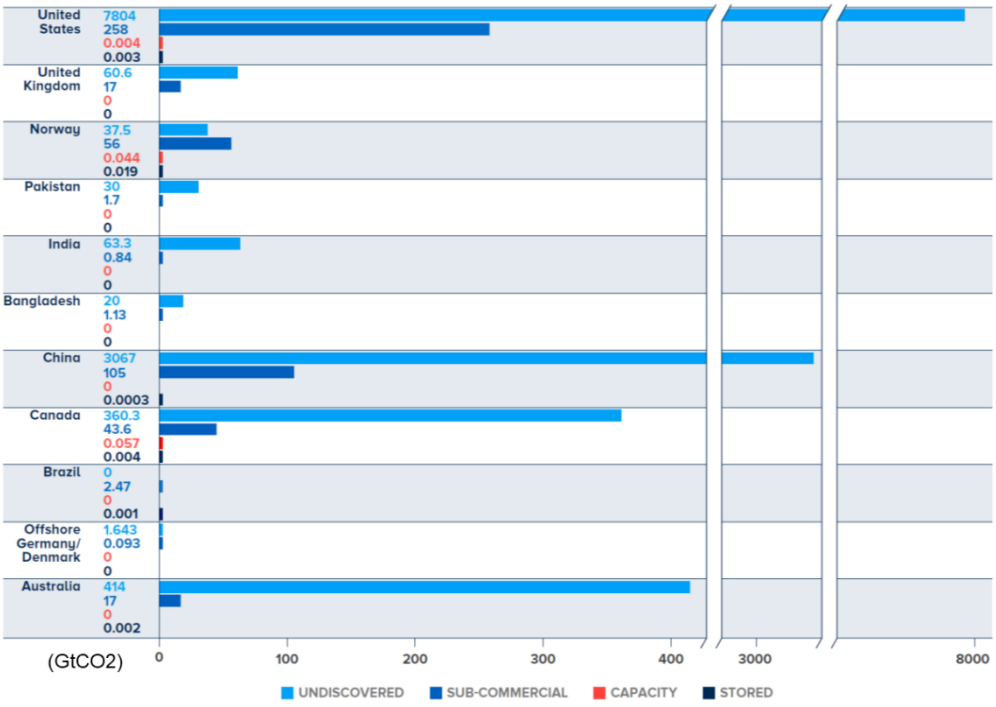


Source: T. A. Meckel, The University of Texas, Scientific reports, 2019

Figure 2.4-29 CO2 Reservoirs on the Seafloor (Gton class)

Figure 2.4-29 shows the CO2 reservoirs on the seafloor (Gton class). The colors shown in the figure (green, light green, yellow, and red) indicate the thickness of the reservoir (m). The figure shows that there are 5,000 m-class reservoirs offshore India and Bangladesh, indicating the potential for CCS in these countries.

(6) Global CO2 storage resource assessment



Source: T. A. Meckel, The University of Texas, Scientific reports, 2019

Figure 2.4-30 Global CO2 Storage Resource Assessment

Figure 2.4-30 shows the global CO2 storage assessments. This figure is the most recent data published in 2020, and these assessments are likely to be updated in the future, but the results for Bangladesh are shown here. This shows potential storage of 20 GtCO2, which is less than in other areas.

(7) Challenges to Achieving CCS

When considering how to realize CCS, the following challenges can be identified.

a. CO_2 Capture

Improvement of CO_2 capture technology:

As already mentioned above, the issues in the CO_2 capture phase require improvements in CO_2 capture technology.

Space required for installation of CO_2 capture system:
The CO_2 capture system needs to be installed in an area adjacent to the power generation system in an area larger than the power generation system (main facilities such as boilers, steam turbines, generators, etc.).
Based on the example of Sask Power's Boundary Dam Power Plant in Canada, the space required for the installation of CO_2 capture system for 1,200 MW can be calculated as follows.
If all of the CO_2 from the 1,200 MW is to be captured, then
1,200MW / 160MW (Boundary Dam Unit 3) ≈ 8 times
Assuming that 8 units of CO_2 capture system are installed in Boundary Dam Unit 3
(35 x 130m) x 8 ≈ 36,000m2CO_2

b. Transportation

How will the collected CO_2 be transported to the area where it can be stored? It is necessary to consider whether a pipeline will be installed on land or whether it will be transported by ship and injected from an offshore base to secure a transportation line.

c. CO_2 storage

The amount of CO_2 storage capacity for injection into the aquifer offshore in Bangladesh is 20 Gton-CO_2 in the published value for 2020. The annual CO_2 emissions from a 1,000 MW coal-fired thermal power plant are about 5 million ton-CO_2.

20 Gton-CO_2/year / 5million ton-CO_2/year = 4,000year

If CO2 is emitted from a 1,000 MW coal-fired power plant, it is calculated that 4,000 years of CO2 can be stored.

d. Economics to realize CCS

From the case of the Sask Power Boundary Dam in Canada, the installation of a CO_2 capture system will increase the total cost of the thermal power plant plus the CO_2 capture system by 1 + 1.4 = 2.4 times.

It is also necessary to consider that there is an in-house power loss of approximately 20% due to the CO_2 capture system.

Furthermore, the economics vary greatly depending on the CO_2 storage location and the method of transport.

e. Conclusion

As described in above, although there are some issues at present, the economics of CCS installation are expected to improve significantly through economies of scale and mass production advantages in the future of CO_2 capture systems.

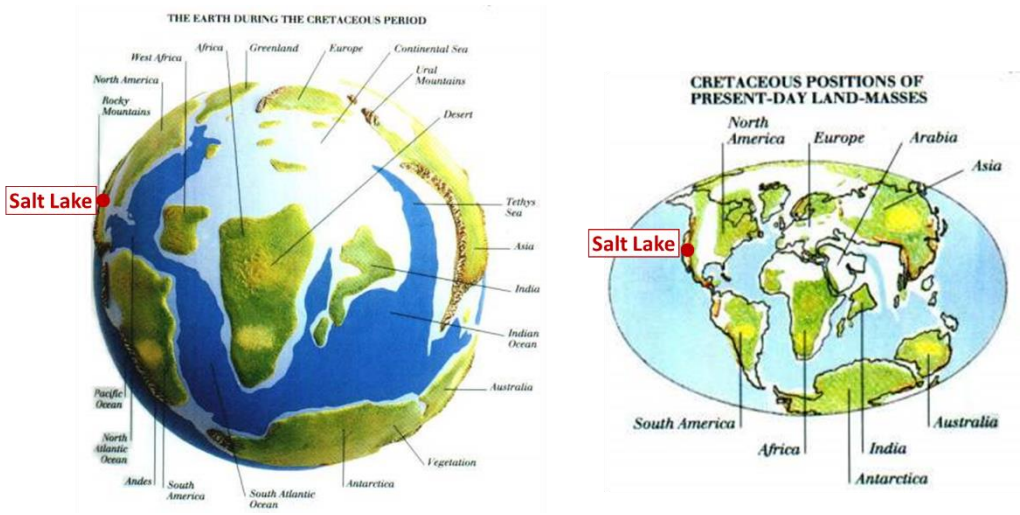
Currently, the world is aiming to reduce costs through economies of scale (i.e., the large-scale implementation of CCS projects), accumulated experience, and technological development, and we need to keep an eye on these trends.

2.4.22 Intermountain Power Project & Green Hydrogen in U.S.

(1) Salt Lake was a sea 146 million years ago

Figure 2.4-31 shows Salt Lake was a sea 146 million years ago.

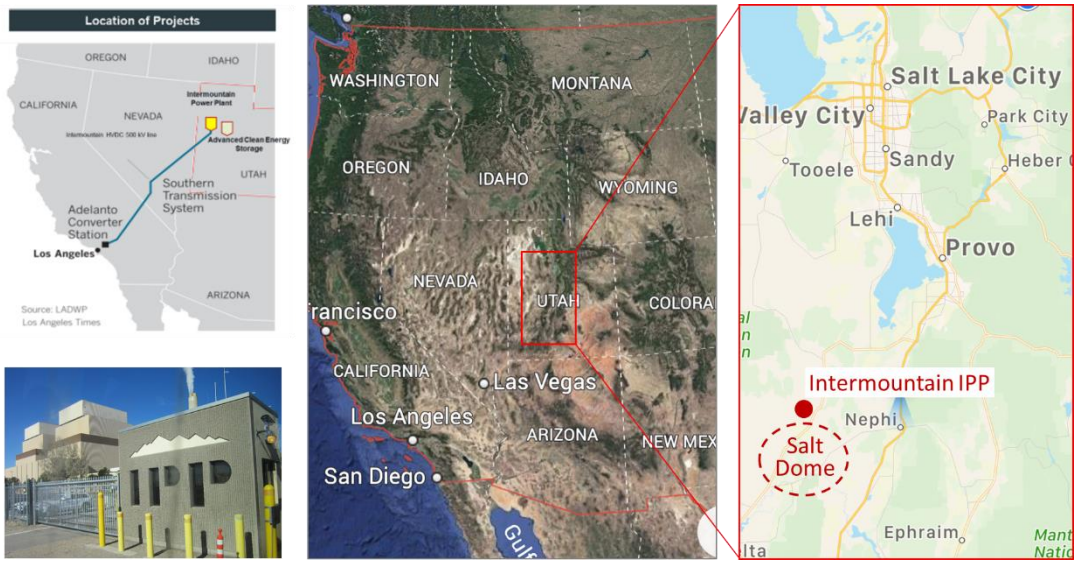
Salt Lake is to the left of the current Rocky Mountains. As you can see on this map, the Rocky Mountains were the sea on both sides. Then, Salt Lake became the lake it is today while maintaining its seawater, so this lake still has higher salt content than seawater.



Source: JICA study team

Figure 2.4-31 Salt Lake was a sea 146 million years ago

(3) Location of Intermountain Power Plant (IPP)

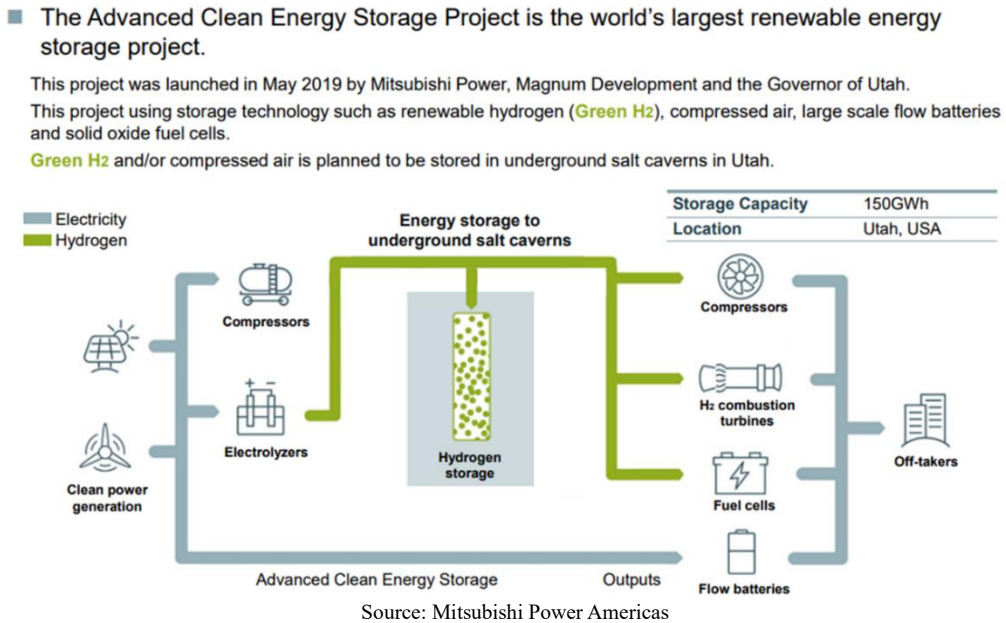


Source: JICA Study team

Figure 2.4-32 Location of Intermountain Power Plant (IPP)

Figure 2.4-32 shows the Location of Intermountain Power Plant (IPP). Intermountain IPP is about a two-hour drive from Salt Lake City to Los Angeles. This area was once an ocean 146 million years ago, and the power plant was built in the middle of the vast plains. The electricity generated here is transmitted to Los Angeles via high-voltage transmission lines.

(3) Advanced Clean Energy Storage Project (US)



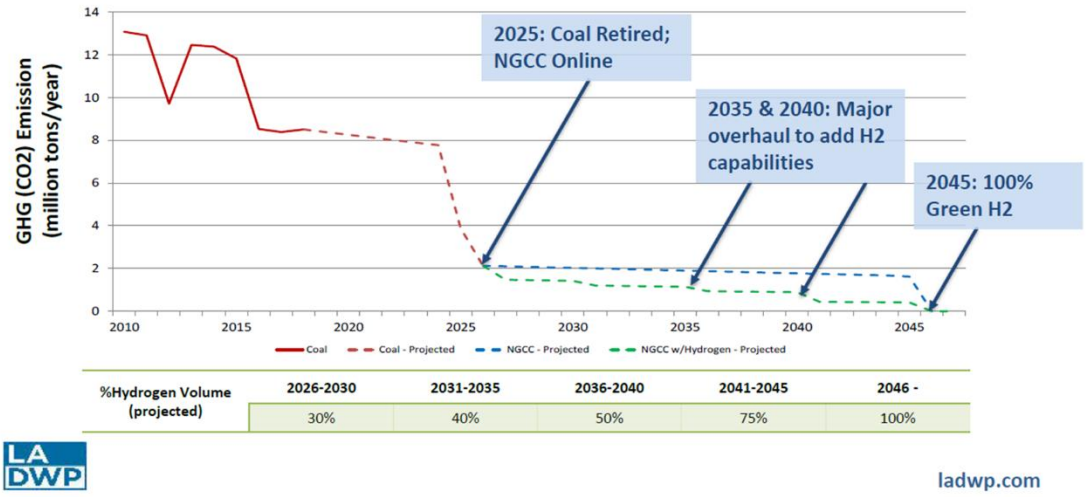
Source: Mitsubishi Power Americas

Figure 2.4-33 Advanced Clean Energy Storage Project (US)

Figure 2.4-33 shows Advanced Clean Energy Storage Project (US). This content is shown in Figure 2.4-33.

(4) IPP Potential Emission Profile

Figure 2.4-34 shows IPP Potential Emission Profile.



Source: LADWP : Los Angeles Development of Water & Power

Figure 2.4-34 IPP Potential Emission Profile

(5) Intermountain IPP from Google earth

Figure 2.4-35 shows Intermountain IPP from Google earth. Construction of GTCC No. 3.4 has begun next to the existing No. 1 and No. 2 boilers.

Source: JICA Study team

Figure 2.4-35 Intermountain IPP from Google Earth

(6) GTCC under construction (view from #2 boiler top)

Figure 2.4-36 shows GTCC under construction (view from #2 boiler top). The Intermountain IPP area is a vast great plain where a sea was 146 Million years ago. It is also said that there are 100 Salt Domes under this area. This project is being carried out by taking advantage of such geographical features.

Source: JICA Study team

Figure 2.4-36 GTCC under Construction (view from #2 boiler top)

(7) Hydrogen facilities are under construction

Figure 2.4-37 Hydrogen facilities are under construction

Construction of a hydrogen production facility has begun south of the Intermountain IPP area.

Source: JICA Study team

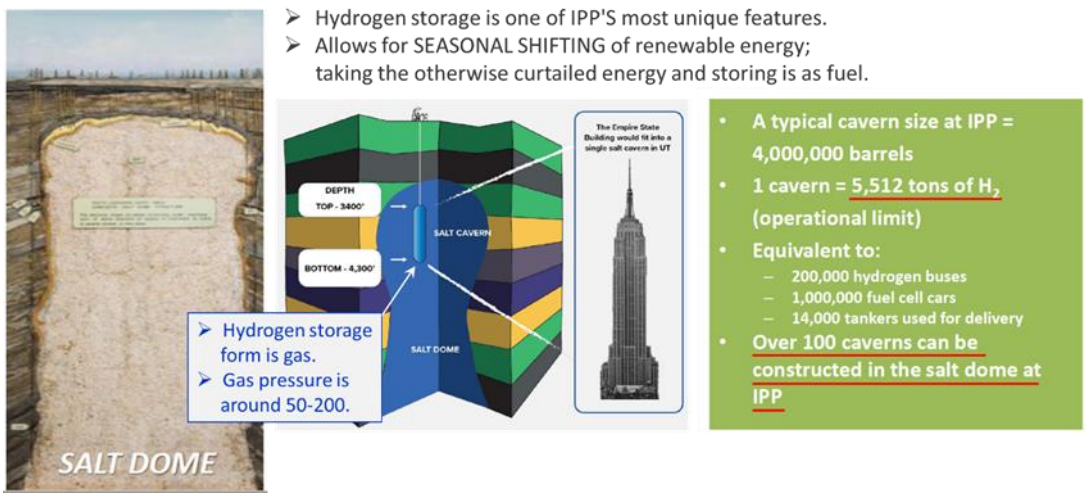
Figure 2.4-37 Hydrogen Facilities under Construction

(8) Hydrogen Storage at IPP

Figure 2.4-38 shows Hydrogen Storage at IPP. The hydrogen utilization project at Intermountain IPP takes advantage of the site that was once an ocean 146 million years ago.

Among them, the world's first hydrogen storage system using Salt Dome is attracting a lot of attention.

The main specifications of this system are shown in Figure 2.4-38



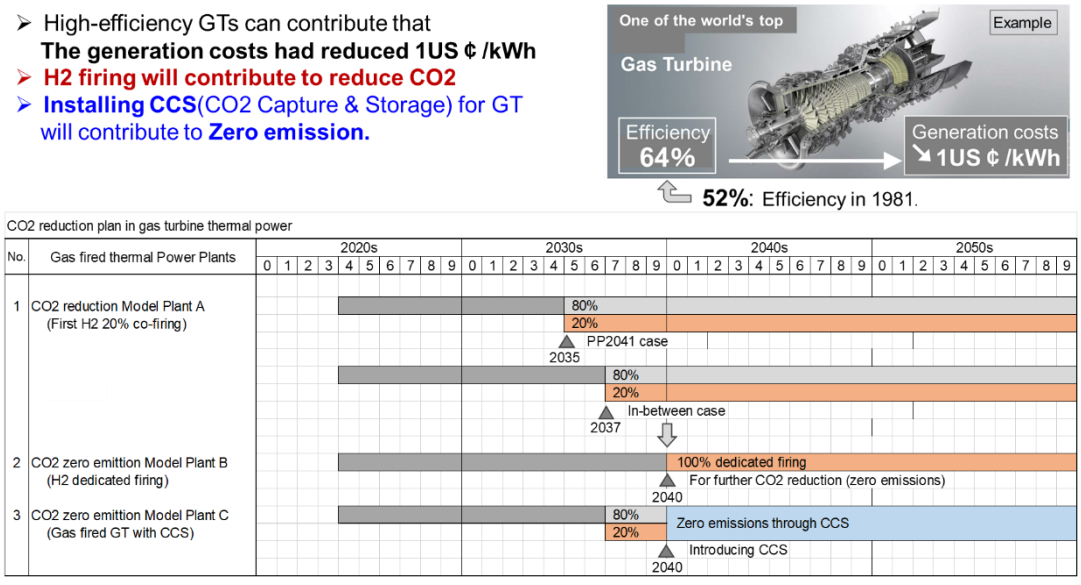
Source: LADWP : Los Angeles Development of Water & Power

Figure 2.4-38 Hydrogen Storage at IPP

2.4.23 ZERO emission through GT with CCS

Figure 2.4-39 shows ZERO emission through GT with CCS.

H2 co-firing will start in 2035 for high efficiency gas turbines. To further reduce CO2 emissions, the gas turbine units will challenge H2 dedicated combustion, and CCS will be introduced by 2040.



Source: JICA study team

Figure 2.4-39 ZERO Emission through GT with CCS

3 Planning and Operation of Distribution Networks

3.1 Distribution Utilities Overview

Six utilities in Bangladesh are responsible for the management and supervision of distribution network, according to their positions and regions. These are Dhaka Electric Supply Company Limited (DESCO), Dhaka Power Distribution Company Limited (DPDC), West Zone Power Distribution Company Limited (WZPDCL), Northern Electricity Supply Company Limited (NESCO), Bangladesh Power Development Board (BPDB) and Rural Electrification Board (Bangladesh Rural Electrification Board: BREB).

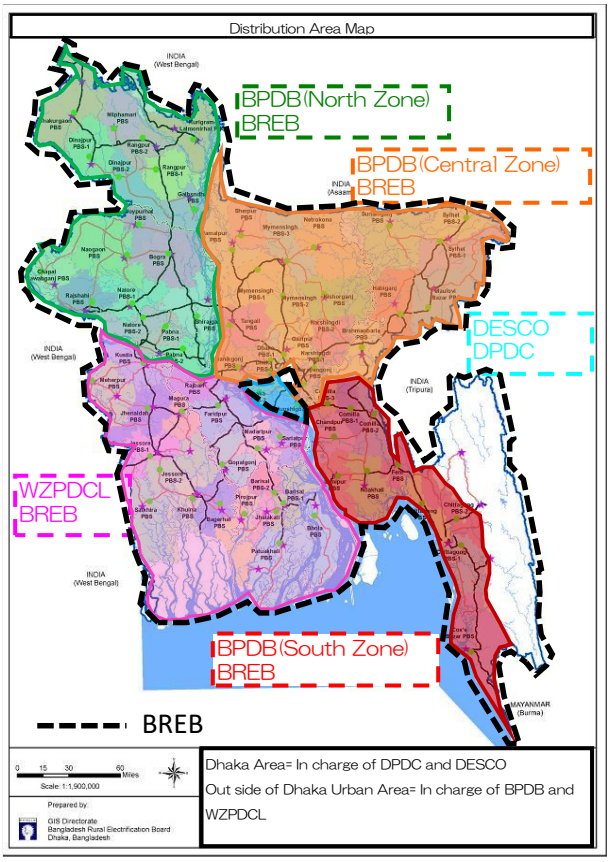
As for the power sector, the Bangladesh Power Development Board (BPDB) had once vertically integrated the power sector from generation to distribution and sales. In 1978, the Rural Electrification Administration (BREB: Bangladesh Rural Electrification Board) was established as a spin-off from the BPDB, and full-scale reform of power sector begun in the 1990s. In 1991, the Dhaka Electric Supply Authority (DESA), established as the public power distribution agency for the Dhaka area, was later spun off as an independent power distribution company, DESCO, which took over some of DESA's assets in 1996. DESCO is in charge of the northern part of Dhaka with the private capital accounting for 25% of total. When being founded, it had the Mirpur area, with demand of 90 MW and had customers of 71,161 units. Since then, it has expanded the area with demand of 1,257 MW and a service area of about 236 km ^{2}. It has 1,820 employees as of 2020. DPDC was established in 2005 as the southern Dhaka Power Distribution Company, taking over DESA's assets and liabilities. It supplies electricity to more than 1 million customers in an area of about 250 km^2 including Siddirgonj, Fatullah and Mokterpur areas in Narayangonj city as well as Dhaka city. The maximum demand is 2,409 MW as of 2021. Those two power distribution companies are responsible for the electricity supply in most of the Dhaka area.

Later, WZPDCL and NESCO were established for the western and northwestern urban areas, respectively. WZPDCL, established during the power sector restructuring in November 2002, has been in operation since 2005 and covers 21 districts in Khulna, Barisal and Greater Faridpur in western Bangladesh and 20 districts in Upzillas. The maximum demand is 995 MW in 2021. Since its separation from the Water and Power Development Department in 1972, the BPDB has been conducting power distribution business by dividing its areas into northern and central regions, and currently operates 22,031 MW (25,235 MW if off-grid is included) of power increasing from the original 500 MW. The covers the Chattogram, Myamensing, Cumilla and Sylhet areas, had sales of 12,309 MkWh in fiscal 2021.

The BREB was established in 1977 on the model of the American Rural Electrification Association and is an implementing agency for the promotion of rural electrification. As a subordinate organization, it has a PBS (Rural Electrification Association) with 80 locations throughout the country to supervise and instruct PBS. In addition to rural electrification, it also carries out economic and social revitalization in rural areas. The total number of contract units

(All sectors, including industry, operations, agriculture and households) nationwide was approximately 32 million as of November 2021.

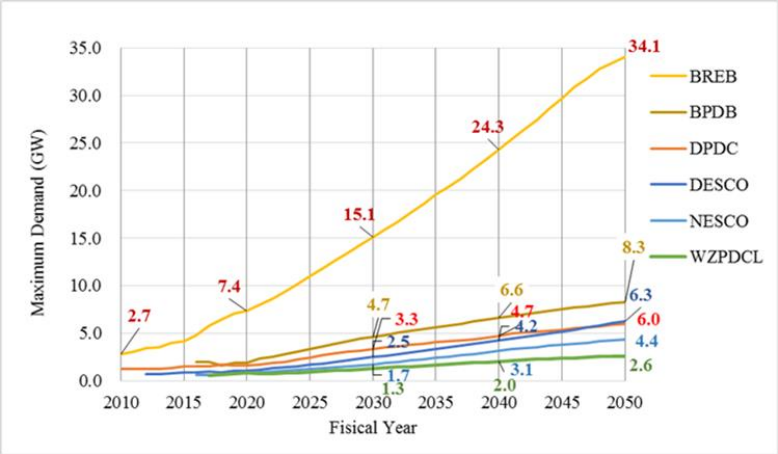
The figure below shows the service area of each distribution company.



Source: JICA Report

Figure 3.1-1 Service Area of Each Utility

3.2 Maximum Demand Trend



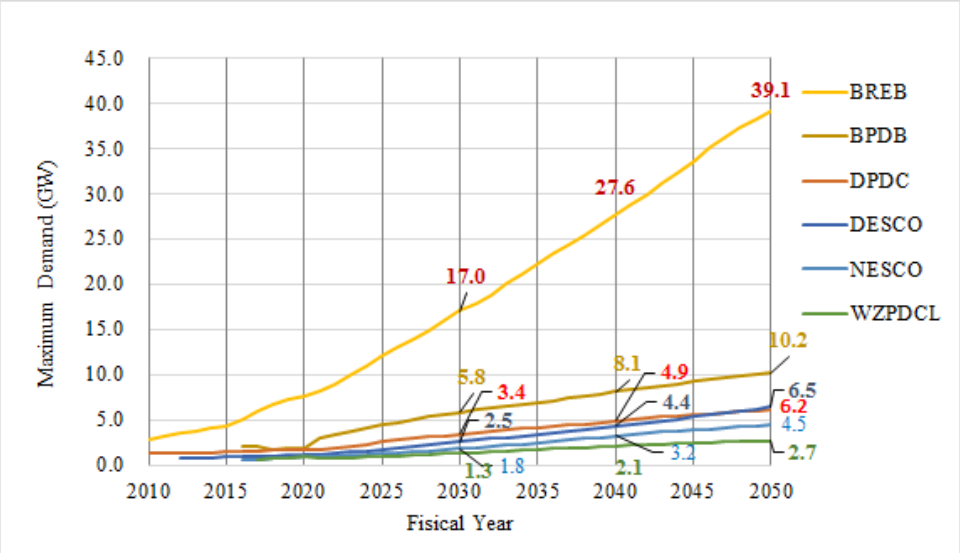
Source: Each Utility

Figure 3.2-1 Maximum Demand Outlook at 33kV Level by Distribution Company

Electricity demand is increasing at all utilities and will maintain the high growth rate. DESCO, covering the northern part of the capital city of Dhaka, has seen an annual 6% increase over the last 10 years, while DPDC is at 3%. Both DESCO and DPDC expect high demand growth of almost 10% over the next few years. Then the growth rate will gradually slow down, and the maximum demand in the DESCO area will reach 6 times the current level and in the DPDC area it will be 3.5 times by 2050. Dhaka city plans to construct 6 MRT rail lines by 2031 and electricity demand will grow accordingly.

The BREB area accounts for 80% of the country, and has seen an annual demand growth of 10% in the past 10 years. Demand growth will slow down after 2025; demand will grow 1.9 times by 2030 and 4.3 times by 2050. The BPDB area has recorded an annual 5% demand increase in recent years, and is expected to see a 10% increase in the coming years. Then, growth will slow down; demand is expected to expand 3.5 times by 2050. The NESCO area has seen a relatively high growth rate, an annual 5.9% over the last few years, and is expected to slow down and to expand 5.1 times by 2050. The WZPDCL area has seen an annual 4.4% demand growth, and this will continue for a relatively longer period, though it will gradually slow down; the demand will expand 3.6 times by 2050.

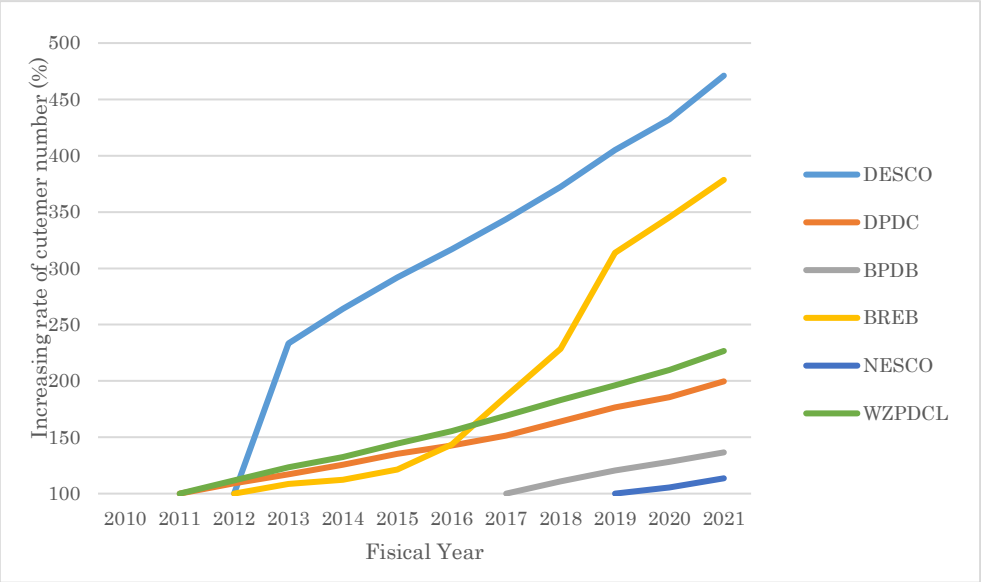
The number of customers is also increasing fast in the BREB area at an annual 10%, in the DESCO area close to 10% and in the WZPDCL area 8%. On the other hand, it is slower in the DPDC area at 7%, compared to the those in the DESCO area.



Source: Each Utility

Figure 3.2-2 Maximum Demand Outlook at 132kV Level by Distribution Company

The rates of the increasing number of customers are shown in the figure below. The number of BREB customers is growing at a high rate with an average rate of 15%, and the DESCO area is close to 10% and the WZPDCL area is about 8%. On the other hand, the rate of increase in the DPDC area is about 7%, which is somewhat lower than that in the DESCO area.



Source: Each Utility

Figure 3.2-3 Customer Growth by Company

3.3 Overview of Facilities

3.3.1 Outlook of Facility

Each utility's equipment consists mainly of 33 or 11 kV as medium-voltage lines and 230/400 V as low-voltage lines. The 33 kV lines are mainly used to supply power from the 132/33 kV substation to the 33/11 kV distribution substation or as interconnected lines between the 33/11 kV distribution substations. 11 kV is mainly used to supply electricity from the 33/11 kV distribution substation. In addition to the 33/11 kV distribution substation, they have jurisdiction over 132 kV transmission lines (underground) and a 132/33 kV substation as well. In DESCO and DPDC, which have jurisdiction over the Dhaka area, distribution lines of 11 kV or less account for 80% of the total, and the underground rate is about 40%. By voltage, the grounding rate of 33 kV medium-voltage lines is 85% while that of 11 kV medium-voltage lines is 31%, indicating that the underground of 33 kV medium-voltage lines is being actively promoted. On the other hand, in rural areas, most of the facilities are overhead except in some city areas. BREB stands out in terms of amount, with approximately 60% of total electricity sales, slightly more than 70% of installed transform capacity, and approximately 80% of customers.

As for distribution loss, those of DESCO, DPDC and BPBD which cover the urban area from 5.6% to 6.7% while the utilities in charge of the rural area, WZPDCL, NESCO and BREB are 7.9% through 10.5%. The average of length of distribution lines with 33kV and low which is relatively longer in the rural area than those in urban areas which can contribute to increase loss.

As for the amount of renewable energy sources (RES) including solar home systems (SHS) installed, rural areas appear smaller than urban areas mainly because they are scattered as small

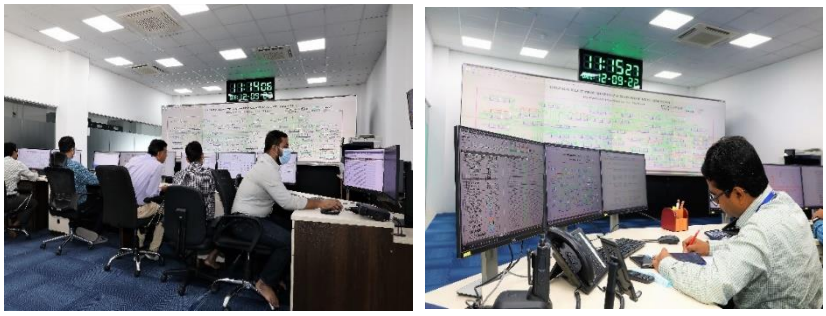
off-grids.

Table 3.3-1 Comparison of Installed Facility by Utilities (as of 2021)

Facility	Level	Type	Unit	DESCO	DPDC	WZPDCL	BREB	BPDB	NESCO
Substation	33/11kV		Nos.	53	60	72	1,160	151	69
			MVA	4,060	3,913	1,793	15,045	4,628	1,870
Feeder	33kV		Nos.		24	126	650		92
			MVA		720	3,098	16,250		2,244
		OH	km	0	161	1,433	19,013	3,605	1,114
		UG	km	615	325	6	0		0
	11kV	Total	Nos.	499	742	341	4,950		335
		OH	km	1,793	1,113	1,470	338,305	11,768	5,490
		UG	km	661	703	17	0	0	0
	11/0.4kV	OH	km	2,193	1,553	3,986	171,319		6,106
		UG	km	0	0	0	0		0
	0.4kV	OH	km	2,246	1,556	5,517	28,731	20,168	8,738
		UG	km	0	0	0	0	0	0
Distribution Transformer	11kV/LV	3P	Nos.	7,666	12,977	8,426	1,323,000	25,607	9,072
			MVA	1,556	2,558	1,537	20,700	4,857	1,706
		1P	Nos.	1,177	38	131	0	0	0
			MVA	29	1	107	0	0	0
RMU	11kV	5U	Nos.	223	137	0	0	0	0
		3U	Nos.	27		0	0	0	0
Customer	HV		Nos.	4,244	12,504	1,285	17,089		1,879
	LV		Nos.	1,054,323	1,457,058	1,349,685	31,586,598		1,687,415
SHS			Nos.	25,019	41,189	388	5,717		14,004
			MVA	25.0	16.9	2.1	0.3	27.0	0.9
Meter	Post-paid	3P	Nos.	98,853	161,017	29,048	303,616	62.65(%)	49,300
		1P	Nos.	416,300	1,325,037	952,680	30,057,916		1,314,443
	Prepaid	3P	Nos.	59,836	40,204	9,958	14,100	37.35(%)	3,597
		1P	Nos.	495,789	474,391	357,999	1,241,464		321,954
Import			MkWh	5,762	9,746	3,680	40,604	12,309	4,221
Sold			MkWh	5,440	9,094	3,391	42,377	11,489	3,779
Loss			%	5.58	6.69	7.88	9.68	6.66	10.48
Load factor			%	58	64	76	60	65	68
C/B ratio			%	104	95	101	97	102	99
CI ratio			%	98	101	93	-	95	89
SCADA			Status	Operating	Introducing	Planning	Operating	Planning	Introducing
DMS			Status	Planning	Introducing	-	Planning	Planning	Planning
GIS			Status	Introducing	Operating	Planning	Introdcing		Introducing
SmartGrid			Status	Planning	Introducing	Planning	Planning		Planning

Source: Each Utility

GIS (Geographic Information System) has been installed or is being installed by most power distribution companies, and SCADA is under operation by DESCO and being installed by DPDC and NESCO while others are planning it. While the smart grid is in the planning stage at each utility, the DPDC is currently preparing to introduce the Distribution Management System (DMS) along with the smart grid project. BPDB and DESCO are also planning to introduce it, and BREB has completed the F/S, and is considering full-scale introduction by each company. Prepaid meters are also being introduced one after another led by DESCO, followed by DPDC, WZPDCL, NESCO, BREB and BPDB.

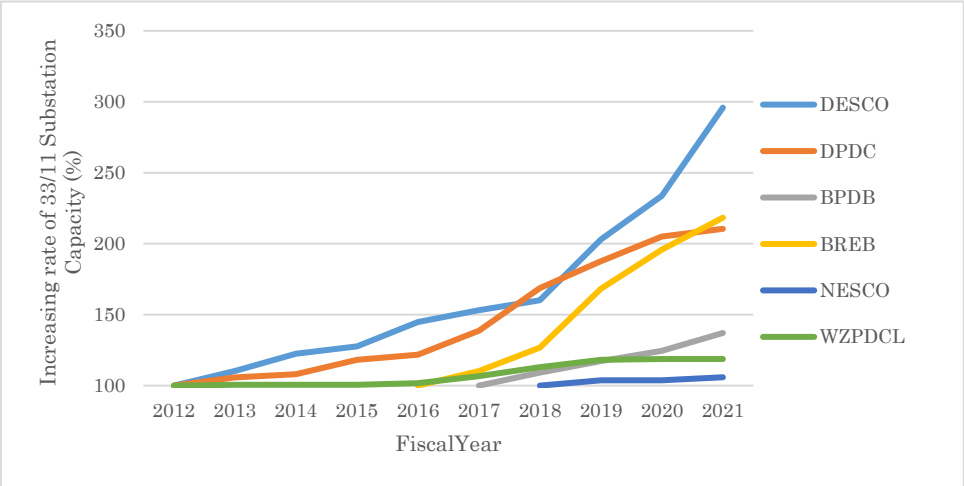


Source: DESCO

Figure 3.3-1 SCADA in Operation

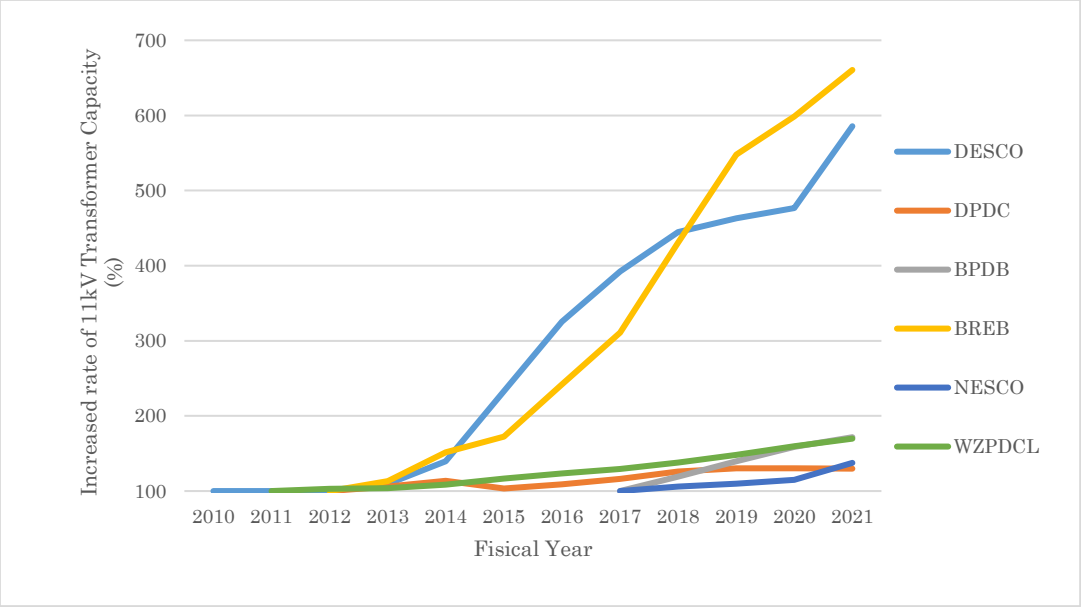
3.3.2 Increase in facilities

DESCO, DPDC and BREB have been upgrading substations and distribution lines to meet the expected demand increase, and are likely to continue. DESCO and DPDC are focusing on the enhancement of substations, while BREB is focusing on the extension of distribution lines and the increasing the amount of field equipment such as pole transformers. While DESCO has plunged into building pole transformers as well as substations, DPDC has not increased field equipment such as distribution lines and pole transformers as much as others.



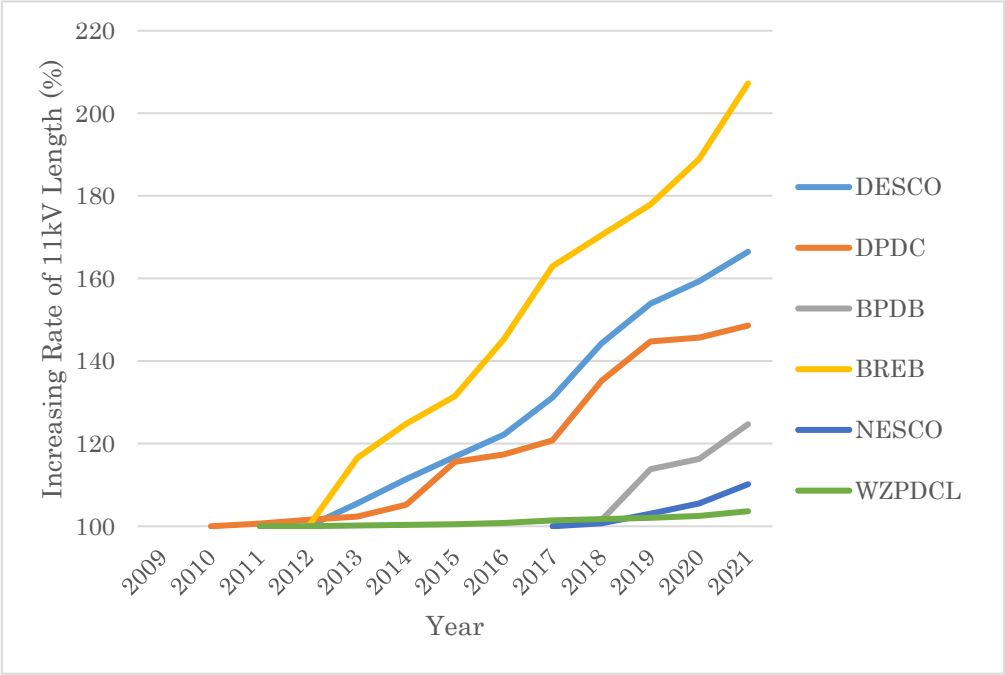
Source: Each Utility

Figure 3.3-2 33/11 kV Substation Capacity Growth Rate



Source: Each Utility

Figure 3.3-3 11 kV Transformer Capacity Increase Rate



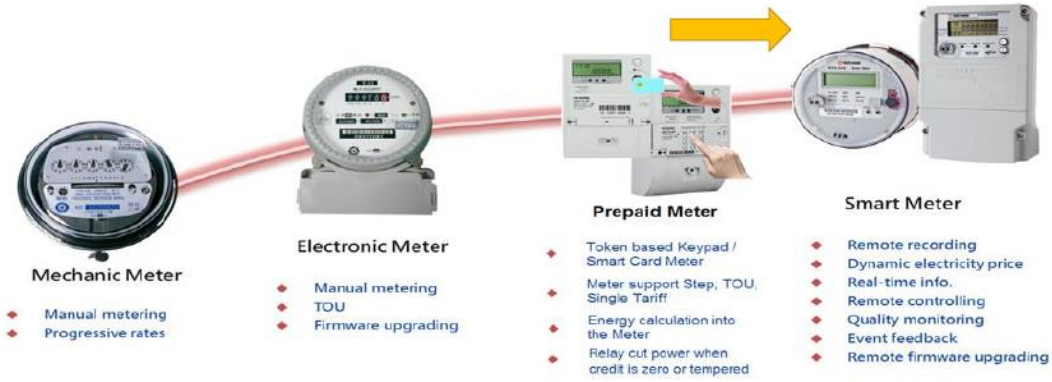
Source: Each Utility

Figure 3.3-4 Increase Rate of Extension of 11 kV Distribution Lines (underground/overhead)

3.3.3 Development of Prepaid Meters

The companies are currently working to shift from postpaid to prepaid meters not only to

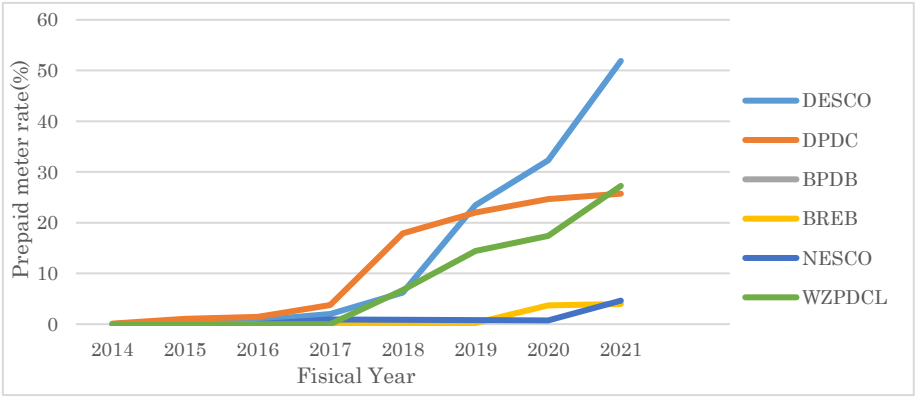
improve operational efficiency but also to increase the bill collecting rate. Once the prepaid meters are rolled out, customers will be able to pay their electricity bills from their smartphones, which leads not only to simplifying of the payments procedure but also to significantly the improve bill collection rate. DPDC and BPDB are planning the introduction of smart meters in the future. Prepaid meters being introduced equipped with various functions suitable for smart meters, such as calculating/recording electricity usage, communication with servers, relays to prevent overvoltage/overload, and functions to prevent unauthorized use, etc.) in addition to a remote payment function.



Source: DPDC

Figure 3.3-5 Meter-Specification Trends

DESCO is aggressively introducing prepaid meters. As of 2021, about half of the customers already have them, and the growing rate is about 15% a year. According DESCO, a 100% deployment rate will be completed by the end of 2023. WZPDCL is also expanding at a similar rate, and DPDC is expanding it at an average annual rate of about 10%. On the other hand, BREB are taking longer to expand with about 1%. NESCO also has a 1% increase rate, however the ongoing promotion project is expected to help improve it. BPDB was about 37% in 2021 and is expected to expand at the same rate of DPDC.



Source: Each Utility

Figure 3.3-6 Prepaid Meters Installed by Each Company

3.4 Power Distribution Enhancement and Extension Project

< Dhaka >

The table below shows a list of current and upcoming major projects.

Table 3.4-1 List of Ongoing/Upcoming Major Projects

Category	Object	Title	Organization	From	To
Demand	Substation	Adding 13 nos. new 33/11kV 3*28/35MVA SS & 4 nos. 33kV 3*28/35MVA substations with grid substations & 1 no 33.11kV 3*50 MVA substations with UGSS	DESCO	Ongoing	2025
Demand	Substation	Adding 22 nos. new 33/11kV 3*28/35 MVA substations and 4 nos. 33/11kV 3*28/35 MVA SS with new grid substations	DESCO	2026	2030
Demand	Substation	Adding 15 nos. new 3*50 MVA 33/11 kV SS and 9 nos.. new 3*50 MVA 33/11 kV SS with new grid substations	DESCO	2031	2035
Demand	Substation	Adding 18 nos. new 3*50MVA 33/11 kV SS and 13 nos. 3*50 MVA substation with new grid substations	DESCO	2036	2041
Demand	Network	Dhaka Power System Expansion and Strengthening Project	DESCO	2022	2025
Demand	Substation	Construction of New 132/33 kV and 33/11 kV Substations	DESCO	Ongoing	
Demand	Network	Expansion and Strengthening of Power System Network	DPDC	Ongoing	2024
Reliablility	Network	Construction and Augmentation of Substation, Installation of Capacitor Bank and Introduction of Smart Grid in Power System	DPDC	2023	2024
Efficiency	Control Center	Installation of SCADA system	DPDC	Ongoing	2022
Efficiency	Control Center	Master Information Centre	DESCO	Ongoing	2023
Efficiency	Meter	Implementation of AMI/MDM Platform	DESCO		
Efficiency	Meter	Installation of Eight Lakh Fifty Thousand Smart Pre-payment Meters	DPDC	Ongoing	2023
Reliablility	Underground	Construction of 132/33/11 kV Underground Grid Substation at Gulshan in Dhaka	DESCO	Ongoing	2023
Reliablility	Underground	Expansion and Strengthening of Electrical Distribution System through Underground Network in Purbachal New Town	DESCO	2023	2028
Reliablility	Underground	Expansion and Strengthening of Electrical Distribution System through Underground Network in Uttara 3rd Phase	DESCO	2024	2028
Reliablility	Network	Power Distribution System Development Project	DESCO	Ongoing	2023
Reliablility	Underground	Dhaka Underground Substation Construction project at Kawranbazar Dhaka	DPDC	Ongoing	2023

Source: Each Utility

Utilities are making efforts focusing on reinforcing the capacity of substations and distribution lines to meet the soaring demand, with many related projects. Those projects are expected to continue in the future, and operational efficiency, such as underground systems and smart grids, have been incorporated in conjunction with the substation reinforcement projects. Those projects are expected to contribute significantly to the improvement of reliability as well. In addition to the introduction of SCADA and prepaid meters, the establishment of data centers is also seen for operational efficiency as a commitment toward automation and digitization. According to the DPDC, projects are expected to be developed in the future to deal with distribution management systems (DMS) and distributed power sources.

< Outside of Dhaka >

The table below shows a list of ongoing and upcoming major projects.

Table 3.4-2 List of Ongoing/Upcoming Major Projects

Category	Object	Title	Organization	From	To
Demand	Nework	Extension & Augmentation of Power Distribution System Project	WZPDCL	Ongoing	
Demand	Nework	Distribution System Improvement Project	WZPDCL	Ongoing	2024
Demand	Nework	Distribution System Improvement Project Phaze2	WZPDCL	2026	2029
Reliability	Transformer	Installation of Transformer Manufacturing Plant and Upgradation of Zonal Repairing Shop	WZPDCL	Upcoming	
Demand	Nework	Power Distribution System Development Project, Chattogram Zone , Rangpur Zone, Sylhet Division, Rajshahi Zone, Mymensingh Zone, Cumilla Zone, Three Hilly Districts	BPDB	Ongoing	2022
Reliability	Nework	Upgradation of Distribution System	WZPDCL	Upcoming	
Eletrificatio n	Nework	Hundred Percent Reliable and Sustainable Electrification of Hatiya Island, Nijhum Island & Kutubdia Island	BPDB	Upcoming	
Reliability	Nework	Development of Power Distribution System in Three Hilly Districts, 2nd Phase	BPDB	Upcoming	
Reliability	Substation	Modernization with capacity enhancement of 230/132 kV Air Insulated Sub-station (AIS) to Gas Insulated Sub-Station (GIS) at Ghorashal Power Station Complex.	BPDB	Upcoming	
Reliability	Underground	Underground Power Distribution System Project	WZPDCL	Upcoming	
Reliability	Control Center	Modernization of Power Distribution Smart Grid Phase-I, Sub-station Rehabilitation and Implementation of Supervisory Control and Data Aquisitionacquisition (SCADA) System Project	WZPDCL	Upcoming	
Efficiency	Control Center	Assessment on System Planning, Project Design and Capacity Building	WZPDCL	Upcoming	
Efficiency	Control Center	GIS Mapping	WZPDCL	Upcoming	
Efficiency	Meter	Prepayment Meter Manufacturing Plant	WZPDCL	Upcoming	
Efficiency	Meter	Pre-payment metering project for distribution, Cumilla & Mymensingh zones.	BPDB	Ongoing	
Efficiency	Meter	Smart Pre-payment Metering Project in Distribution Zones	BPDB	Upcoming	
Efficiency	Control Center	SCADA implementation	NESCO	ongoing	2025.6
Efficiency	Control Center	GIS in 5 S&DDs in the 2nd phase,	NESCO	ongoing	2022.12
Efficiency	Control Center	SAIDI-SAIFI Automation to another 172 feeders	NESCO	Upcoming	
Efficiency	Meter	12 lac Smart prepaid meter installing	NESCO	ongoing	

Source: Each Utility

In addition to reinforcing the capacity of substation, extending distribution lines and increasing the number of pole transformers projects to meet the increasing demand are seen. The company is also working on projects to improve the operational efficiency with smart grids and prepaid meters including data monitoring, and to train human resources as well as strengthen substations and distribution systems projects for the purpose of improving reliability.

3.5 Challenges in the Networks

3.5.1 Equipment Upgrades Challenges

(1) Challenges in Substation Expansion

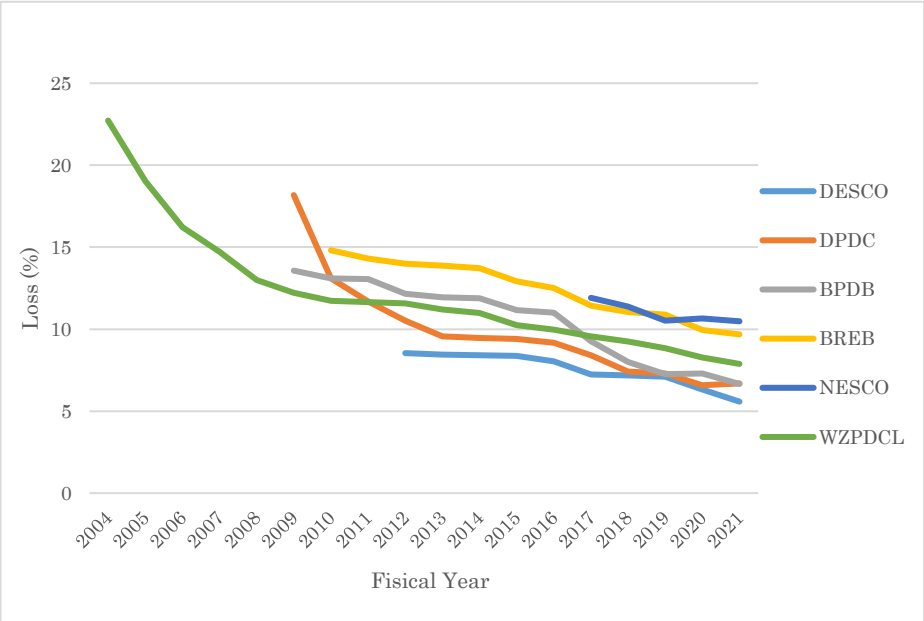
To meet the rapidly increasing demand, effective renewal or upgrade of substations and other facilities should be planned and implemented. Although each utility is currently systematically upgrading the facilities of its substations and distribution lines, effective coordination among the companies in the event of an emergency disaster has not yet been realized, and there are not yet operational coordination or coordination of plans among utilities including the transmission companies (PGCB). In order to increase capacity of facilities effectively, information exchange

among companies and adjustment of demand forecast are required.

(2) Challenges in the Underground

In urban areas, underground installation of electric wires is a major challenge. There are many narrow roads where it is hard to find enough space for underground systems, especially for ground facilities. Communication lines are installed on utility poles without permission. Since these lines need to be managed properly when underground, it is necessary to exchange information and coordinate construction among road managers, communication ministries and companies, as well as to establish methods for selecting appropriate underground areas and suitable equipment capacity, as well as applying fitting underground specifications.

3.5.2 Challenges in Distribution Loss

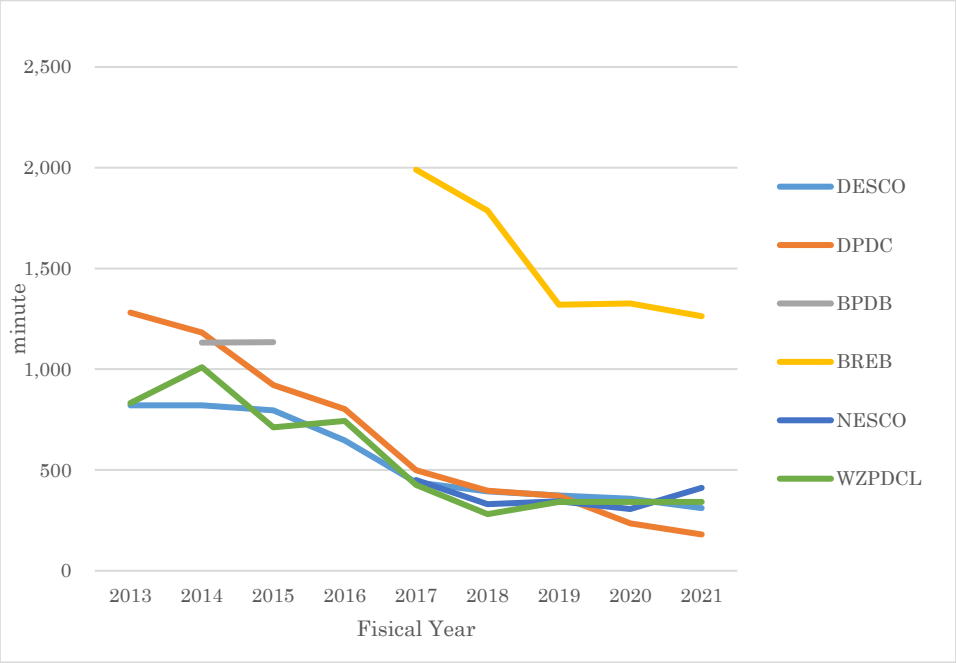


Source: Each Utility

Figure 3.5-1 Transition of Loss

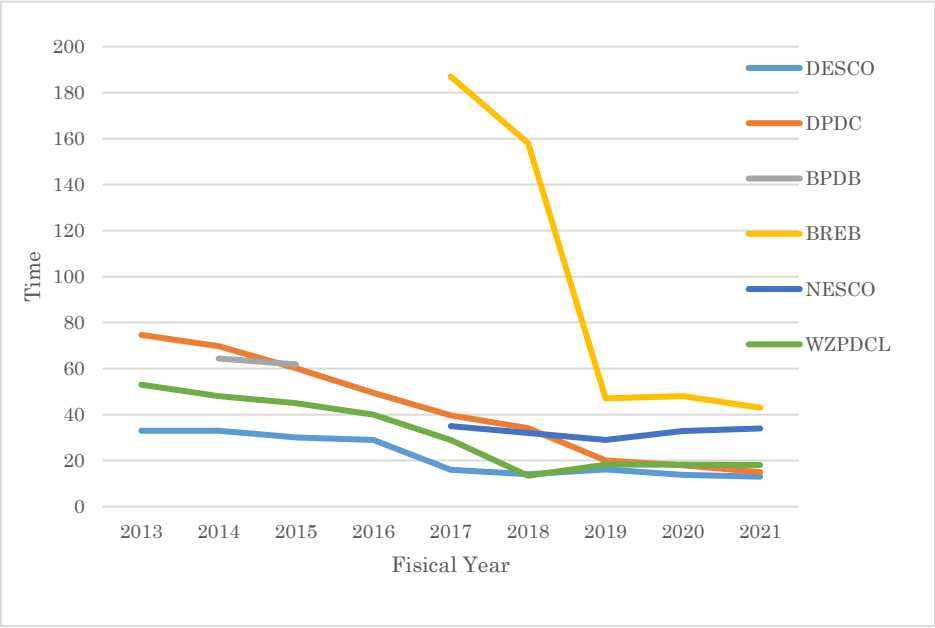
Each loss has improved year by year, with DESCO reaching 5.6%, DPDC at 6.7%, BPDB at 6.7%, BREB at 9.7%, NESCO at 10.5% and WZPDCL at 7.9% in 2021. While the loss in urban areas has been kept low, there is still room for improvement in some areas with around 10% loss. There are relatively high voltage drops caused by long-distance distribution lines (NESCO, BREB, WZPDCL, BPDB), overload transformers (WZPDCL), and aging facilities (NESCO, BPDB) as well. In order to solve these problems, countermeasures are being taken, including to divide the load, shorten line lengths (BREB), and boost system voltage (from 11 kV to 33 kV) (BPDB) in addition to updating the equipment, Since BPDB has a higher proportion of 11 kV lines than others, boosting voltage is expected to be effective. The loss reduction rate of BPDB (0.5% a year) is relatively higher than that of others (0.3% a year).

3.5.3 Challenges in Reliability



Source: Each Utility

Figure 3.5-2 Transition of SAIDI



Source: Each Utility

Figure 3.5-3 Transition of SAIFI

The figures of DESCO and DPDC, covering the Dhaka area, have been improving year by year,

with DESCO having SAIDI of about 310 minutes per year and SAIFI of about 13 times per year, DPDC about 180 minutes and about 15 times per year respectively. DESCO has collected that information automatically with SCADA, and analyzed the causes of power outages, showing that 60% of the causes are lightning. In addition, leakage accidents from customers are another factor for outages. According to interviews with DPDC, the most common causes of power outages are cable damage due to road and other construction, transformer failure or overload, and contact with wildlife. Although no special countermeasures are taken, the reliability improved as a result of expanding/reinforcing the facilities to meet the growth in demand.

On the other hand, reliability levels in some areas are low, with BPDB showing little improvement with SAIDI of about 747 minutes and SAIFI of about 47 times per year, and NESCO about 411 minutes and SAIFI of about 34 times per year. Even in such circumstances, WZPDCL has some improvement, with approximately 340 minutes and 18 SAIFI per year. The causes of power outages outside of Dhaka are aging facilities (NESCO, BPDB), natural disasters such as cyclones (NESCO, WZPDCL, BREB, BPDB), lightning strikes (NESCO, BREB), power outages due to construction (NESCO), tree contact and flying objects (NESCO, WZPDCL, BREB, BPDB). Countermeasures are being taken such as covering wires (BREB, WZPDCL, BPDB), converting GIS substations (BREB), installing loop network systems (NESCO), automating distribution system (NESCO), automatic collection of outage information (NESCO), and underground (WZPDCL, BPDB). Since most of the utilities have not collected statistical data on the cause of the accident, it seems to take time to see efficient and effective improvement.

A radial network system with no switch for a compartment in the middle of the lines leads to widespread power outages and long recovery times throughout the distribution line once a distribution line accident occurs. And the location of the accident point to the repair requires significant time and effort, which may be a factor of low reliability.

3.5.4 Challenges in improving the Efficiency of Operations

To improve operation efficiency, some projects are underway at each utility. While new systems such as SCADA, GIS, prepaid meters, and data centers are being introduced one after another, policies and guidelines need to be formulated for effective connections and utilization of such data.

3.5.5 Human resources development, Cybersecurity

(1) Human resources Development

Each utility systematically develops human resources in line with its own program based on its policy. In order to cope with the introduction of RES and new systems in the future, various training programs aiming to enhance the skill of specialization and practical ability for workers are required. It is also important to improve the training/development systems itself, training organization structure, and testing environments/facilities.

(2) Cybersecurity

Specific policies and related guidelines including human resources development have not been established for strengthening the security of the installed systems, although there is a basic policy. It has been recognized as a future issue.

3.5.6 List of issues by Dhaka/Other

The comments and ideas from interviews on the issues are shown below.

< Dhaka >

Table 3.5-1 Issues in Dhaka

	Issues and Requests
Reliability	・ Cyber Security Enhancements (DESCO) ・ Equipment specifications and technical knowledge due to frequent accidents caused by lightning and leakage of power outages from customers (DESCO) ・ Consideration for loop system, ring system and system redundancy due to radial systems (DESCO) ・ Underground distribution lines and substations (DESCO, DPDC)
Efficiency	・Exploring ways to minimize power outages during hotline work or distribution lines are down (DESCO) ・Developing master plan with SCADA projects (DESCO) ・Introduction of distribution management system (DMS) and linkage of related systems (DAS, SCADA, GIS). (DPDC) ・Development of communication system between Central Power Supply Command Station (NLDC) and substations (DPDC)
Demand	・Review Demand Forecast Methods (DESCO) ・Demand Forecast (DPDC)
Other	・Improvement of Human Resources, including training facilities and human resource development systems (DESCO, BREB) ・Formulation of policies and division of roles for jurisdiction areas (DESCO, DPDC)

The demand forecast is a challenge in urban areas, and reviews are required concerning what they are working on. While it is expected that the automated systems being introduced will make a significant contribution to improving the operational efficiency in the future as cooperation with other systems is being promoted, the utilization of such data and future system cooperation are still under consideration. In addition, advice on cyber security of those systems is also requested. Meanwhile, it is recognized that there are challenges regarding underground construction. In addition, human resource development and the role of each jurisdiction area are also mentioned.

< Outside of Dhaka >

Table 3.5-2 Issues Listed outside of Dhaka Area

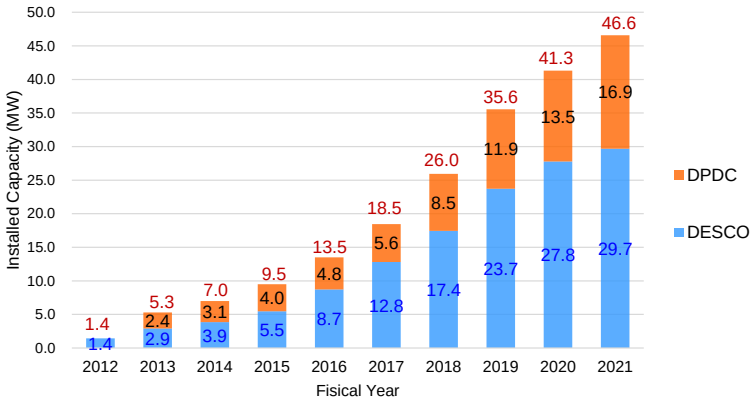
	Issues and requests
Reliability	・Improved reliabilities, including SAIDI and SAIFI (Introducing wire insulator, GIS substations, shortening of distribution line, equipment upgrades, etc.) (BREB) ・Responding to natural disasters, such as dry, flood in wet seasons (NESCO) ・SAIDI and SAIFI improvements (NESCO, WZPDCL) ・Improvement of voltage drop due to long-distance lines (BPBD, NESCO) ・Accident in distribution line due to aging equipment (NESCO) ・Loss due to overload transformer (WZPDCL)
Efficiency	・Modernization of distribution lines (Introduction of automated system (SCADA, GIS) and smart grids (smart meters)) (BREB)

Improving supply reliability is a major issue in rural areas. In particular, the improvement of SAIDI and SAIFI is a pressing issue, and the maintenance of distribution facilities and control of dropping voltage in the long lines, response to natural disasters, and dealing with aging of facilities are also listed as issues. Long-lasting power outages have occurred, due to transformer failures caused by lightning, broken lines caused by trees collapsing due to cyclones, and contact with trees and wildlife.

3.6 Current Status and Challenges of Introducing Renewable Energy Sources

3.6.1 Introduction of Renewable Energy Sources

The global trend toward a low-carbon society is driving the increased RES. In the future, it is expected that distributed solar facilities will be connected to the distribution network system in Bangladesh with high capacity over a short duration. Therefore, development of an enhancement plan that enables the efficient supply of the generated power to users while maintaining the stability and reliability of the network are essential. It is also necessary to speed up and improve the efficiency of operations simultaneously. The RES in Bangladesh mostly consists of solar facilities (rooftop solar and field) with net metering. Some of them are connected to the system, while others are independent on a small scale. In many rural areas, those are used as a power source for irrigation and other agricultural purposes. The figure below shows the amount of installed renewable energy sources in the DESCO and DPDC areas, which have jurisdiction over the capital city of Dhaka.



Source: DESCO, DPDC

Figure 3.6-1 Rooftop Solar Installations

The NESCO area has 2.72 MW with 14,004 projects in solar generation including 0.91MW off-grid and 1.81MW on-grid, and the BREB has 0.251 MW with 5, 717 projects. In addition, more 30MW solar generation is supposed to be connected to NESCO's grid in the future.

RES in Bangladesh mostly consists of solar PVs with net metering. Some are connected to the system, while others are small and independent. In many rural areas, they are used for irrigation and other agricultural purposes. To cope with increasing RES, proper enhancement plans should be developed to enable efficient supply of the generated power while maintaining stability and reliability of the network. It is also necessary to speed up and improve the efficiency of operations. Furthermore, in the future, grid connection of RESs may expand explosively with the introduction of RES support policies such as the FIT system. In order to realize the maximum grid connection of RESs, it is necessary to prepare for the preparation of grid connection conditions and the improvement of grid reliability.

3.6.2 List of issues by Dhaka/Other

The comments and ideas from interviews on issues are shown below.

Table 3.6-1 Challenges with Introduction of Renewable Energy

	Issues and requests
Dhaka	・Forecast of future renewable energy installations (DPDC) ・Impact study on distribution networks by electric vehicles (DPDC) ・How to leverage Energy Storage System (DPDC)
Other	・Responding to disruption of current by small-scale Solar Facilities (NESCO) ・Creation of guidelines for renewable energy interconnection (NESCO) ・Adverse effects of EVs and fast chargers on the network system (WZPDCL) ・Response to harmonics caused by renewable energy interconnection (WZPDCL)

According to the interviews with utilities, the issue related to introducing RES is not yet coming to light. Although net metering has advanced, especially in rural areas, it has not yet caused any major problems impacting networks since many cases are off-grid. Based on the interviews with independent power distribution companies, Infrastructure Development Company Limited, off-grid solar power generation will keep the mainstream of grids with RES, and it is expected to be deployed more in remote areas such as islands and places outside of the traditional grid expansion (accounting for about 10% of the country). Solar power generation, with its simple system configuration and easy-to-understand unit price, began to be used as a power source for irrigation systems that traditionally used diesel power. Although rooftop solar systems once became mainstream after the Maldives program, solar power for irrigation systems is mainstream again. As for capacity, solar systems tend to be in the 100 kW to 10 MW range, while irrigation solar systems are in the 10 ~ 50 kW range.

Although these systems are not expected to be on the grid for the time being, there is a possibility that they will be connected in the future. Issues including grid connection requirements for RES, capacity of grids, and trade fees can be actualized in the future.

3.7 Recommendations and Effectiveness of Distribution Plans in Dhaka area

3.7.1 Countermeasures against RES connections

To realize a low-carbon society, maximizing the amount of RES connections is needed. When the amount of RES connections increases, the power flow on the distribution networks becomes very complicated. This makes it difficult to manage the voltage and current. In Japan, there have also been widespread voltage flurries caused by the inverter aiming to prevent independent operation, which is attached to RES. Based on these cases, we recommend the following measures.

- ✓ Development of technical requirements for RES connections
- ✓ Installation of Sensors for gaining power data in medium-voltage lines
- ✓ Introduction of voltage control equipment to medium-voltage lines
- ✓ Introduction of Distribution Management System (DMS) for gaining power data
- ✓ Remaining proper voltage by optimal control of line equipment based on DMS results

3.7.2 Measures for Improving of Reliability

In the case of Japanese electric power companies, they have a history of improving the reliability of the supply by introducing insulated wires, lightning protection equipment, Distribution Automation System (DAS), preventive maintenance, and accident detection technologies. In addition, the multi-division and multi-connection (MDMC: Multi Divided and Multi Connected) distribution line system configuration, in which one distribution line is divided into several sections by a division switch and these sections are connected to other distribution lines. MDMC contributes to the improvement of supply reliability by enabling the separation of accident sections and transmitting to sound ones smoothly. Reliability improvements also allow the maximum use of RES power. Furthermore, it can be possible to quickly and automatically

separate a fault section and re-electrify sound sections by utilizing combined systems with DAS and MDMC.

- ✓ Insulated covered Wire (in progress)
- ✓ Equipped with lightning protection
- ✓ Introduction of DAS
- ✓ Introduction of MDMC configuration
- ✓ Hybrid overhead/ Underground equipment promotion
- ✓ Improvement of accident point exploration technology

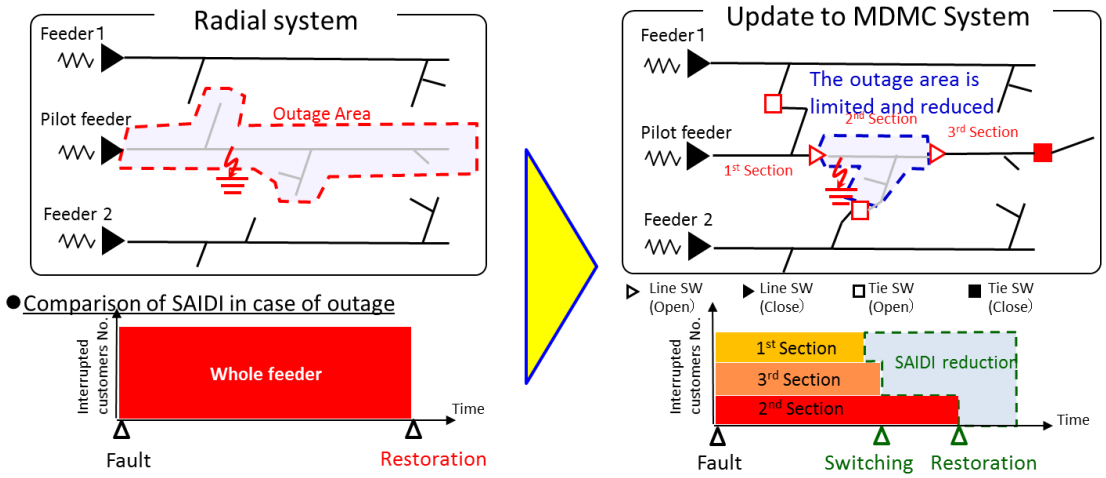


Figure 3.7-1 Concept of Reducing Outage Duration by MDMC

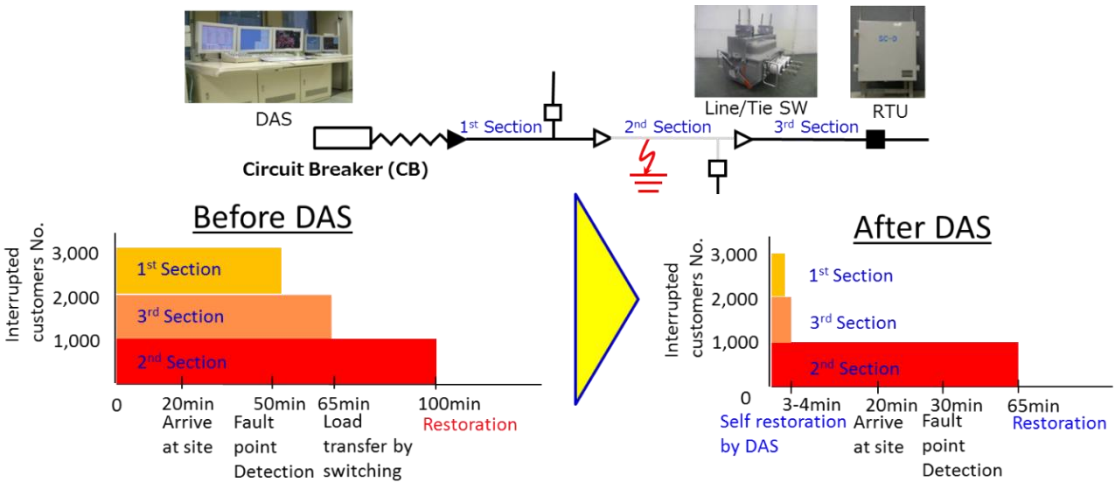


Figure 3.7-2 Concept of Reducing Outage Duration by DAS

3.7.3 Operational Efficiency Measures

Aiming at efficient operation, utilities in developed countries including Japan are working on the acquisition and analysis of data such as voltage, current and power factor. And they try to

optimize the configuration of distribution line systems to minimize loss and reducing duration of outages. The digitizing information of operation and facilities is a key to achieve the goal. Introducing high-speed communication technologies also support them. In addition, in order to further promote the hybrid overhead/ underground system, it is necessary to follow international standards along with improved technology on supporting the construction of facilities, the measurement technology specific to the system and the underground configuration itself. The following items are currently proposed as measures to improve the operational efficiency of facilities.

- ✓ Introduction of smart meters and data operation with management technology
- ✓ Improvement of communication technology
- ✓ Facility management using GIS (Geographic Information System)
- ✓ Data management integrated with DMS, DAS, SCADA and distribution simulation software
- ✓ Underground related technology (System configuration, equipment configuration, construction technology, and measurement technology)
- ✓ Ensuring cyber security at GIS, SCADA, DAS, DMS etc. systems

Table 3.7-1 Functions and Contents of DAS

DAS Functions	Required Contents
Monitoring and Controlling	Monitoring and control equipment (LBS, RMU, FPI, re-closers) Interconnections with SCADA/SAS, display line skeletons
Fault Location	Fault location with automatic separation of health section
Operation Support	Automatic creation/execution of operation procedures for switching
Planning	Demand forecast, power flow calculation, Optimization of sections
Power Quality	Harmonics analysis, voltage imbalance improvement
Loss Reduction	Reduction of Technical/Non-Technical Loss
Asset Management	Management of facility/equipment for asset management

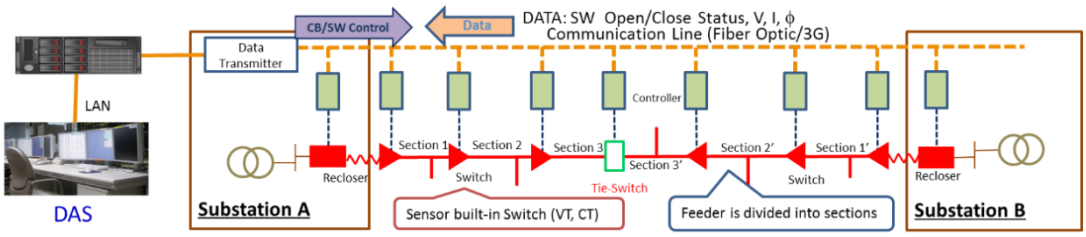
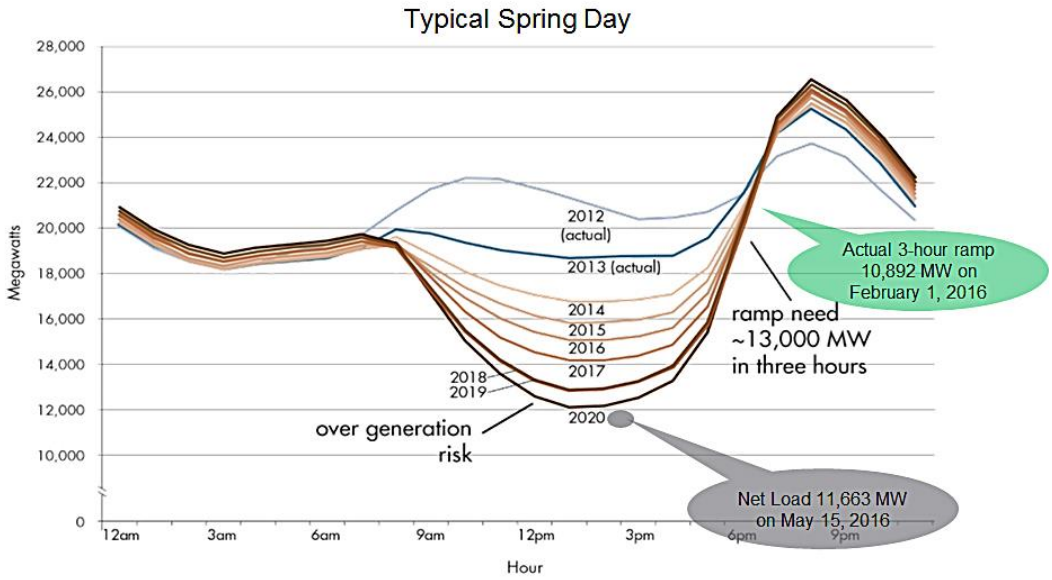


Figure 3.7-3 DAS Configuration

On the other hand, demand side management (DSM) is also an effective method for effective use of facilities. In areas where a large amount of RES, mainly PV (Photo Voltaic), is connected to the grid, it has been reported that net electricity demand, or total demand deprived from the difference between actual electricity consumption and the amount of RES output deviate largely from the expected depending on the time of day.



Source: California Independent System Operator

Figure 3.7-4 Duck Curve Created by Real Electricity Demand

When massive PV is connected to the grid, the amount of electricity consumption during the daytime is compensated by RES output, which greatly reduces net electricity demand. As PV output decreases in the evening, the total demand tends to increase sharply after sunset. This demand trend is called a duck curve as it looks like the shape of a duck. It is thought that shifting the peak demand by utilizing electricity bill systems such as Time of Use, and special equipment are effective as a countermeasure. The following items are proposed for encouraging demand shifts, pending actual implementation through future coordination.

a. Introduction of smart meters along with practical use of the obtained data with management technology
b. Improvement of communication environment
c. Introduction of a Time Of Use fee systems
d. Use of water heaters and air conditioning systems with ice storage
e. Introduction of batteries and electricity storage equipment

3.7.4 Approximate Timing of Adaptation

Although each utility has improved its reliability, SAIDI and SAIFI, attributed to its efforts, they are still at a relatively high level compared to developed countries. This is a short-term issue to be addressed. Electric wire coverage is being actively adopted in rural areas, and it is better to introduce that measure gradually in urban areas where demand is expected to become even denser in the future. In addition, it is highly probable that lightning protection equipment and accident point exploration technology will lead to further improvement of reliability. To improve operational efficiency, it is necessary to further utilize smart meters and GIS data that are being introduced.

The issued related to introduction of RES ought to be addressed from a medium- to long-term perspective, considering the current situation. It is recommended to give consideration together with distribution automation, data management, and system reconstruction as well as underground systems with narrow walkways.

(1) Short-term Measures

- ✓ Wire covering and lightning protection of equipment
- ✓ Improvement of accident point exploration technology
- ✓ Introduction of technology to operate and manage smart meters and other data

(2) Medium- and Long-term Measures

- ✓ Deploying Distribution Automation System and Data Management
- ✓ Remaining proper voltage by optimal control of site equipment based on simulation result by DMS
- ✓ Introduction of Multi-Division and Multi-Connection distribution system configuration
- ✓ Underground system and related technologies
- ✓ Development of technical requirements for RES connections
- ✓ Installation of sensors for power parameters and voltage control equipment

3.8 Recommendations for Distribution Plans Outside of Dhaka Areas

It is based on recommendations for distribution plans in Dhaka areas, and it is also needed to take mini-grids or stand-alone grid operation and how to connect to traditional grids into consideration in some areas.

3.8.1 Short-term measures

- ✓ Consideration of mini-grid or independence grid system configuration

3.8.2 Long-term measures

- ✓ Upgrading distribution systems for mini-grids or stand-alone grids
- ✓ Dealing with the challenges of connecting mini-grids/independent-grids with existing distribution network systems

3.9 Recommendations for Subsequent Projects

3.9.1 Background

The nation's demand for primary energy increased about 1.5 times in the 10 years from 2007 to 2017 (IEA 2017) in line with its robust economic growth and is expected to increase in the future, and the National Determined Contributions (NDC) formulated by the government set a target of reducing greenhouse gas emissions by 36 Mt CO2 e (more than 15% reduction)

compared to the Business As Usual (BAU) scenario. As the introduction of renewable energy sources (RES) continues to advance in line with the global trend toward low-carbon societies, it is expected that distributed solar power facilities will be connected to the country's electricity distribution system with high capacity in a short period. Therefore, while maintaining the stability and reliability of the network, it is necessary to carry out an enhancement plan that enables the efficient supply of power generated to the users, as well as to streamline and improve efficiency of operation.

3.9.2 Subsequent Projects for Dhaka area

(1) Purpose

Under the above circumstances, the project aims to support the development of a Detail Distribution Master Plan in Dhaka areas, which would focus on adaptation to a "low-carbon society" while seeking to improve "reliability" and "operational efficiency." In this project, a plan will be prepared to build a reliable electricity distribution network to meet the increase in RES installations by strengthening the operational capacity of DESCO and DPDC, which have jurisdiction over the Dhaka area of Bangladesh, in order to realize a low-carbon society.

(2) Target

Planning and operational capacity of power sector agencies will be enhanced for reliability and efficiency of operations in response to increased RES installations.

(3) Summary

(a) Development of a plan for reliability and efficiency of operations in response to the increase in RES installations

For DESCO and DPDC which cover the jurisdiction of the Dhaka area, this paper proposes a business planning policy that will contribute to rising reliability including the improvement of electricity quality in response to the increase in RES installations, as well as the method of demand side management which contributes to effective facility operation, reinforcement of medium- to long-term capacity planning, operational efficiency through systematization of distribution operations, and human resource development.

- ✓ Discussion on future business strategy
- ✓ Response to the increase in RES installations
- ✓ Improving supply reliability
- ✓ Analysis and confirmation of demand Forecast
- ✓ Enhancing the planning capacity for facilities over the medium- to long-term
- ✓ Promotion of operational efficiency through systematization of distribution operations
- ✓ Analysis of economic and finance aspect
- ✓ Proposals for human resource development
- ✓ Enhanced cybersecurity

- ✓ Establishment of a cooperative system for stakeholders

(b) Implementation and Evaluation of an Advanced Distribution System Pilot Project for Reliability Improvement

In order to cope with the complexity of voltage and current management in the distribution system due to the degradation of power quality caused by RES connections, such as voltage rise, harmonics and voltage flickers, as well as the adverse flow, it is necessary to improve the reliability of the power supply and power quality by upgrading the distribution line network and managing the voltage and current appropriately. The following are effective to upgrade the distribution line network: simulation for system operation and management of voltage level by systematization of distribution operations with acquired data from voltage/current sensors installed on distribution equipment, asset management of distribution line equipment including map information, rapid recharging to sound sections and efficient expansion of distribution network by MDMC system in case of power outage, identification of fault sections using built-in sensor switches, and a timed switch system for forward transmission that facilitates identification of accident sections in case of a line accident. The goal is for the timed switch system to be used in conjunction with the built-in sensor switch to limit the areas of recharging in the accident zone as much as possible to enhance safety.

As a specific pilot project area, some available distribution lines in Dhaka where demand is concentrated are re-configurated into the MDMS system. Built-in sensor switches as well as communication networks will be deployed, a timed switch system will be introduced, and voltage and current data will be acquired. At the same time, two systems for distribution operation will be deployed at the distribution offices that manage/control the distribution network, and the effects of improving reliability and operational efficiency through the use of these systems will be verified from technical and financial aspects. Specific implementation details are as follows:

- ✓ Selection of pilot area
- ✓ Understanding the current state of supply reliability and operational efficiency (Daily operating hours, isolation time of accident zone, etc.)
- ✓ Feasible study for the pilot project
- ✓ Installation of a distribution service system and a timed switch system in the pilot area
- ✓ Procurement and deployment of sensor equipment and communication lines
- ✓ Training on how to use the introduced equipment

Valuation of the result in the pilot area

- ✓ Proposals for deployment methods and expected effects

(c) Propose and implement further Demonstration Projects for Expand Adoption of RES

Demand-side management, which enables efficient operation of power facilities by suppressing peak demand, is considered to be an effective measure for future facility efficiency operation in

the county where introduction of RES is expected to increase in addition to the surge in electricity demand. Propose and implement demonstration projects that will contribute to the efficient operation of power facilities, with an eye to future demand and RES adoption trends. The specific implementation time, necessary equipment, costs, etc. will be discussed and decided in this project after a feasible study.

(4) Implementation schedule

Table 3.9-1 Draft Implementation Schedule

	1Y				2Y				3Y			
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Formulation of master plan												
Proposal of Distribution Automation System												
Ascertaining the current situation and sorting out issues												
Formulation of a basic plan												
Implementation of pilot project												
Selection of substations and distribution lines												
Feasible study												
Procurement and installation of equipment												
Training on how to use it												
Valuation of effects												
Proposals for further deployment												
DSM demonstration project												
Ascertaining the current situation and sorting out issues												
Formulation of a basic plan												
Feasible study												
Implementation of demonstration projects												

(5) Required inputs (not including DSM demonstration projects)

(a) Expert Dispatch: 70 MM

- ✓ Development of a distribution master plan: 50 MM
- ✓ Automation Systems Project: 15 MM
- ✓ DSM demonstration project proposal: 5MM

(b) Equipment:

- ✓ A complete set of Distribution Automation Systems (Monitoring control terminal, monitoring/control server, external storage device, information transmission device,

printer, etc.)

- ✓ A complete set of Distribution Management System (Power system simulation software, data management server, etc.)
- ✓ Site equipment set (Sensor switches, remote controllers, communicator parent and child stations, etc.)

(c) Training in Japan:

- ✓ About 10 persons, 1 week

3.9.3 Subsequent projects for Outside of Dhaka areas

(1) Purpose

The project aims to support the development of a Detail Distribution Master Plan outside of Dhaka areas that sought to improve the reliability and operational efficiency of power distribution facilities while focusing on compliance with a "low-carbon society." This paper suggests creating a Master Plan for outside of Dhaka, likewise the DDMP (Detail Distribution Master Plan for Dhaka). It is for building up a reliable distribution network that can handle the increase in RES connection through strengthening planning and operation capacity of utilities, which cover the jurisdiction outside of Dhaka where there are unique mini-grids or independent grids in rural areas.

(2) Target

Planning and operational capacity of power sector agencies will be enhanced for reliability and efficiency of operations in response to increased RES installations. In addition, the method of distribution facility operation in a mini-grid or independent grid and connecting these with the traditional distribution system are proposed.

(3) Summary

(a) Development of a plan for reliability and efficiency of operations in response to the increase in RES installations and suggestion the distribution facility operation method in a mini-grid or independent grid connecting these with the traditional distribution system

For electricity distribution companies with jurisdiction outside the center of Dhaka city, this paper proposes a draft business planning policy that will contribute to rising reliability including the improvement of electricity quality in response to the increase in RES installations, as well as the reinforcement of medium- to long-term capacity planning, operational efficiency through systematization of distribution operations, and human resource development.

- ✓ Discussion on future business strategy
- ✓ Response to the increase in RES installations
- ✓ Improving supply reliability
- ✓ Operation of mini-grid or independent-grid

- ✓ Suggestion on methods for connecting mini-grid or independent-grid with main distribution network
- ✓ Enhancing the planning capacity for facilities over the medium- to long-term
- ✓ Promotion of operational efficiency through systematization of distribution operations
- ✓ Proposals for human resource development
- ✓ Enhanced cybersecurity
- ✓ Establishment of a cooperative system for stakeholders
- ✓ Economic and financial analysis

(b) Proposal and implementation of further demonstration projects that contribute to the expansion of RES introduction

Propose and implement a demonstration project that contributes to efficient operation based on demand and RES introduction in the future. After conducting a feasibility study, the detail plan for implementation, such as specific period, required equipment, and costs will be discussed and decided by the project implementer.

(4) Required Input

- ✓ Expert Dispatch: 50 MM (Development of Distribution Master Plan)

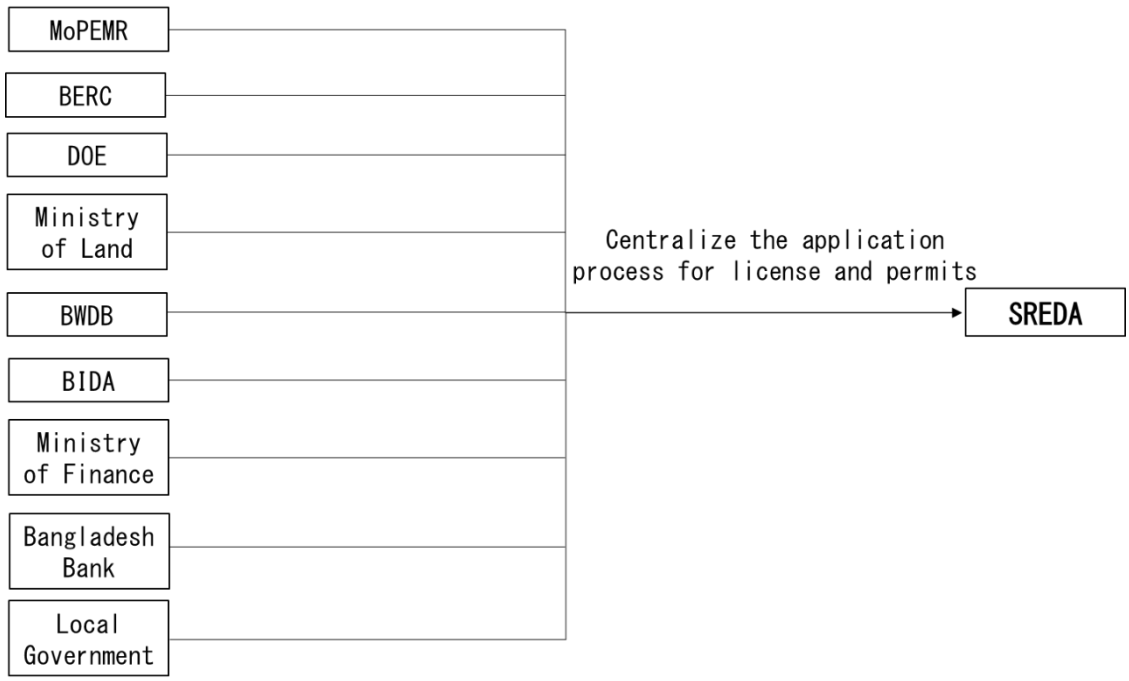
4. Promotion policy of renewable power generation

4.1 Policies

1) Permissions and bidding procedures

f. Simplification of permissions and centralization of focal point

The procurement of renewable electricity in Bangladesh is done through competitive bidding by the BPDB. Companies selected in the bidding process need to obtain more than 30 permits and licenses from various competent authorities before signing a contract, which is a cumbersome, complex, and time-consuming procedure for companies, especially foreign companies that do not have a strong presence in Bangladesh. In light of the above, the government of Bangladesh should consider whether all these permits and licenses are necessary, and omit those that can be omitted, or combine multiple permits and licenses to simplify the process. In addition, the fact that applications for permits and licenses are scattered among many ministries and agencies is a major obstacle for businesses entering the renewable energy market in Bangladesh. Therefore, centralizing the application process for licenses and permits in SREDA would greatly reduce the burden on businesses.



Source: Prepared by IEEJ

Figure 4.1-1 Centralization of Application Process for Licenses and Permits in SREDA

g. Facilitate transfer of authority to SREDA

In many foreign countries where the introduction of renewable power generation is progressing, the government ministries responsible for renewable energy serve as the contact point for competitive bidding for power procurement and manage a series of bidding processes. In the case of competitive bidding for the procurement of renewable electricity based on the Integrated Energy and Power Master Plan approved by the Cabinet of Ministers, it is not always necessary for the BPDB to be responsible for managing the bidding process. In order to make a strong impression of the commitment of the government of Bangladesh to the development of renewable energy, it would be desirable for SREDA to manage the bidding process as the responsible entity. For this purpose, it is necessary to boldly transfer the authority from BPDB to SREDA.

h. Expand SREDA's workforce and implement capacity building

Closely related to the transfer of authority mentioned above, it is essential to expand SREDA's workforce in order to strongly promote measures to promote the introduction of each renewable energy technology as described in 6.5.1 (2) and later. In addition, capacity building such as training programs for SREDA staff, including those who have been newly recruited, should be properly implemented.

2) Solar PV

a. Solar Park

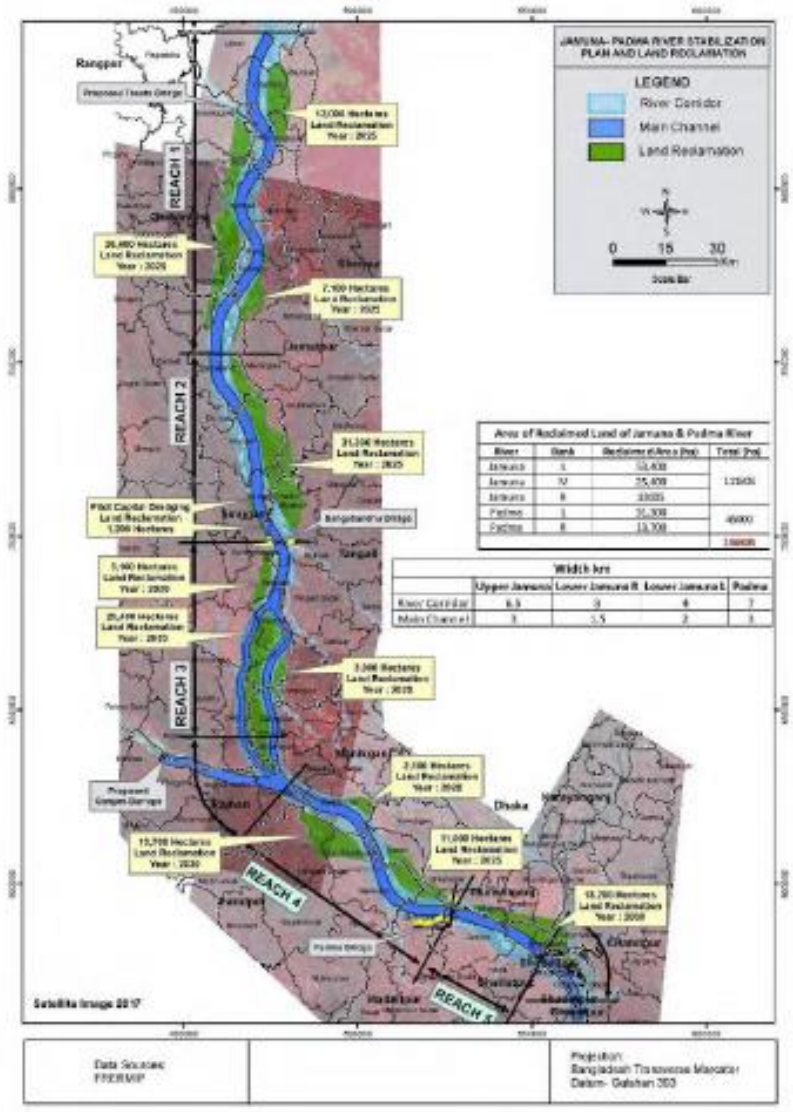
In order to expand the use of solar PV in Bangladesh, it is necessary to promote the introduction of solar parks as aggressively as possible. In order to promote the introduction of solar parks, the following measures are considered important.

b. Identifying suitable locations for Solar Parks

As repeatedly mentioned, the biggest impediment to promoting the introduction of Solar Parks in Bangladesh is land constraints. The country's limited land area and extremely high population density naturally limit the suitable sites for solar parks. In addition, the conversion of agricultural land into solar parks is strictly restricted in order to maintain and expand food self-sufficiency. It is necessary for SREDA to identify suitable locations for Solar Parks and disclose them to developers.

c. Government-led expansion of land suitable for Solar Parks

In parallel, based on the potential assessment in the [DRAFT] National Solar Energy Roadmap, 2021-41, SREDA needs to work with the Ministry of Land to expand the area of land suitable for the introduction of Solar Parks by reclaiming riverbanks and reclaiming land unsuitable for cultivation in coastal areas.



Source: [DRAFT] National Solar Energy Roadmap, 2021-41, Figure 7.2 (p.98)

Figure 4.1-2 Example of Government-led Reclamation Plan of Riverbanks

i. Figure 4.1-2 Example of government-led reclamation plan of riverbanks (Stabilization Plan for Jamuna-Padma and potential locations for reclamation)

j. Conducting Site Specific Survey for suitable locations for Solar Parks

In order to provide raw data to the operators in competitive bidding and to respond appropriately to questions and answers from the operators regarding technical and physical conditions, a systematic and speedy implementation of the Site-Specific Survey for the identified suitable locations for Solar Parks is required.

k. Increase in the number of competitive bids through the BPDB's land provision scheme

Considering the particularities of Bangladesh, even if the measures to promote the introduction of renewable energy are introduced, the issue of land constraint will not be completely eliminated. In view of that, the availability of land is an obstacle to the participation of developers in competitive bidding and to the successful completion and start of operation of projects as planned, it is necessary to increase the number of competitive bids for the procurement of renewable electricity under the scheme in which the BPDB provides land.

3) Rooftop PV

Considering the land constraints and extremely high population density in Bangladesh, the introduction of large-scale solar parks in Bangladesh will be limited. Therefore, for Bangladesh, which aims to improve energy security and make a smooth transition to a clean energy society, expanding the introduction of Rooftop PV is one of the most important and high-priority initiatives in the PV sector in Bangladesh. In view of the above, it is recommended that the following measures to promote the introduction of Rooftop PV be considered.

a. Public Sector: Mandatory introduction of Rooftop PV

As mentioned in 2.3.4 (2), in September 2019, the Government of Bangladesh requested all governmental agencies to install Rooftop PV as per NEM Guideline 2018 which came into effect in 2018. This is expected to result in the installation of 300 MW of Rooftop PV in four years. It is hoped that Rooftop PV will be made mandatory for public sector buildings to ensure widespread adoption.

b. Industrial and Commercial Sector: Introduction of measures to increase adoption in the RMG sector

In order to expand the use of Rooftop PV, it is essential to expand efforts in the industrial and commercial sectors. In particular, the Ready Made Garment (RMG) industry, which accounts for about 90% of the country's total exports, is already part of the international supply chain and is subject to stringent GHG emission reduction requirements from European customers etc. As the RMG industry's efforts to decarbonize will contribute significantly to the reduction of GHG emissions in Bangladesh, it is hoped that the NEM Guideline 2018 will be revised to increase the amount of installed capacity that can be connected to the grid (currently a maximum of 3 MW) and the amount of available electricity load (currently a maximum of 70%).

c. Residential Sector: Introduction of incentive system

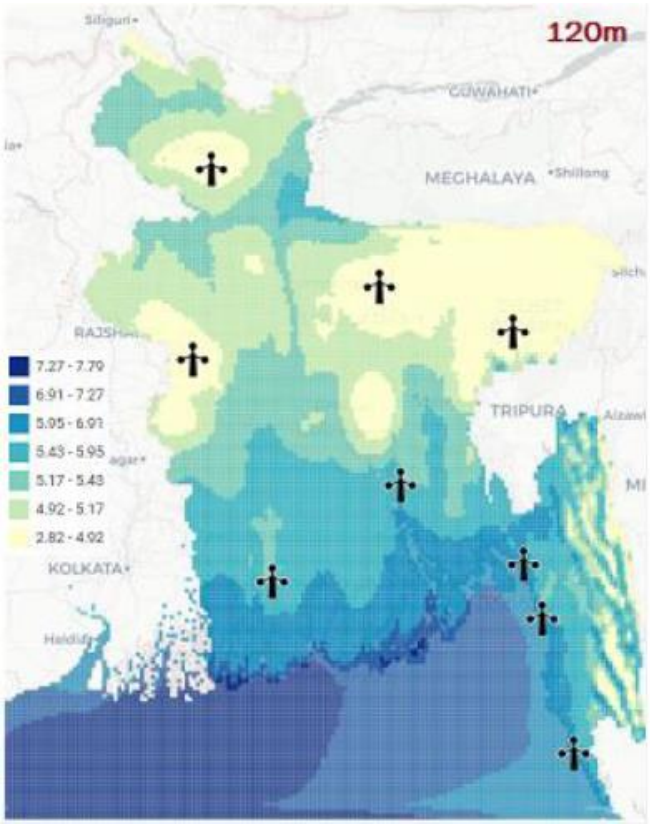
In order to further expand the use of Rooftop PV, it is also important to introduce additional promotion measures in the consumer sector, given its broad base. As described in Section 2.3.4 (2), the initial cost of Rooftop PV is still considered to be a significant investment burden for most households, even though the sale of surplus electricity by NEM can generate

revenue. Therefore, in addition to the application of the NEM, additional attractive incentives such as the Investment Tax Credit (30% in the first year, gradually reduced and eventually eliminated) should be introduced. In the DRAFT National Solar Energy Roadmap, 2021-41, the cumulative installed capacity of Rooftop PV throughout Bangladesh by 2041 is targeted at 6 GW in the Medium case and 12 GW in the High case. Although these targets are based on theoretical potentials, it should be noted that most of the houses in Bangladesh are of simple construction, which makes it difficult to install widely used PV panels, and these houses need to be equipped with lightweight and thin models or special PV panels that can be attached to the wall. Therefore, it is necessary to consider the introduction of investment tax credit with higher tax deduction rate or direct subsidy to promote the installation of such equipment. Therefore, it is necessary to consider the introduction of an investment tax credit with a higher tax deduction rate and direct subsidy to promote the installation of such equipment.

4) Wind

The implementation of wind power in Bangladesh has not always been smooth. However, as described in section 2.3.4 (3), SREDA has accurately identified the issues through analysis of the causes and is steadily implementing the measures. Specifically, SREDA is preparing raw data by sequentially conducting site specific surveys of candidate sites with high wind resource potential, and is conducting competitive bidding after establishing a system that can respond to questions and answers. Thus, it is judged that additional measures to promote the introduction of wind power are not particularly necessary as the initiatives are making slow but steady progress. However, in order to ensure the introduction of wind power as required in the ATS scenario, it is desirable to increase the number of specialized wind power personnel in SREDA and to carry out capacity building to acquire the required skills, as well as to increase the number of areas covered in the Site Specific Survey and to increase the number of areas covered by the Site Specific Survey and the speed of its implementation.

As for offshore wind power, SREDA has already started a feasibility study and is considering future implementation. However, a comparison of the wind conditions off the coast of Bangladesh with those of developed countries shows that Bangladesh's wind resource potential is limited, as the UK, for example, has a very favorable wind speed of 9-10m/s (at 100m height), while Bangladesh has a wind speed of about 5.95～6.91m/s (at 120m height). [In order to realize the ATS scenario, further technological innovation and price reduction are expected in the medium to long term, such as the development of wind turbines that can operate stably even at wind speeds of 3.0 m/s and can cope with cyclones. On the other hand, in order to introduce offshore wind power within the next 10 years, in addition to the implementation of SREDA-led oceanographic surveys and the provision of leasing schemes, measures to promote the introduction of offshore wind power, such as production tax credits (which can be reduced or exempted depending on the number of years), will be necessary to mitigate the risks for business operators.]



Source: [DRAFT] National Solar Energy Roadmap, 2021-41, Figure 1.6 (p.20) (Original source: RE Data Explorer, NREL, USAID)

Figure 4.1-3 Wind Speed Distribution over Bangladesh at 120m off the coast of Bangladesh

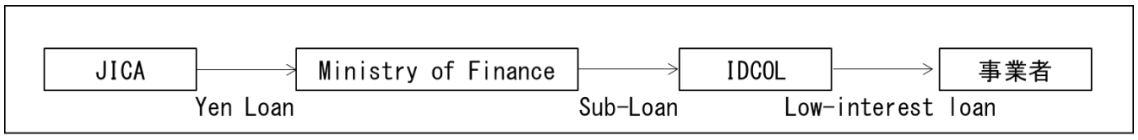
5) Waste to Power

Waste to Power is useful from the perspective of 3R (Reduce, Reuse, Recycle). 42.5 MW of Waste to Power was installed in Gabtali, northwest of Dhaka in 2021 through competitive bidding. In the future, it is expected to expand the introduction of several MW class in rural areas, in addition to the introduction of power plants of the same scale in metropolitan areas such as Chattogram. The introduction of incentive programs such as the Production Tax Credit should be considered, as it is expected to be difficult to ensure the profitability of small-scale Waste to Power projects.

6) Improving the fund-raising environment

It has been pointed out that there are still limited financing options available in the renewable energy sector in Bangladesh. Low-interest loans have been provided through IDCOL for the installation of renewable energy facilities such as solar PV and biomass power generation in rural areas, but financing options for Solar Park and wind power projects in the private sector are limited. Therefore, the provision of yen loans from JICA to the Ministry of Finance of Bangladesh, the provision of two-step loans through sub-loans from the Ministry of Finance to IDCOL, and the scheme of low-interest loans from IDCOL to project developers are considered to be effective

in further promoting the introduction of renewable energy. In addition, since the renewable energy market in Bangladesh is still immature and the use of loans by private financial institutions is still limited, it is desirable to consider introducing a capacity building program for private financial institutions.



Source: Prepared by IEEJ

Figure 4.1-4 Two-step Loans Scheme for Renewable Power Generation Projects promoted by Private Companies

4.2 Renewable Energy Generation Introduction Plan

The development plans for renewable energy-derived power sources are discussed in this section.

4.2.1 Renewable Energy Generation Introduction Plan

In Bangladesh introduction of the renewable energy power generation is presently planned as shown in Table 4.2-1.

Table 4.2-1 Introduction of Renewable Power Generation

Item (Unit: MW)	Availability	Advanced Technology Scenario		
		2030	2041	2050
Solar PV	-	5,061	9,500	18,000
→Solar-park solar PV	20%	3,061	3,500	6,000
→Rooftop solar PV	18%	2,000	6,000	12,000
Wind Power	-	750	7,575	20,000
→On-shore wind	25%	750	1,575	5,000
→Off-shore wind	30%	0	6,000	15,000
Traditional biomass	80%	10	15	20
Modern biomass (Waste to Energy)	80%	93.5	150	230
Hydropower	-	230	230	230

Source: JICA Study Team

Reviewing the above plan, there still remain various issues to be addressed before materializing the introduction of these renewable power sources. In-depth study is necessary on each renewable energy source to finalize the practicable introduction plan.

In the above plan, the amount of renewable power generation is set to achieve the target that

the amount of power generation by clean energy sources will exceed 40% in 2041. This target is larger than that projected in the Revising PSMP 2016 in line with the global trend of expanding renewable energy utilization.

Table 4.2-2 Addition of Renewable Energy Generation by Energy Source (2017 to 2041)

Year	Solar (MW)	Wind (MW)	Biomass (MW)	Total (MW)
2017				**0**
2018	427	60		**487**
2019	1080	100	1	**1181**
2020	315			**315**
2021	100	150		**250**
2022	300			**300**
2023				**0**
2024				**0**
2025				**0**
2026				**0**
2027		50		**50**
2028				**0**
2029				**0**
2030				**0**
2031	100			**100**
2032				**0**
2033				**0**
2034				**0**
2035		150		**150**
Total	**2322**	**510**	**1**	**2833**

Source: Revisiting PSMP 2016

4.2.2 Solar PV generation

Solar power generation considered for installation in this plan is classified into a) large-scale solar power plants such as solar park and b) roof-mounted photovoltaic power generation. Introduction plans of them are explained below. Also solar power generation is used for irrigation pumps widely in Bangladesh, which should be considered in due course but not elaborated in this report.

(1) Solar Park

With regard to the trend of solar park construction, 229 MW of solar power plants were in operation in August 2022, while the total Committed Plant was 1,147 MW and the total Planned Plant 1,685 MW to be installed by 2030. Even the plan up to 2030 exceeds the target set by the Revisiting PSMP2016 reflecting the recent tendency to increase introduction of the renewable energy sources.

Though renewable energy development is progressing in Bangladesh, there are no reports

on potential surveys and development plans on them. In-depth study is necessary on top of this IEPMP study to address utilization of the solar park system appropriately.

In this Master Plan, the generation capacity of solar parks to be installed by 2030 was set based on the materials received from the BPDB system planning. According to BPDB, it is also planned to introduce 6,000 MW by 2050.

The Study Team discussed the introduction plans for 2041 and 2050 and found that the planned capacity for introduction is feasible.

(a) Concept on introduction capacity of Solar Park

In this study, introduction capacity of the solar park is determined considering the following characteristics of Bangladesh.

- Land is scarce in Bangladesh.
- Particularly on the agricultural land, it is not possible to install solar PV generation.
- Due to the geographical feature, vast areas of the country are prone to flood damage such as cyclone and storm surge.
- In consideration of construction of the transmission lines, it is desirable to introduce the solar parks as closer to the demand center as possible.

In order to clear these conditions, candidate sites were selected to consider introduction of solar parks with reference to the Bangladesh Delta Plan 2100. It describes mitigation measures against floods and candidates for land reclamation. The areas listed as candidate for reclamation are shown in the Figure 4.2-1, in addition to the existing and planned plots. The Study Team has examined possibilities of installing solar power generation plants in these reclaimed lands where countermeasures against flood are taken, and selected the areas near Dhaka where it is not necessary to construct the additional power transmission lines crossing the big river.

Table 4.2 3 Existing Solar Power Plants

Name of Existing Power Plant	Installed Capacity (MW)
CHATTOGRAM Kaptai 7 MW Solar PP	7
CHATTOGRAM Teknaf 20MW PP (Solartech)	20
DHAKA Manikganj 35MW (Spectra Solar Plant Ltd.)	35
MYMENSING Sarishabari(Sharishabari) 3 MW Solar Plant	3
MYMENSING Sutiakhali 50 MW Solar PP (HDFC Sin Power Ltd.)	50
RAJSHAHI Sirajgonj 6.55 MW Solar	6
RANGPUR Mazipara, Tatulia 8 MW Solar PP (Symba)	8
Other Commissioned Plant 100MW Solar Park	100
Total	229

Source: BPDB

Table 4.2 4 Committed Solar Power Plants

Name of the Power Plant	Capacity (MW)	Fuel	Sector	Ownership	Expected COD
Barishal 1 MW Solar Power Plant	1	Solar	Public	BPDB	Dec, 2022
Lalmonirhat 30 MW Solar Park	30	Solar	Private	IPP	Aug, 2022
Patgram, Lalmonirhat 5 MW Solar Power Plant	5	Solar	Private	IPP	Dec, 2022
Gowainghat, Sylhet 5 MW Solar Power Plant	5	Solar	Private	IPP	Dec, 2022
Dhormopasha, Sunamganj 32 MW Solar Power Plant	32	Solar	Private	IPP	Dec, 2022
Jamalpur 852 kW Rooftop Solar Project on 22 Gov. Buildings in Jamalpur district (8237.35 square meter area)	0.852	Solar	Private	IPP	Dec, 2022
Sonagazi 50 MW Solar Power Plant Project	50	Solar	Public	EGCB	Dec, 2023
Sagarkandi, Sujanagar, Pabna grid-tied 64 MW Solar PV Power Plant	64.55	Solar	JV	BCRECL (NWPGCL)	Dec, 2023
Soydabad, Sirajganj Sadar, Sirajganj 68 MW Solar Park	68	Solar	JV	BCRECL (NWPGCL)	Dec, 2023
Sundarganj, Gaibandha 200 MW Solar Park (Teesta Solar Limited)	200	Solar	Private	IPP	Mar, 2023
Tetulia, Panchagarh 30 MW Solar Park	30	Solar	Private	IPP	Jun, 2023
Pabna 100 MW Solar Power Plant [Shapoorji Pallonji]	100	Solar	Private	IPP	Jun, 2023
Bera, Pabna 3.77 MW Solar Power Plant	3.77	Solar	Private	IPP	Jun, 2023
Chandpur Sadar 7 MW Solar Power Plant	7	Solar	Private	IPP	Dec, 2023
Dimla, Nilfamari 50 MW Solar Power Plant	50	Solar	Private	IPP	Dec, 2023
Debiganj, Panchagarh 20 MW Solar Park	20	Solar	Private	IPP	Dec, 2023
Madarganj 100 MW Solar Power Plant at Kaijer Char, Madarganj, Jamalpur	100	Solar	JV	B-R Powergen Ltd. JV	Jun, 2024
Moulovibazar, Sylhet 10 MW Solar Power Plant	10	Solar	Private	IPP	Jun, 2024
Panchagarh 50 MW Solar Park	50	Solar	Private	IPP	Jun, 2024
Baraiyarhat, Chattogram 50 MW Solar Power Plant	50	Solar	Private	IPP	Jun, 2024
Krishnopur, Jibonnogor, Chuadanga 50 MW Solar Power Plant	50	Solar	Private	IPP	Jun, 2024
Terokhada, Khulna 50 MW (AC) grid-tied Solar PV Power Plant	50	Solar	Private	IPP	Jun, 2024
Netrokona 50 MW Solar Power Plant	50	Solar	Private	IPP	Jun, 2024
Ishwardi, Pabna 70 MW Solar PP	70	Solar	Private	IPP	Dec, 2024
Muktagachha, Mymensingh 50 MW PP	50	Solar	Private	IPP	Dec, 2024
TOTAL Committed	**1,147**				

Source: BPDB

Table 4.2 5 Planned Solar Power Plant

Name of the Power Plant	Capacity (MW)	Fuel	Sector	Ownership	Expected COD
Sonagazi, Feni 100 MW Solar Power Plant Project-2	100	Solar	Public	EGCB	Jun, 2024
Construction of Madarganj 100 MW Solar Power Pant at Sheikh Hasina Solar Park, Jamalpur	100	Solar	Public	RPCL	Aug, 2024
Gazaria 50 MW Solar Power Plant Project	50	Solar	Public	RPCL	Dec, 2024
Panchagarh 30 MW Solar Power Plant	30	Solar	Public	RPCL	Dec, 2024
Sonagazi, Feni 100 MW Solar Power Plant Project-1 (JV of EGCB)	100	Solar	Public	EGCB	Dec, 2024
Potuakhali 200 MW Solar PV Power Plant	200	Solar	Public	APSCL	Dec, 2025
Sonagazi, Feni 82.50 MW Solar Park	82.5	Solar	Public	BPDB	Jun, 2026
Gangachara, Rangpur 68.60 MW Solar Park	68.6	Solar	Public	BPDB	Jun, 2026
Rampal 260 MW Solar PP, BPDB	260	Solar	Public	BPDB	Jun, 2026
Barishal 2 MW solar project (Phase-1)	2	Solar	Public	BPDB	Dec, 2027
Raypura, Narsingdi 120 MW Solar PV Power Plant	120	Solar	Public	APSCL	Dec, 2027
Barishal 2 MW solar project (Phase-2)	2	Solar	Public	BPDB	Dec, 2028
Matarbari 50 MW solar project	50	Solar	Public	CPGCBL	Dec, 2028
Sonagazi, Feni 100 MW Solar Power Plant Project-3	100	Solar	Public	EGCB	Jun, 2029
Maheshkhali 160-250 MW Solar PP, BPDB	160	Solar	Public	BPDB	Dec, 2029
Bay of Bengal Power Company Ltd (BBPCL), 160-250 MW Solar PP	160	Solar	JV	BBPCL	Dec, 2029
Sheikh Ahmed Dalmook Al Maktoum, UAE 100 MW Solar PP	100	Solar	Private	IPP	Jun, 2030
TOTAL Planned	**1,685**				

Source: BPDB

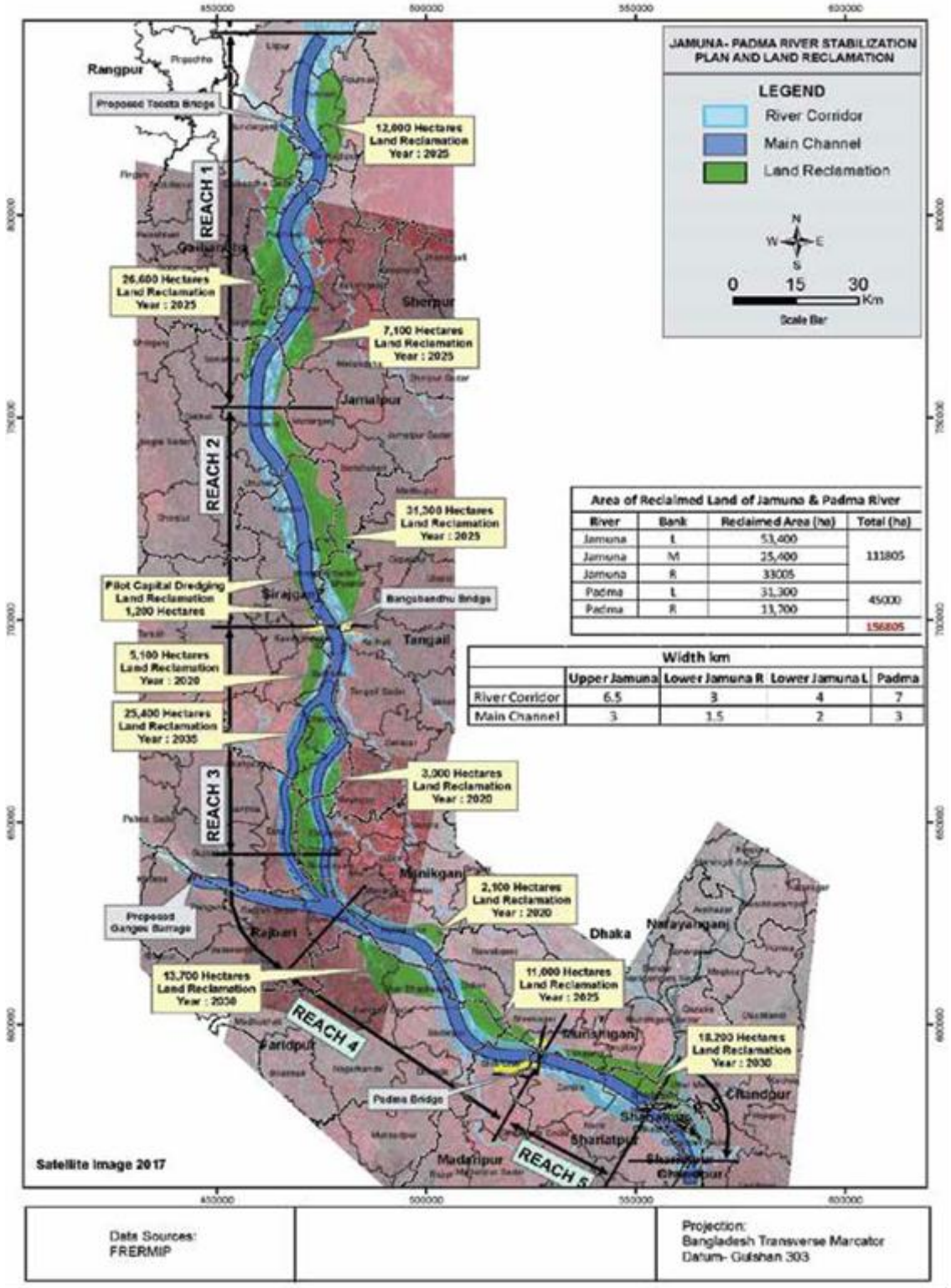


Figure 4.2 1 Map of Reclaimed Land of Jamuna & Padma River

Source: Bangladesh Delta Plan 2100

Among the candidate sites shown in the figure, the areas shown in the Table 4.2-6 are planned for reclamation. In this project, construction of the solar park on 313 km2 of the reclaimed land on the left bank of the Padma River is considered.

Table 4.2 6 Reclaimed Land of Jamuna and Padma River in Bangladesh Delta Plan 2100

Area of Reclaimed Land of Jamuna & Padma River			
River	Bank	Reclaimed Area [km^2]	Total [km^2]
Jamuna	L	534	1,118
Jamuna	M	254	
Jamuna	R	330	
Padma	L	313	450
Padma	R	137	
Total			1,568

Source: JICA study team based on Bangladesh Delta Plan 2100

a) A case of introduction

Based on the above conditions, the Study Team examined whether it is possible to construct the solar parks of the projected capacity by 2050 on the candidate sites. Figure 4.2-2 shows site locations of polders on the Padma River near Dhaka, where introduction of solar power park is considered in the areas indicated by ① and ②.

Figure 4.2 2 Candidate Sites for Solar Park

Source: Made by JCIA study team based on Bangladesh Delta Plan 2100

Areas of the candidate sites ① and ② in the above figure are 70km2 and 130km2, respectively. Of the total land area of 200 km2, 60 km2 or 30% will be allocated for

installation of the solar-park. In the plan, considering the experiences of the existing power plants in Bangladesh, 75 MW/km2 is adopted as the standard generation capacity of solar parks to be installed at the candidate sites. Based on the above investigation, it is considered possible to introduce more than 3,000 MW of photovoltaic power generation plants. Table 4.2-7 shows the development flow of the generation capacity from 2030 through 2050. The introduction is slow during the earlier period from 2030 to 2041 because certain time is necessary for land reclamation and construction of embankment: afterwards, the construction will accelerate.

The above candidate sites are selected as an exercise case. However, for actual application of the concept to utilize reclaimed lands, it is necessary to select realistic candidate sites and conduct potential survey on the energy resource, hazard survey on safety of the land and feasibility study on the project plans, including optimum linkage with the entire power system, so as to ensure that solar parks can be introduced there .

Table 4.2 7 Installation Plan of Solar Park

Year	Installed Capacity	Candidate sites
2030	3,061 MW	
	↓ +439MW	Use the ① area of around 5.9 km^2
2041	3,500 MW	
	↓+2,500 MW	Use ① area and ② area 33.3 km^2
2050	6,000 MW	

Source: JICA Study Team

(2) Roof-top Solar PV Generation

For Bangladesh, rooftop solar power generation is considered as the easiest way to introduce renewable energies as it would be least affected by the land and flood problems. Therefore, roof-mounted solar power generation is considered more for introduction in Bangladesh in the future. At present, the net metering system is in place to sell the power generated by the rooftop solar PVs, and thus the platform for introduction of rooftop solar PV is being developed progressively.

In this IEPMP, 12,000MW was set as the target for introduction of the roof-top solar power generation. Theoretically speaking, if there is a roof on a house, factory, public facility and etc., most of them can be considered as candidate. Therefore, it is not easy to accurately define the amount that will be used for roof-top PVs. In this regard, therefore, a comparative study was conducted considering cases in Germany and Japan as shown in Table 4.2-8.

Table 4.2 8 Estimation of Roof-top PV Potential: Bangladesh, Germany and Japan

	Germany	Japan	Bangladesh		
	Present	Present	Present (A)	(B/A)	2050 (B)
Population (million)[UN 2022]	83.9	125.6	167.9	1.27	214.0
Households (million) (α)	40.2 (Wohnen und Bauen in Zahlen 2010-2011)	51.8 (Gov.statistics 2018)	41.0 (Population and Housing Census 2022)	Assumed to be proportional to population growth. In reality, the number of households will increase more than the population as the economy development. 41.0×1.27=52.1	
Houses (million)	42.2 (OECD 2020)	62.4 (OECD 2020)	–		–
Detached house (million)	–	28.8 (Gov.statistics 2018)	–		–
Rooftop solar PV (MW) (β) (The value in Japan is only for the roof of a detached houses. Germany and Bangladesh include roofs other than detached houses.)	30,000 (The Daily Star, 12:00AM,September 17,2019)	Approx. 13,000 (Gov.statistics 2018)	400		(Germany β/α) 38,867 (Japan β/α) 13,025 >12,000
(β/α)	746	250			

Source: JICA Study Team

In this comparison, the amount of PV installation is examined based on the ratio of the number of households to the number of rooftop solar power generation. The population of Bangladesh in 2050 was projected, the number of households was assumed, and thus the introduction amount was estimated. Using Germany's installed capacity index as a reference, the installed capacity is expected to be 38,867 MW, and using Japan as a reference, the installed capacity is expected to be 13,025 MW. Based on these figures, it is considered that the installed capacity of 12 GW is not an excessive estimation.

Roofs at factories are also assumed as potential installation sites for roof-mounted PVs According to the Special Economic Zone (SEZ) plan of Bangladesh, a total of 68 SEZs are scheduled with about 300km2 of land to be procured. Considering that the roofs of these factories are likely to be used, introduction of roof-mounted PVs will proceed more easily. Thus, about 3,000 MW of solar panels can be installed on roofs of 60 km2, a 20% of the 300 km2, assuming a generation capacity of 50 MW/km2.

On the other hand, according to SREDA, a study on roof-mounted PV is being conducted by the World Bank. Incorporating such outcome, the amount of solar PV calculated as above needs to be fine-tuned with in-depth study on the issues anticipated for project implementation.

Solar PV installation is expected to increase for the purpose of self-use together with electricity sale through the Net Metering System. As such, the introduction of rooftop solar PV will be the easiest measure of introducing renewable energies in Bangladesh, as it is least affected by the land and flood problems.

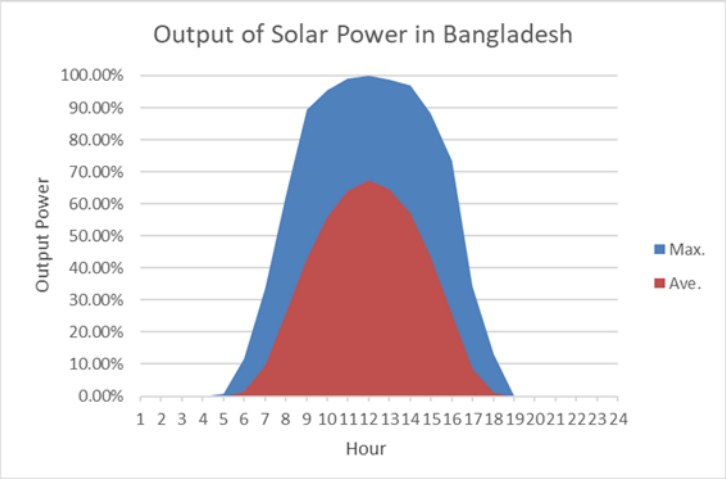
(3) Availability of Solar Power Generation

The availability of the solar power generation is estimated from the records on the existing solar power plants as shown in Table 4.2-9 and Figure 4.2-3.

Table 4.2-9 Record of the existing solar power plant

Time	Max.	Ave.
1	0.00%	0.00%
2	0.00%	0.00%
3	0.00%	0.00%
4	0.00%	0.00%
5	0.78%	0.00%
6	11.61%	1.24%
7	33.75%	9.48%
8	62.09%	25.57%
9	89.31%	42.78%
10	95.50%	55.83%
11	98.97%	64.13%
12	99.88%	67.23%
13	98.66%	64.59%
14	97.06%	56.98%
15	88.30%	43.52%
16	73.33%	25.59%
17	34.37%	8.70%
18	13.28%	1.04%
19	0.12%	0.00%
20	0.00%	0.00%
21	0.00%	0.00%
22	0.00%	0.00%
23	0.00%	0.00%
24	0.00%	0.00%
Ave.	37.38%	19.44%

Source: JICA Study Team



Source: JICA Study Team

Figure 4.2-3 Output of existing solar power plant

4.2.3 Wind Power Generation

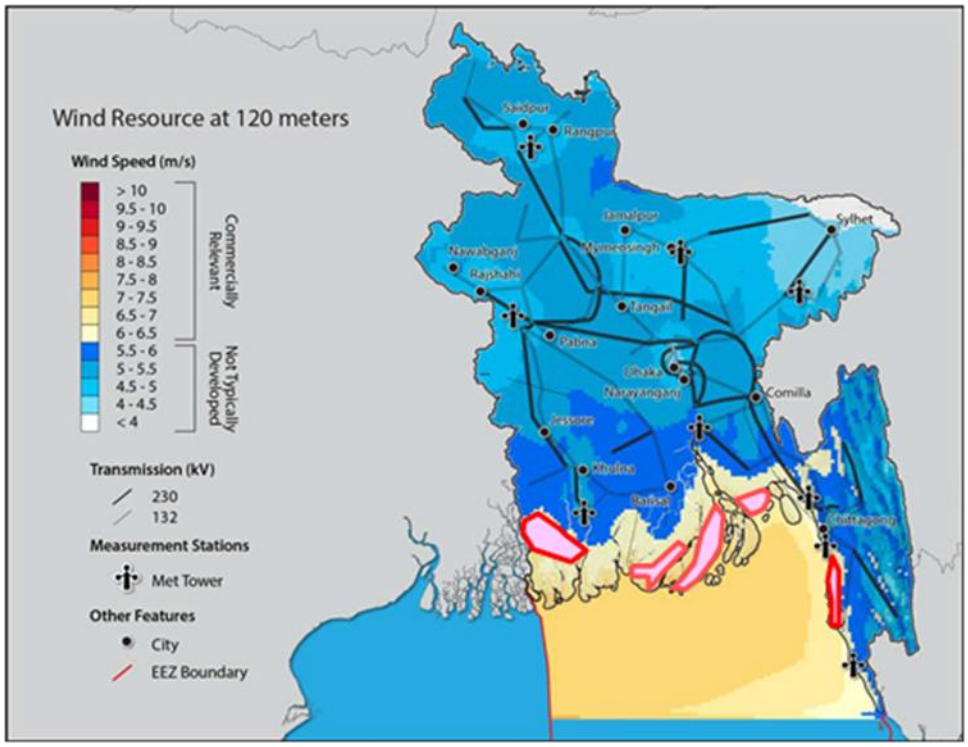
Wind power generation is classified into onshore wind power and offshore wind power. The introduction plan up to 2050 is as follows.

(1) Onshore wind Power

A potential survey was implemented and completed under the USAID-NREL Partnership, and the report entitled "Assessing the Wind Energy Potential in Bangladesh " was published in September 2018, which reports the study on the onshore wind power generation potential in Bangladesh. Based on the survey results, SREDA is promoting introduction of onshore wind power. It should be noted that this report also concludes that Bangladesh has a wind

power potential of 30,000 MW in an area of 20,000 km2.

In the report, a map of the wind resource potential at the position 120m above the ground level is presented as shown in Figure 4.2-4. It is observed that most of the inland areas of Bangladesh have an average wind speed of 6.0 m/sec. or less, while the coastal areas have better wind conditions with wind speeds of 6.0 m/sec. or more. Based on the survey, SREDA is proceeding with studies aiming at an goal of introducing 5,000 MW along the Bay of Bengal.



Source: USAID-NREL, "Assessing the Wind Energy Potential in Bangladesh"

Figure 4.2 4 Potential Map of Wind Power on Bangladesh

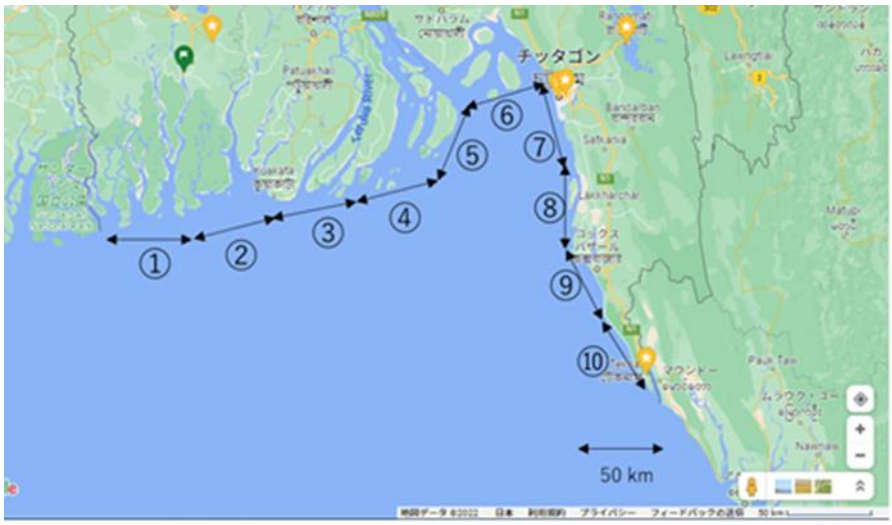
In order to introduce this 5,000 MW, an area of 3,333 km2 is required in the coastal area that is blessed with better wind conditions. As Figure 4.2-5 shows the approximate areas, it is not impossible.

The potential survey was conducted in this IEPMP. Since there is a plan for developing the wind power in the Bay of Bengal area where the average wind speed is relatively high, the policy of SREDA is adopted in this study and the development target is set at 5,000 MW by 2050.

(2) Offshore wind power generation

At present, there is no offshore wind power project classified in the category of the "Committed" or "Planned" by 2030. Compared to the onshore wind power generation, there

is a problem on the offshore wind power generation that resource potential survey has not been completed yet. Therefore, the introduction amount with reference to "Assessing the Wind Energy Potential in Bangladesh", which can be a potential survey of offshore wind power, was examined as below.



Source: JICA Study Team

Figure 4.2 5 Coastline of Bangladesh

The plan is to introduce wind power generation in the territorial waters along the coastline of the gulf regions of Bangladesh, extending for about 500 km. In this proposal, along the coastline, a sea area of 10,000 km2 within the territorial water is allotted for the wind power generation.

In the above report, it is stated that “there are more than 20,000 km2 of land with a gross wind potential of over 30,000 MW.” Therefore, if a sea area of 10,000 km2 could be secured in the territorial water, a potential generation capacity of 15,000 MW can be obtained by a simple calculation.

If we apply this explanation “there are more than 20,000 km2 of land with a gross wind potential of over 30,000 MW”, an average generation capacity of 1.5 MW/km2 is obtained. Compared with the cases as shown in Table 4.2-10, it looks hard to expect the generation performance of 1.5 MW/km2.

Table 4.2 10 Examples of Wind Turbine Projects in Japan

Location	Capacity	Unit	Area	Capacity/Area	Unit/Area
Site A (Akita pref.)	480 MW	38	62.688 km^2	7.65MW/km^2	0.61 unit/km^2
Site B (Akita pref.)	820 MW	65	130.4 km^2	6.29MW/km^2	0.50 unit/km^2
Site C (Chiba pref.)	390 MW	31	39.487 km^2	9.88MW/km^2	1.27 unit/km^2

Source: https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/yojo_furyoku/pdf/011_02_00.pdf

4.2.4 Biomass Power Generation

A 230 MW of waste incineration power generation and a 20 MW of biogas power generation are planned to be introduced by 2050. In total, a 250 MW of biomass-related generation capacity will be introduced by 2050. "A COMPREHENSIVE ASSESSMENT OF THE AVAILABILITY AND USE OF BIOMASS FUELS FOR VARIOUS END-USES WITH SPECIAL ATTENTION TO POWER GENERATION" which describes the biomass potential of Bangladesh received from SREDA was referred. The table below shows the amount of biomass fuel in each country including Bangladesh.

Table 4.2-11 Status of Biomass Fuels in Selected Developed and Developing Countries and in Bangladesh in 2015

Name of the Country	Reference	Area of the Country km^2	Area Covered by Tree resources km^2	Area Covered by Agricultural Crops (Net/total cropped area) km^2	Supply of Biomass Fuel, Terajoules						Biomass Fuels			
					Tree Residues	Agricultural Residues	Animal Residues	Industrial Wastes	Municipal Wastes	Liquid and Gaseous Biofuels	Amount of BF used for heating, TJ	Amount of BF used for power generation, TJ	BF based Installed power plants (MW)	Power generated (GWh) by using BF
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
EU	IEA (2017) UN (2015)	4,475,757	1,647,764	969,643	2,973,628	10,496	343,621	665,587	781,861	1,216,057	3,099,069	2,625,123	39,497	200,900
USA	IEA (2017) UN (2015)	9,833,520	3,625,283	1,577,021	434,061	696,343	353,073	783,884	2,94,282	1,391,021	1,789,341	929,649	14,286	80466
China	IEA (2017) UN (2015)	9,478,000	2,530,000	1,350,000	1,623,834	258,327	-	200,666	1,580,328	350,436	3,688,152	917,746	14,762	52,700
India	IEA (2017) UN (2015)	3,287,469	717,940	1,983,600	4,149,351	4,572,192	-	-	46,000	-	7,400,587	620,902	5,940	26,900
Bangla-desh	IEA (2017) UN (2015)	1,47,570	25,770	91,622	156,300	234,455		-		0.4	-	-	-	-

Source: Data for columns 3, 4 and 5 – Statistical Yearbook 2015 (for India and China); Eurostat 2015 (for EU); US Census of Agriculture 2015 - land usage pattern (for United States); Statistical Yearbook 2015 (for Bangladesh)

Source: A COMPREHENSIVE ASSESSMENT OF THE AVAILABILITY AND USE OF BIOMASS FUELS FOR VARIOUS END-USES WITH SPECIAL ATTENTION TO POWER GENERATION

While the amount of biomass power generation in Bangladesh is not indicated in the table, it is possible to identify the difference in the amount of fuel supplied in India. The amount of biomass fuel in Bangladesh is shown to be about 1/25 of that in India. Table 4.2-12 shows the potential amount of biomass power generation in India, which is expected to be 25,000 MW.

As it is a simple calculation, the amount of biomass fuel available in Bangladesh will be 1/25 of that in India: so the potential can be estimated as 1,000 MW for Bangladesh. However, considering possible constraints in Bangladesh, introduction of biomass power generation is projected at a quarter of this or 250 MW.

In waste incineration power generation, there are a total of 3 plants that are treated as

"Committed" and "Planned" in the introduction plan until 2030 with a total planned generation capacity of 93.5 MW. The MEPMP plans to introduce 230 MW by 2050, with accelerated introduction in the 2030s onwards.

On the other hand, biogas power generation is planned to be 10 MW in 2030 and 20 MW in 2050. It uses methane generated from animal waste to generate electricity. It is a power generation method that is difficult to introduce without a certain scale of livestock industry, a well-developed sewage treatment system, and a garbage collection system. Therefore, it is assumed that up to 20 MW will be introduced by 2050 with combined application of sewage treatment systems and collection systems for food wastes.

Table 4.2-12 Biomass Fuels Power Generation in Selected Countries in 2015

Country	Reference	Installed Capacity (MW)				Potential (MW)	
		Biomass fuels and Biofuels to Power	Waste to Energy	Biogas/ Landfill Gas	Total	Biomass Fuels to Power	Waste to Energy
1	2	3	4	5	6	7	8
EU 28	EU (2017)	17352	8309	11413	37074		
Germany		1592	1924	5643	9159		
Sweden		3700	876	2	5278		
UK		2738	925	1615	4578		
USA	EIA (2016)	9475	2441	2370	14286		
China	China Energy Portal (2015) & Qin et al. (2018)	7009	7253	500	14762	100700	
India	MNRE (2017)	5665	275		5940	22536	2554

Source: A COMPREHENSIVE ASSESSMENT OF THE AVAILABILITY AND USE OF BIOMASS FUELS FOR VARIOUS END-USES WITH SPECIAL ATTENTION TO POWER GENERATION

4.2.5 Hydropower Generation

Hydropower generation capacity of 230 MW in 2030 refers to the Kaptai hydropower plant.

There is no other plans to introduce large-scale power plants through 2050. Due to the geographical features of Bangladesh, it is difficult to construct a large-scale hydroelectric power plant without any more promising sites. A survey was conducted on small-scale hydroelectric power generation. Candidate sites for power plants with a scale of about 100 kW were listed, but not considered in this plan.

5. Demand side management

When the power supply cannot be enough as planned due to troubles at the power plant or insufficient power generation capacity, wide-area power outages (blackouts) must be avoided, and measures for that are required.

The program to save energy and electricity are planned as policies and measures in EECMP2016.

In the industrial sector, the introduction of an energy management program (energy manager program and periodical reporting program) is being promoted, and in the residential and commercial sector, programs such as the energy efficiency standards and labeling program and building code are implanting. These programs and measures also include energy saving measures for electricity. However, the purpose is to reduce the total amount of energy and the total amount of electric power, and it is not always consistent with the supply of peak electric power that causes a power outage.

When the power supply is restricted, the following measures are being considered overseas.

The introduction of these measures in Bangladesh requires thorough investigation and verification, and is a future initiative.

- Time-of-use. Pricing program
- Demand response

5.1 Time-of-use. Pricing program

The Time-of use program suppresses the use of electricity demand in time with high electricity demand by setting the electricity price hourly. There is a method of fixing the electricity price for each hour in advance and a dynamic pricing method of the electricity price in real time according to the balance between supply and demand of electricity.

In either case, the price is set for each power supply area, and the aim is to curb demand depending on the power supply status of each region. For example, this program aims to reduce the electricity demand by setting the electricity price during the daytime when the amount of electricity used is higher than other times.

The following is an outline of the Time-of-use program:

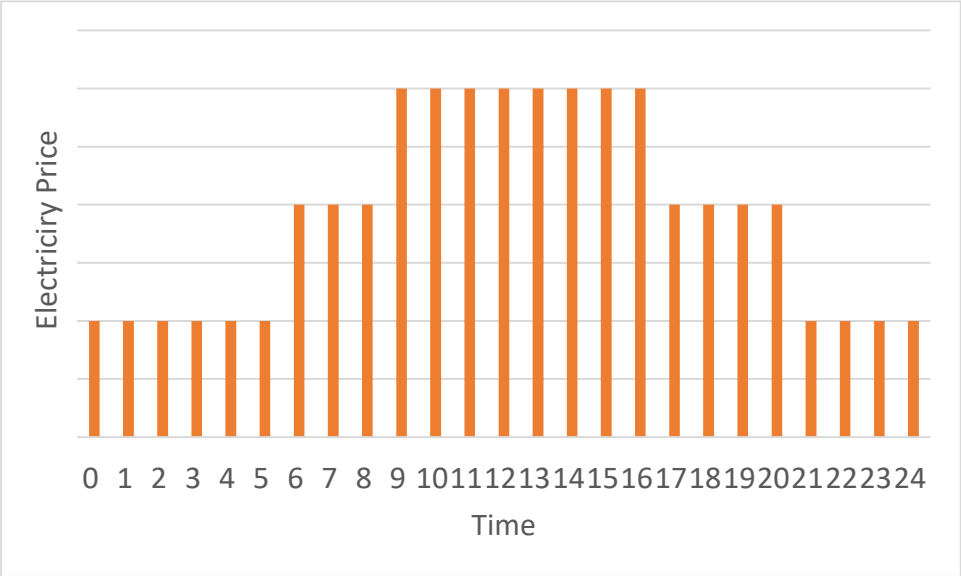


Figure 5.1-1 Explanation of Time-of-use

5.2 Demand response

Demand response is to change the electricity consumption pattern so that consumers can curb electricity usage in response to the setting of electricity prices or the payment of incentives when the wholesale market price rises or the grid reliability declines.

For example, in areas where electricity supply shortages are expected to occur, grid operators and electricity supply companies make contracts with private businesses in advance and supply electricity upon request (utilization of private electricity generation, etc.) to increase the supply amount. In addition, about curbing electricity demand, it is a mechanism to reduce demand by making contracts with private entities and households and reducing electricity demand in response to requests when electricity supply is insufficient. Private entities that respond to the supply of electricity will be given an incentive to participate by purchasing them at a price higher than the contract or market price, which is positioned as a reserve and pays funds. Incentives such as participation fees (or points, etc.) and discounts on electricity price will be given to private entities and households that have responded to electricity reducing.

In the above description, when a constraint occurs on the electricity supply side, the electricity supply-demand balance can be maintained by increasing the supply or decreasing the demand. In either case, it will be managed in the electricity supply area.

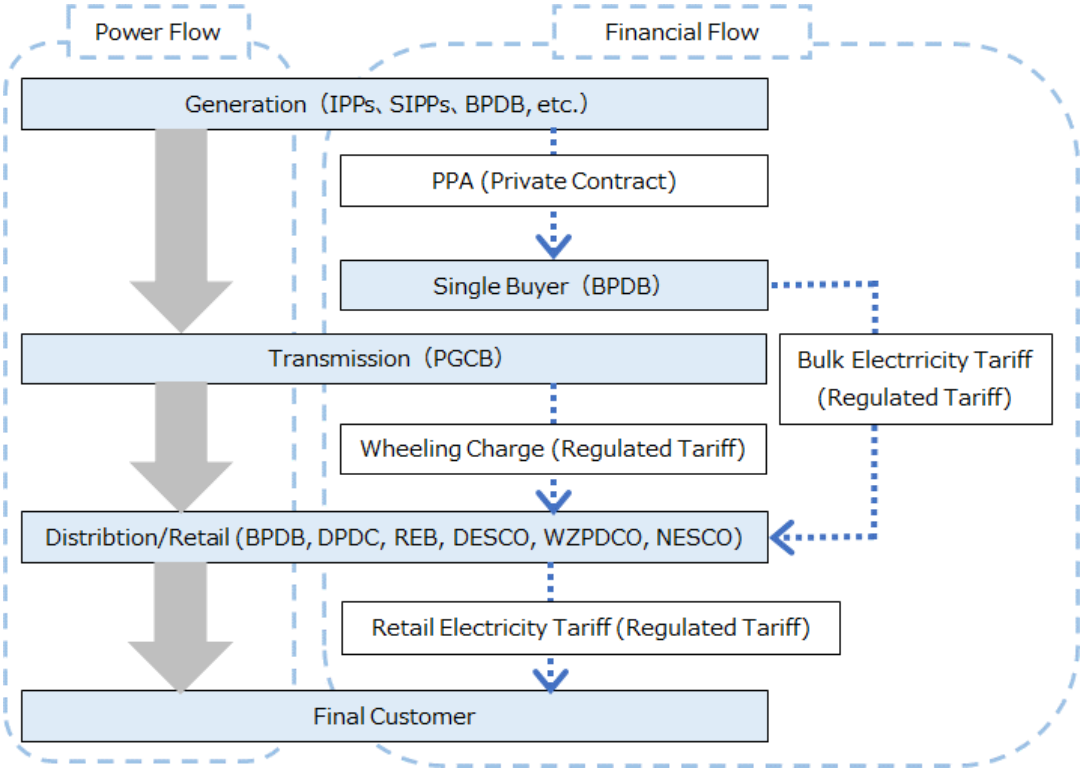
6. Electricity trading, tariff analysis

6.1 Market structure of electricity trading

1) Power Sector Overview

Figure 6.8.1 shows the flow of power supply and billing in the power sector. The electricity generated by generation companies is supplied to final customers through the transmission network of Bangladesh Power Grid Company of Bangladesh (PGCB) and the distribution network of distribution companies.

On the other hand, regarding the billing flow, it is as follows. IPP, SIPP (Small Independent Power Producers), Bangladesh Power Development Board (BPDB) owned plants as well as public plants that generate electricity. And BPDB, a single buyer, buys generated and imported electricity. The electricity generated by each plant is sold to distribution companies at the regulated bulk electricity tariff and transmitted through the PGCB network. When using the transmission network, each distribution company paya electricity transmission tariff / wheeling charge to the PGCB. Ultimately, the retail electricity tariff, which is a regulated rate, is used by distribution companies to sell electricity to the final customers.[1]



Source: created by The Institute of Energy Economics, Japan

Figure 6.1-1 Power Flow and Billing Flow in the Power Sector

[1]PSMP2016, Part 3, p.19-10

2) Policy trends

In the Electricity Act 2018, the establishment of an independent system operator (ISO) has been stipulated, but ISO has not yet been established and no particular discussion has progressed.[2]

In addition, in the review committee set up in the Power Division, Power Cell considered formulating a Private Sector Power Transmission Policy aiming to open a transmission business in the private sector and was scheduled to announce it in the first half of 2021. But, at the moment the status cannot be confirmed on their homepage. Bangladesh has succeeded in increasing generation business through private investment and is considering utilizing private investment to reinforce transmission facilities as the number of power plants increases.

6.2 Electricity price

1) Overview of electricity charges

In 2003, the Bangladesh Energy Regulatory Commission (BERC) was established by the BERC Act 2003. The BERC is responsible for managing, operating and pricing the electricity, domestic natural gas and oil sectors, as well as enacting rules and regulations for these sectors.

Also, wholesale purchase tariff for generators, bulk electricity tariff for distribution companies, retail electricity tariff and energy supply to final customers are determined in accordance with policies and methodologies developed by the BERC in consultation with the government. The BERC tariff rules stipulate policies and methodologies for setting electricity tariffs, but these rules can be adjusted to some extent as necessary.

And, when conflicts arise, the BERC considers solutions. In addition, Article 22 (i) of the BERC Act, The BERC may also cooperate and advise the government on generation, transmission and distribution and energy storage as needed.[3]

Retail electricity tariff set by the BERC in 2020 is as shown in the table below. A single tariff policy has been adopted, and different rate systems have been introduced according to the type of customer.[4]

Table 6.2-1 Electricity Charges, Dispute Resolution, and Government relations under BERC Act of 2003

Item	Main contents
Charge issues	Art.22 (b) to ensure efficient use, quality services, determine tariff and safety enhancement of electricity generation and transmission, marketing, supply, storage and distribution of energy;

[2]BERC Hearing (2021.11.30)
[3]PSMP2016, Part3, p.19-1
[4]PSMP2016, Part3, p.19-2, BERC Hearing (2021.11.30)

Dispute resolution	Art.22 (j) to resolve disputes between the licensees, and between licensees and consumers, and refer those to arbitration if considered necessary; (k) to ensure appropriate remedy for consumer disputes, dishonest business practices or monopoly;
Relationship with the government	Art.34 (1) Notwithstanding anything contained in any other law for the time being in force, the price of generation in wholesale, bulk and retail, and the supply of energy at the level of end-user, shall be determined in accordance with the policy and methodology made by the Commission in consultation with the Government: Provided that this shall not be applicable in those cases, the tariff of which were determined by the agreement executed between the private company and the Government or by any of its agency before this Act comes into force.

Source: Bangladesh Energy Regulatory Commission

Table 6.2-2 Retail Electricity Tariff (effective March 1, 2020)

Tension	Consumer Class	Energy Rate/Charge (Tk / kWh)	Demand Rate/Charge (Tk / kW / month)
Low Tension (LT) 230 / 400V	LT-a: Residential Life Line: 1-50 units First Step: From 00 to 75 units Second Step: From 76 to 200 units Third Step: From 201 to 300 units Fourth Step: From 301 to 400 units Fifth Step: From 401 to 600 units Sixth Step: From 601 to above	3.75 4.19 5.72 6.00 6.34 9.94 11.46	30.00
	LT-b: Agricultural pumping	4.16	30.00
	LT-c 1: Small Industries Flat Rate Off-Peak Time Peak Time	8.53 7.68 10.24	30.00
	LT-c 2: Construction	12.00	100.00
	LT-d 1: Education, religious and charitable organizations and	6.02	35.00

	hospitals		
	LT-d 2: Street lamp and water pump	7.70	60.00
	LT-d 3: Battery charging station		
	Flat Rate	7.64	
	Off-Peak Time	6.88	60.00
	Super Off-peak Time	6.11	
	Peak Time	9.55	
	LT-e: Commercial & Office		
	Flat Rate	10.30	60.00
	Off-Peak Time	9.27	
	Peak Time	12.36	
	LT-t: Temporary	16.00	100.00
Medium Tension (MT) 11kV	MT-1: Residential		
	Flat Rate	8.40	60.00
	Off-Peak Time	7.56	
	Peak Time	10.50	
	MT-2: Commercial & Office		
	Flat Rate	9.12	60.00
	Off-Peak Time	8.21	
	Peak Time	11.40	
	MT-3: Industries		
	Flat Rate	8.55	60.00
	Off-Peak Time	7.70	
	Peak Time	10.69	
	MT-4: Construction		
	Flat Rate	11.46	100.00
	Off-Peak Time	10.31	
	Peak Time	14.33	
	MT-5: General Purpose		
	Flat Rate	8.45	60.00
	Off-Peak Time	7.61	
	Peak Time	10.56	
	MT-6: Temporary	15.00	100.00
	MT-7: Battery charging station		
	Flat Rate	7.56	
	Off-Peak Time	6.80	60.00
	Super Off-peak Time	6.05	
	Peak Time	9.45	
	MT-8: Agricultural pumping		60.00

	Flat Rate	5.00	
	Off-Peak Time	4.50	
	Peak Time	6.25	
High Tension (HT) 33kV	HT-1: General Purpose		
	Flat Rate	8.41	60.00
	Off-Peak Time	7.57	
	Peak Time	10.51	
	HT-2: Commercial & Office		
	Flat Rate	9.02	60.00
	Off-Peak Time	8.12	
	Peak Time	11.28	
	HT-3: Industries		
	Flat Rate	8.45	60.00
	Off-Peak Time	7.61	
	Peak Time	10.56	
	HT-4: Construction		
	Flat Rate	10.60	60.00
	Off-Peak Time	9.54	
	Peak Time	13.25	
Extra High Tension (EHT) 132kV 230kV	EHT-1: General Purpose		
	Flat Rate	8.36	60.00
	Off-Peak Time	7.52	
	Peak Time	10.45	
	EHT-2: General Purpose		
	Flat Rate	8.31	60.00
	Off-Peak Time	7.48	
	Peak Time	10.39	

Source: Bangladesh Energy Regulatory Commission

2) Changes in electricity prices

Except for DPDC and DESCO supplied in the Dhaka region, BPDB, a single buyer, continues to record a constant deficit because wholesale electricity charges are cheaper than wholesale supply costs, as will be described later.

To shrink the difference between wholesale supply costs and wholesale electricity charges, the government presented three scenarios in PSMP (Power & Energy Sector Master Plan). The government considers the burden on low-income customers, has indicated a policy to raise a retail electricity price in stages and also points out the need to raise wholesale electricity charges. In line with this policy, an average 5.3% increase in retail electricity prices was implemented in December 2017, and a 5.3% increase in retail electricity prices was implemented in March 2020.

In addition, when a retail electricity tariff was raised in March 2020, the bulk electricity tariff was raised by 8.4% and the wheeling charge was raised by 5.3%.

Table 6.2-3 Example of an Electricity Price Increase Scenario up to 2041 (from PSMP2016)

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

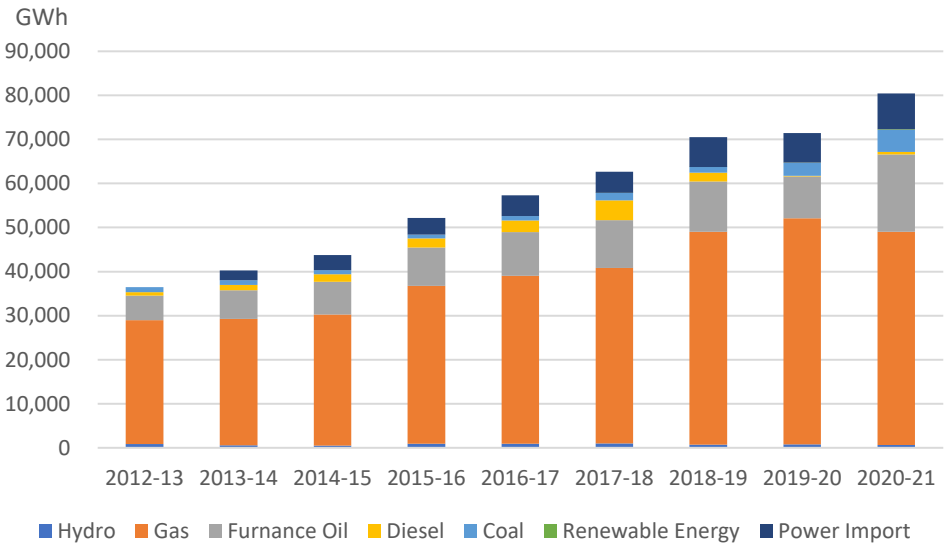
Source: JICA, PSMP2016Final Report

6.3 Supply cost

1) Generation cost

Figure 6.3-1 shows the breakdown of generation by fuel type in Bangladesh. Due to the recent diversification of energy, the proportion of gas has decreased, but it still accounts for an overwhelming proportion of about 60%. On the other hand, the proportion of coal is increasing, and the proportion of oil, which costs more than gas, is increasing. In addition, the amount of electricity imported from India is also on the rise.

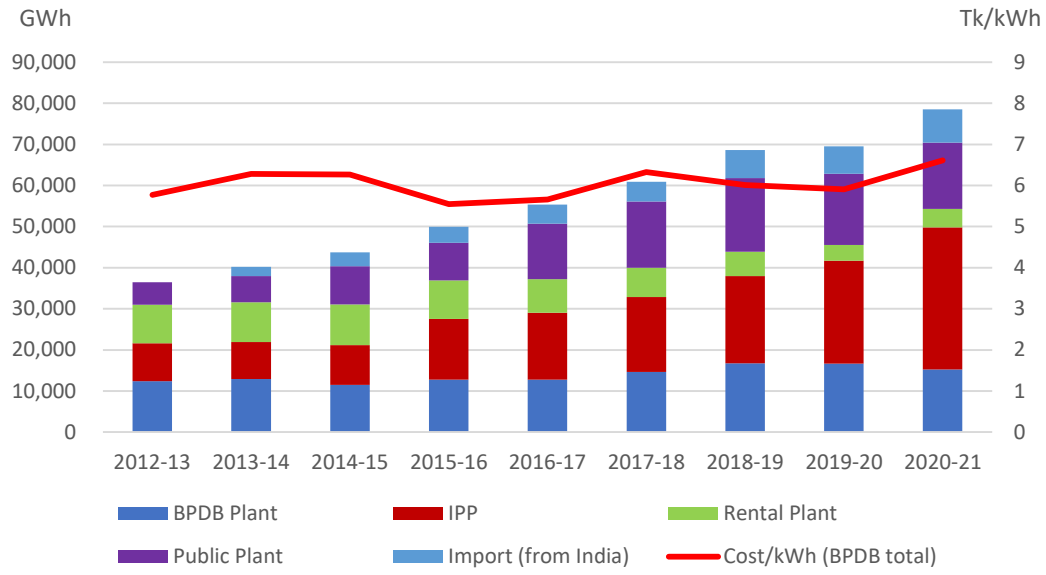
Figure 6.8.4 shows the breakdown of the sources of electricity procured by BPDB and Figure 6.3-2 shows wholesale electric power cost (Electricity Purchase Costs/Electricity Purchase kWh). The average cost is flat at around 6Tk / kWh, however, it increased to 6.61 Tk / kWh in 2020-2021. Previously, it has been pointed out that the increase in the amount of electricity purchased from rental plants is the cause of the increase in purchase cost of wholesale electric power. On the other hand, the government has indicated that it will abolish the purchase of electricity from rental plants in the future, and in recent years there has been a tendency for the purchase of electricity from rental plants to decrease. However, although the purchase of electricity from the rental plant was supposed to expire in 2021, it was approved in September 2021 to extend it for 5 years.



Source: BPDB Annual Reports

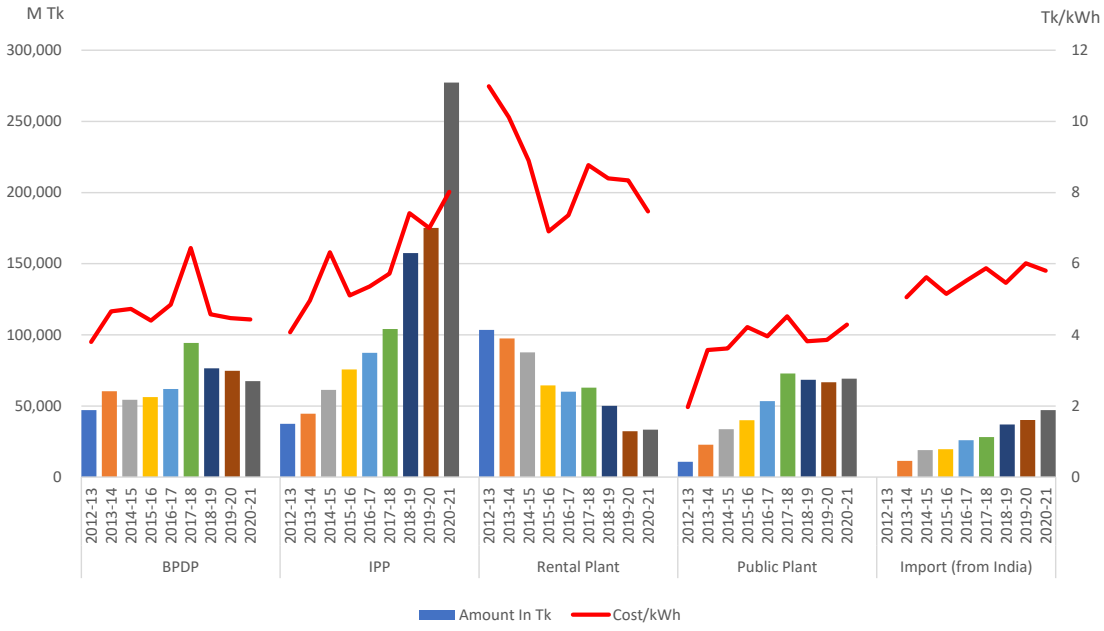
Figure 6.3-1 Breakdown of Generation by Fuel Type in Bangladesh

On the other hand, regarding IPP and SIPP (Small Independent Power Producers), public plants, imported electricity, the procurement volume and the average purchased cost of wholesale power tend to be increased. Especially, IPP and SIPP have a remarkable tendency. The purchase amount is about eight times higher than 37.5 billion Tk in 2012-2013 to 277.3 billion Tk in 2020-2021, on average. The average purchase cost is about doubled from 4.07Tk / kWh to 8.02Tk / kWh. This is because IPP and SIPP are increasing new construction and the power plants based on oil and diesel which are more expensive than gas continue to be operated. The same type of power plants is scheduled to operate for the next few years, after which, many gas-fired power plant projects are planned.



Source: BPDB Annual Reports

Figure 6.3-2 BPDB Power Procurement Status

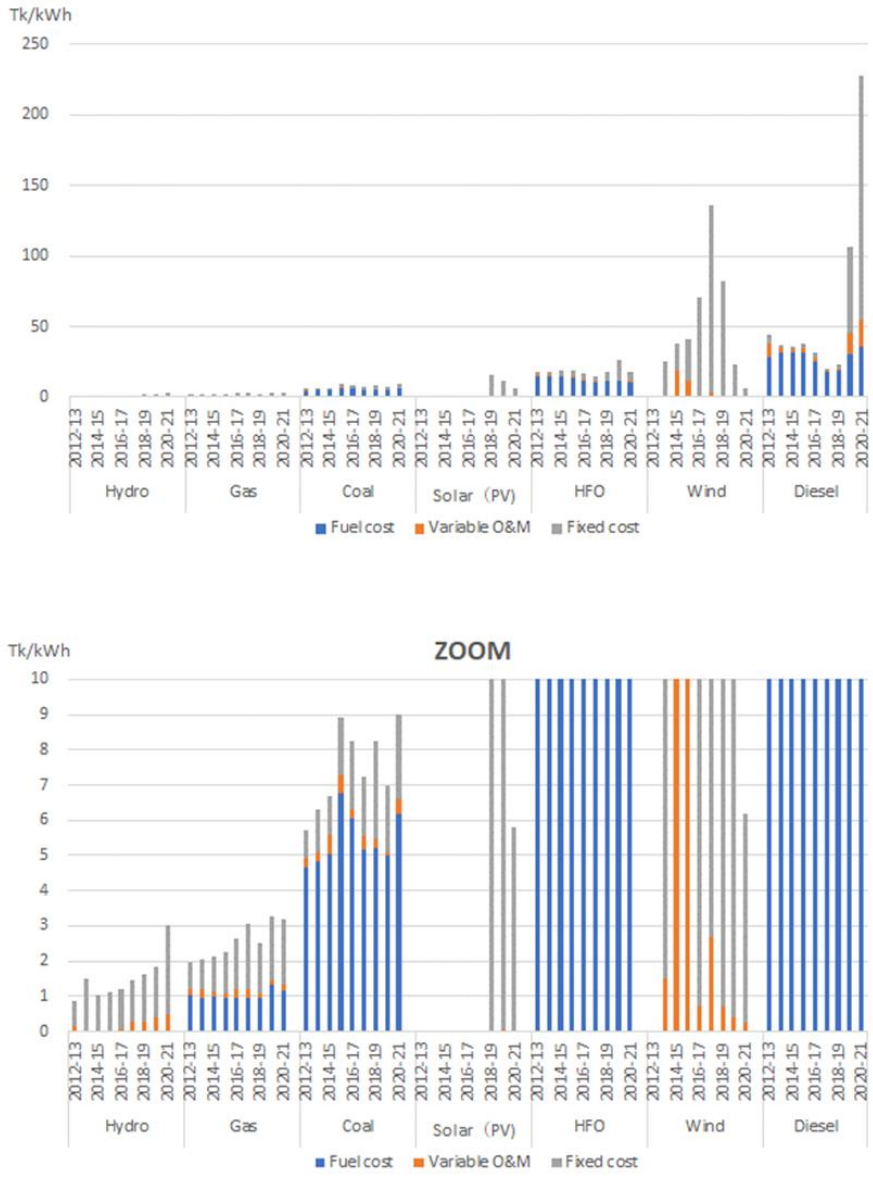


Source: BPDB Annual Reports

Figure 6.3-3 BPDB Wholesale Electricity Purchase Cost (by plant owner)

Figure 6.3-4 shows the cost (Total Generation Cost/Net Generation) of generation plants owned

by BPDB. Gas-fired generation cost is extremely low at around 3Tk / kWh. This is because the gas for generation depends on domestic fuel and the prices have been kept low compared to international standards. However, domestic gas fields tend to be exhausted, so Bangladesh has started importing LNG. If the gas supply price is increased to the international level in the future, the country's power source composition and the existing power source plan mentioned above are expected to have a significant impact on the overall generation cost.



Source: BPDB Annual Reports

Figure 6.3-4 Generation Cost (fuel type) of the Plants owned by BPDB

2) Wheeling charge

The BERC will have the authority to decide on the wheeling charge. As mentioned above, the wheeling charge has been increased from March 1, 2020. The calculation method of the wheeling charge is as follows.

a. To the total assets of PGCB for operation costs multiplied by a certain ratio added amount (assumed total expenditure)
b. Current income
c. a-b + tax

- Wheeling unit price = b + c (expected total income) / wheeling power volume

Table 6.3-1 Wheeling Charge

Voltage	July 1, 2019-February 29, 2020	From March 1, 2020
230kV	0.2744 Tk / kWh	0.2857 Tk / kWh
132kV	0.2768 Tk / kWh	0.2886 Tk / kWh
33kV	0.2791 Tk / kWh	0.2944 Tk / kWh

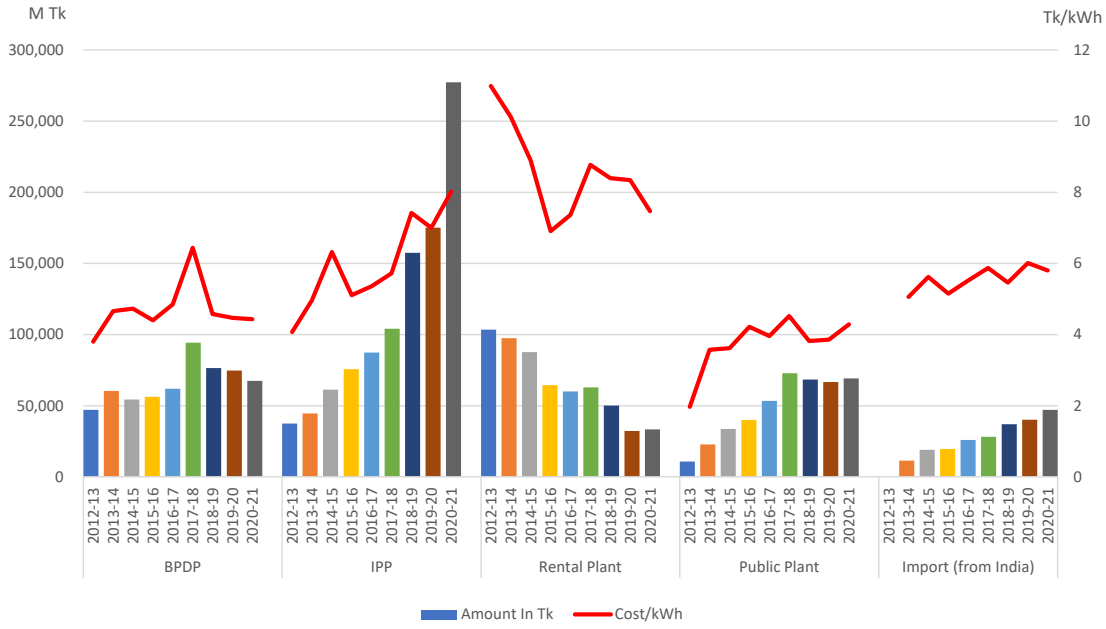
Source: Bangladesh Energy Regulatory Commission

3) Import / Export price

Bangladesh imports electricity from India. In 2020-2021, electricity was imported by 8,129GWh and the average electricity purchase cost was 5.80 Tk / kWh. The electricity purchased from India comes from fossil fuels, but the generation cost of BPDB-owned plants in the same year was 3.17Tk / kWh for gas-fired power and 8.99Tk / kWh for coal-fired power.

In September 2021, the governments agreed on a short-term electricity transaction regarding the import of hydro generation from Nepal. In the energy cooperation agreement between the two countries signed in August 2018, importing 9,000 MW is planned by 2040[56].

[5] https://myrepublica.nagariknetwork.com/news/nepal-b-desh-agree-on-cross-border-power-trade/
[6] https://thehimalayantimes.com/business/bangladesh-nepal-energy-cooperation-the-horizon-of-new-possibilities



Source: BPDB Annual Reports

Figure 6.3-5 BPDB Electricity Purchase Cost (by plant owner) (repost)

Regarding international power interconnection in BBIN (Bangladesh, Bhutan, India, Nepal), an individual project between countries is being carried out mainly in India. In 2014, at SAARC (South Asian Association for Regional Cooperation), the framework for energy cooperation in the electric power field was agreed on.

Concerning the institutional design related to international power interconnection, in fact, bilateral transactions are operated based on the Indian system. India has established Guidelines for Import / Export (Cross Border) of Electricity- 2018, MOP, December 2018. Matters related to charges and accounting are as follows.

1) Electricity import charges by Indian operators are subject to competitive bidding or mutual recognition in accordance with Indian tariff policy. If agreed by Indian companies, import charges are determined according to the rules of CERC (Central Electricity Regulatory Commission).
2) Import and export charges have been mutually agreed by the Government of India and the governments of neighboring countries, and participating companies of both countries are applied by the contents of the agreement.
3) Import and export charges determined through intergovernmental negotiations, including intergovernmental agreements, will continue until the agreement expires or until competitive bidding charges are bilaterally determined.
4) The export charges based on long-term / medium-term / short-term contracts are determined by bilateral agreements or competitive biddings on the condition of paying wheeling charges applied in the Indian transmission system.

5) Transmission charges, operations, measurements, accounting, deviant settlement, stable operation of the Indian system, and other related operational mechanisms are subject to the relevant rules of the Government of India.
6) The Indian Ministry of Power will notify the responsible agencies of each neighboring country of the settlement of grid operation-related charges in accordance with CERC rules.

6.4 Financial status in the power sector

1) BPDB financial status

BPDB purchases electricity from all generation companies as a single buyer and does a wholesale sale to distribution companies. Concerning a wholesale purchase tariff, a two-part tariff system has been adopted. Generation companies recover their variable costs with an energy-based tariff and their fixed costs with a contract capacity-based tariff.

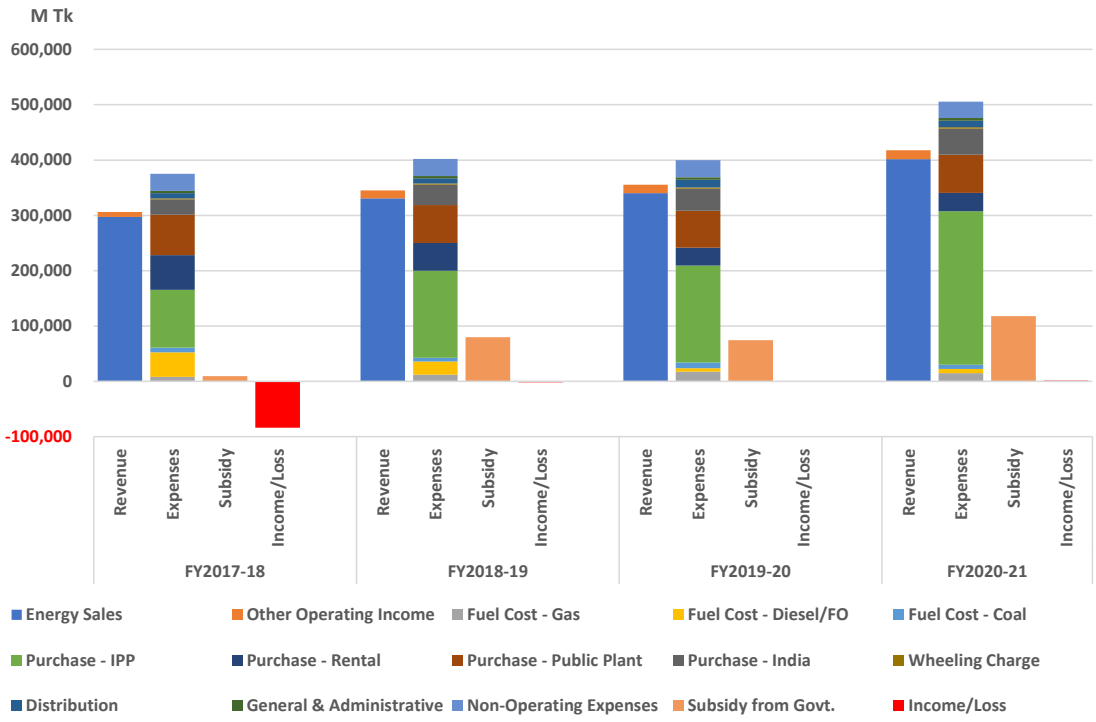
Figure 6.4-1 shows the operating balance of BPDB and other balances. The operating balance for 2020-2021 was a loss of 86.6 billion Tk. However, the government gives BPDB a subsidy of 117.8 billion Tk. As a result, the balance of BPDB is almost zero.

The reason of BPDB's operating loss is that BPDB does a wholesale sale based on the cheaper bulk electricity tariff than the averaged bulk supply cost to distribution companies other than DPDC and DESCO, which supply the Dhaka region.

In March 2020, the increase of bulk electricity tariff was approved by BERC. However, it is expected that the situation will continue where BPDB cannot make operating profits because the bulk electricity tariff is cheaper than the wholesale supply cost, except for DPDC and DESCO. Also, for 2020-2021, the wholesale supply cost exceeds the bulk electricity tariff in even DPDC and DESCO.

The bulk electricity tariff was revised in March 2011, March and September 2012, September 2015 and March 2020. The operating balance of BPDB has been improved slightly, but the debt has been increased by the difference between wholesale supply cost and bulk electricity tariff with the increase in electricity sales and the increase of wholesale supply cost.

As the basic income and expenditure structure of the entire electric power sector, each charge is set at a level that can secure the profits of each operator of generation, transmission, and distribution, and BPDB will remove the final wrinkles. For this reason, BPDB receives a subsidy from the government and the government uses taxes. To reduce national treasury expenditure, it is necessary to streamline facilities related to electric power and to reform the management of each company, as well as to raise the retail electricity tariff to final customers.



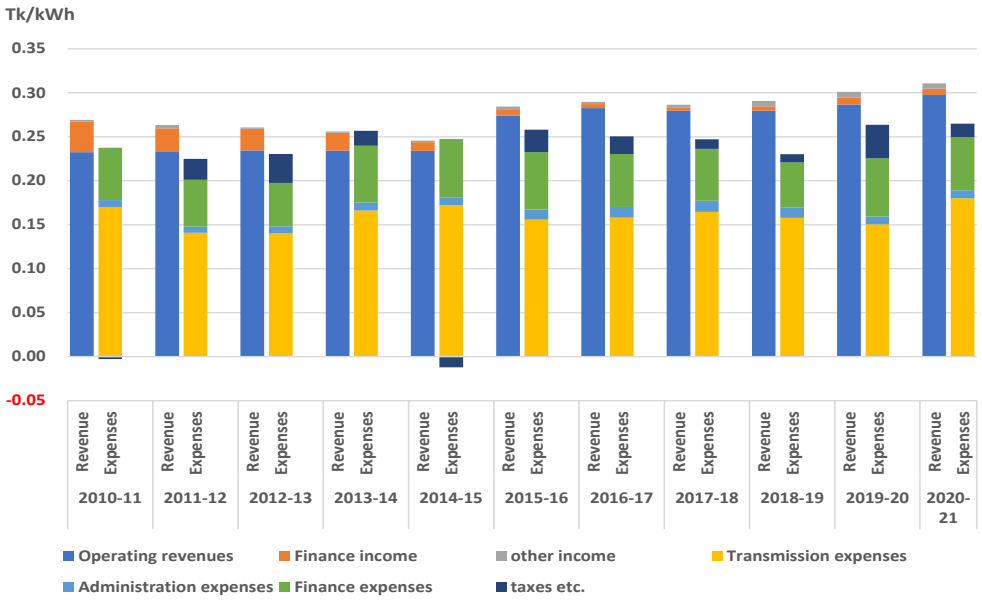
Source: BPDB Annual Reports

Figure 6.4-1 BPDB Balance Status

2) Financial status of PGCB

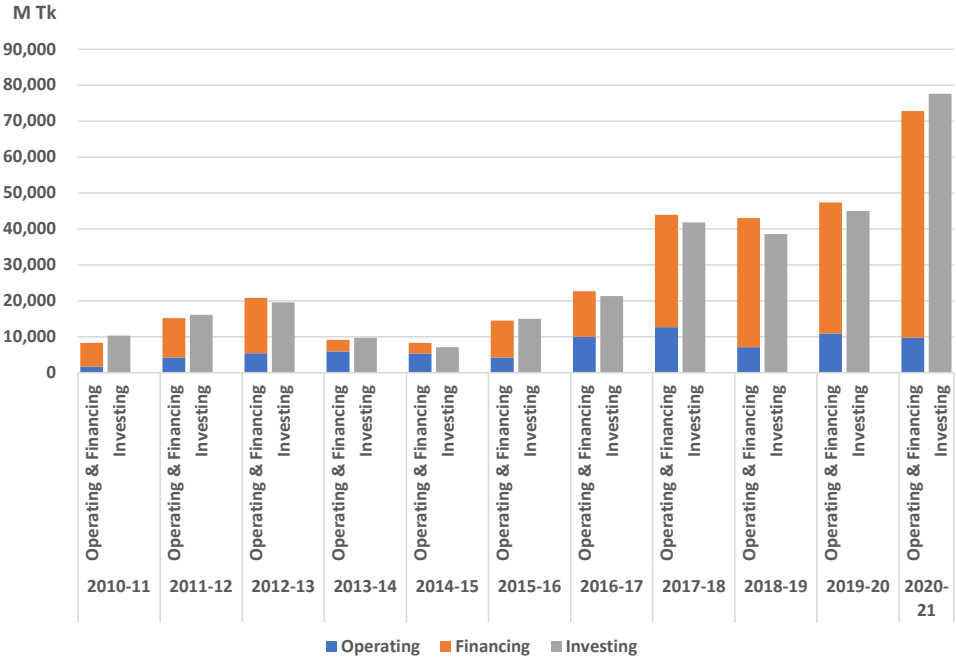
Each distribution companies pays a wheeling charge approved by the Bangladesh Energy Regulatory Commission (BERC) to the Bangladesh Power Grid Company of Bangladesh (PGCB), which is licensed for transmission.

Figure 6.4-2 shows PGCB's balance per unit of electricity supplied and Figure 6.4-3 shows PGCB cash flow. Compared to BPDB, the operating balance and operating cash flow have been positive in recent years. And on March 1, 2020, the wheeling charge will be increased on average from 0.2787Tk / kWh to 0.2934Tk / kWh. However, the borrowing is increasing significantly every year because the needs of the capital investment of network is increased. In particular, in FY2020-2021, long-term bond borrowing was approximately 55.6 billion Tk for a funding flow of approximately 63 billion Tk. Of this amount, about 3.6 billion Tk is used for repayment of long-term bonds, and about 1.9 billion Tk is used for dividends. In addition, the single-year cash flow for the same year was minus about 4.8 billion Tk.



Source: PGCB Annual Reports

Figure 6.4-2 PGCB's Balance per Unit of Electricity Supplied



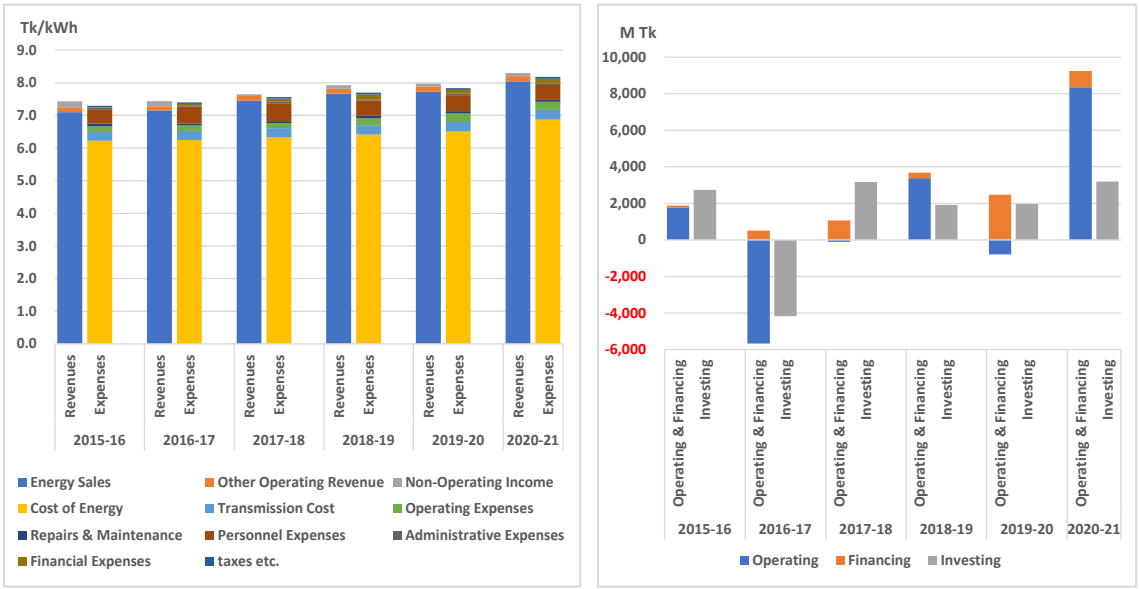
Source: PGCB Annual Reports

Figure 6.4-3 PGCB Cash Flow

3) Financial status of distribution companies

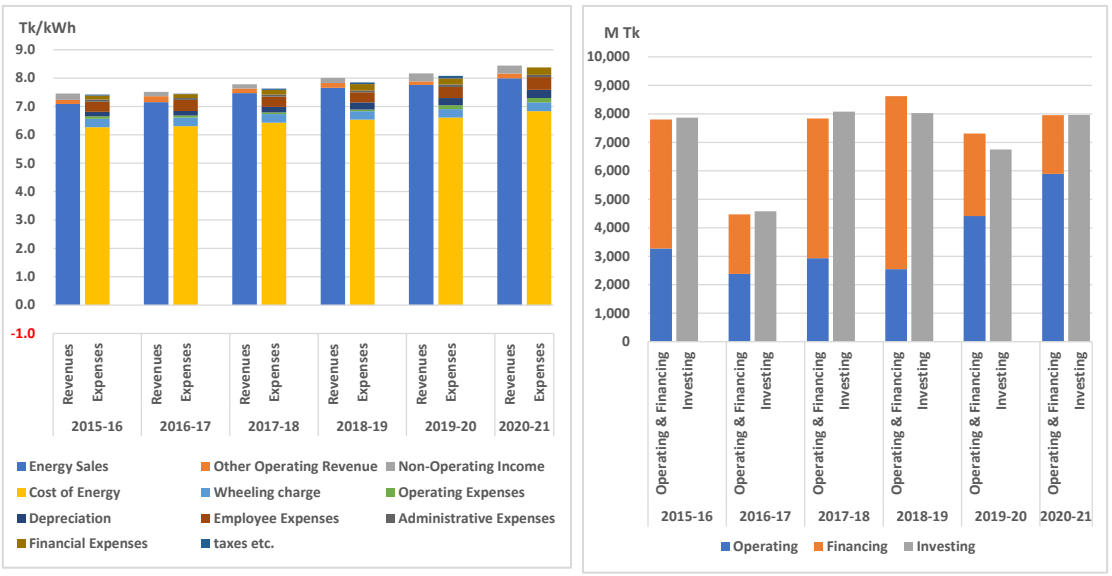
Figure 6.4-4~7 shows the financial status of each distribution company (DPDC, DESCO, WZPDCL, NESCO). Regarding the income and expenditure of each distribution company, the income and expenditure is almost balanced based on regulated charges. The retail electricity tariff has been revised when the bulk electricity tariff is raised. In the immediate vicinity, bulk electricity tariff was revised in September 2015 and March 2020 and retail electricity tariff was revised in December 2017 and March 2020.

However, focusing on cash flow, it has become commonplace in recent years for distribution companies other than DPDC to have a large shortage of operating cash flow for capital investment, and additional borrowing is occurring.



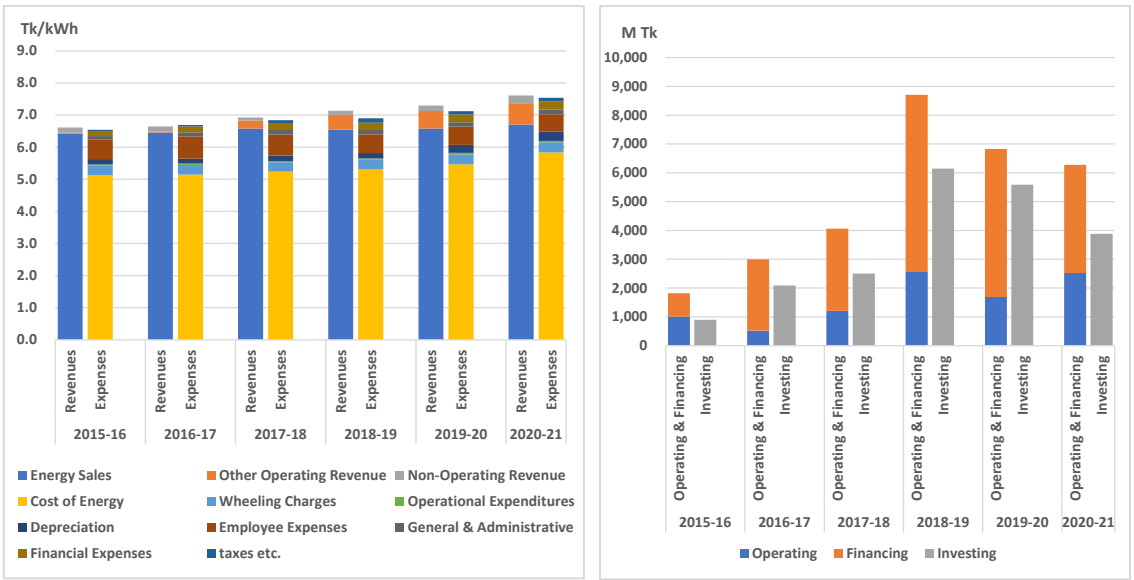
Source: DPDC Annual Reports

Figure 6.4-4 DPDC Financial Status (left: balance per electricity volume, right: cash)



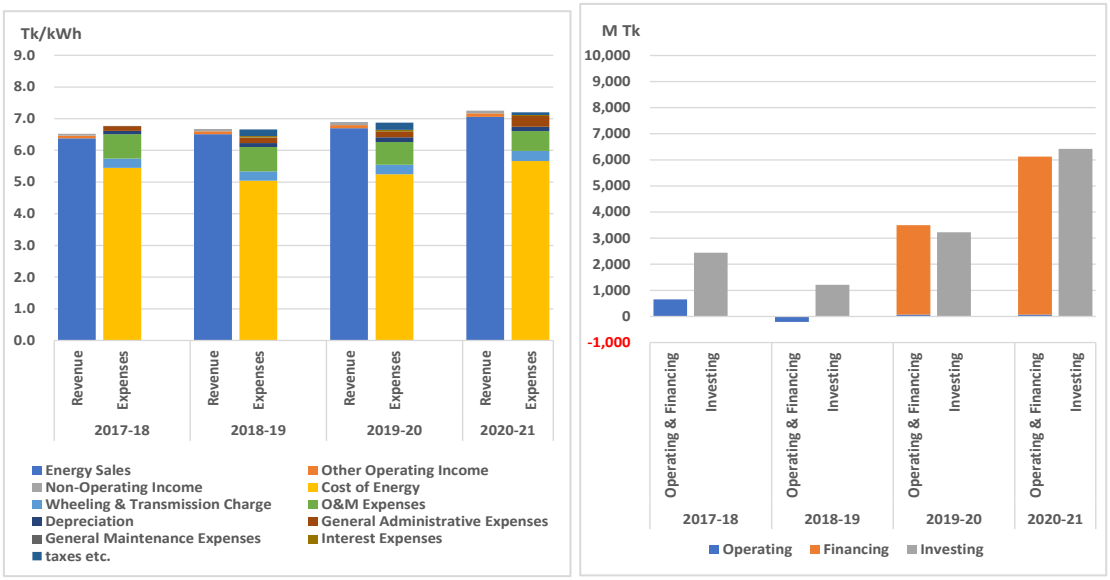
Source: DESCO Annual Reports

Figure 6.4-5 DESCO Financial Status (left: balance per electricity volume, right: cash flow)



Source: WZPDCL Annual Reports

Figure 6.4-6 WZPDCL Financial Status (left: balance per electricity volume, right: cash flow)



Source: NESCO Annual Reports

Figure 6.4-7 NESCO Financial Status (left: balance per electricity volume, right: cash flow)

6.5 Suggestions for the future

Current retail electricity charges are far below the level commensurate with the wholesale supply cost, and even if the market liberalization will be aimed, it is necessary to aim for the situation where the cost is properly recovered and the price signal can be sent.

Regarding generation cost, the gas supply price is in a state of being suppressed to a fairly low level. On the other hand, the operation start of generation facilities with high cost fuel like FO (Furnace Oil) and HSD (High Speed Diesel) has been increasing recently. Also, regarding transmission and distribution cost, capital investment tends to be increased.

In the above market environment, it is necessary to increase retail electricity tariff and to reduce the wholesale supply cost (reducing generation cost and making appropriate power transmission and distribution plan). In particular, it is considered that a wholesale market should be implemented to reduce generation cost and the contract details of individual PPA should be reviewed.

The 8th 5-year plan includes the above-mentioned contents, and the relevant part is quoted below.

<Reference: 8th Five Year Plan July 2020 --June 2025,,p.531.＞[7]

[7]https://oldweb.lged.gov.bd/UploadedDocument/UnitPublication/1/1166/8FYP.pdf

Power subsidy: Even so, the average bulk supply tariff of electricity is less than the average cost of production. The resulting financial losses continue to create pressure on the national budget. BPDB has received budgetary support from the Government due to losses between bulk supply cost and bulk supply tariff. Thus, the electricity budgetary support increased from Taka 44 billion in FY2016 to Taka 74 billion in FY2020. The recent decline in international fuel oil prices could provide some relief for the budget. Yet, in view of the uncertainties, this will not only help lower the financial burden on the Treasury of international oil prices, electricity pricing and subsidy could still continue to pose policy challenges during the Eighth Plan. Full cost recovery for all power and energy products is an important goal for the 8FYP, and it will help conserve energy and support the development of renewable energy.

7. Other Information

7.1 Reports Referenced in Section 5.5 Transmission System Plan

JICA Team would like to thank Power Division and PGCB for sharing the following valuable materials and for hearing and commenting.

1) "Consulting Services for Transmission Planning and Projects Preparatory Studies for PGCB", Power Grid Corporation of India Ltd.

2) "Grid Reliability Study for Integration of Renewable Energy Into The National Grid of Bangladesh", STEAG Energy Services India Pvt. Ltd. in association with Technobin Engineering Services Limited, Bangladesh.

3) "Consulting Services for Feasibility Study for Rearrangement/Alternative Arrangement for Overhead and Underground High Voltage Transmission of Dhaka City and Adjacent Areas", Energoprojekt Entel PLC and BCL Associates Limited Joint Venture.

4) (4) "Summary of PGCB Comments on TWG-2 Meeting (on IEPMP) held on 17-08-2022 at Biddyut Bhaban, Dhaka", PGCB.

7.2 The Area Name and the ZONE Number

The Area Name	The ZONE Number
Barishal	ZONE 1
Cumilla	ZONE 2
Chattogram	ZONE 3
Dhaka	ZONE 4
Khulna	ZONE 5
Mymensing	ZONE 6
Rajshahi	ZONE 7
Rangpur	ZONE 8
Sylhet	ZONE 9

7.3 Zone-wise Demand Forecast

ZONE-wise demand forecasts for 2021 to 2050 were obtained from BPDB on October 16 and 18, 2022, along with demand forecasts by DISCOMs.

The demand shares of each zone to the total demand for each fiscal year is as follows.

ZONEwise peak demand share									
Year	Barishal	Cumilla	Chattogram	Dhaka	Khulna	Mymensingh	Rajshahi	Rangpur	Sylhet
2021	3.295%	8.617%	12.587%	33.978%	11.632%	8.728%	9.679%	6.238%	5.247%
2022	3.250%	8.697%	13.007%	33.881%	11.501%	8.636%	9.646%	6.211%	5.172%
2023	3.193%	8.799%	13.801%	33.720%	11.128%	8.663%	9.530%	6.020%	5.147%
2024	3.164%	8.692%	14.180%	33.951%	10.945%	8.605%	9.422%	5.951%	5.091%
2025	3.089%	8.660%	14.721%	33.804%	10.824%	8.578%	9.361%	5.905%	5.059%
2026	3.070%	8.707%	14.755%	33.797%	10.775%	8.592%	9.350%	5.895%	5.058%
2027	3.048%	8.802%	14.780%	33.751%	10.746%	8.574%	9.344%	5.886%	5.069%
2028	3.045%	8.888%	14.591%	33.756%	10.767%	8.569%	9.376%	5.910%	5.096%
2029	3.023%	8.922%	14.842%	33.612%	10.734%	8.548%	9.344%	5.899%	5.076%
2030	3.011%	8.801%	15.079%	33.491%	10.713%	8.525%	9.373%	5.919%	5.088%
2031	3.012%	8.722%	14.954%	33.627%	10.751%	8.494%	9.429%	5.957%	5.054%
2032	3.005%	8.688%	14.938%	33.623%	10.788%	8.466%	9.488%	5.994%	5.009%
2033	2.990%	8.627%	15.080%	33.718%	10.748%	8.389%	9.494%	6.001%	4.954%
2034	2.996%	8.592%	14.914%	33.812%	10.803%	8.350%	9.567%	6.048%	4.918%
2035	2.994%	8.530%	15.040%	33.741%	10.820%	8.282%	9.622%	6.080%	4.891%
2036	3.000%	8.536%	14.913%	33.688%	10.851%	8.302%	9.701%	6.135%	4.876%
2037	3.003%	8.501%	14.781%	33.722%	10.884%	8.306%	9.770%	6.181%	4.851%
2038	3.009%	8.495%	14.741%	33.635%	10.905%	8.291%	9.857%	6.232%	4.834%
2039	3.014%	8.505%	14.556%	33.691%	10.925%	8.290%	9.919%	6.276%	4.823%
2040	3.018%	8.471%	14.390%	33.793%	10.952%	8.256%	9.987%	6.321%	4.814%
2041	3.018%	8.482%	14.331%	33.837%	10.956%	8.179%	10.034%	6.351%	4.812%
2042	3.026%	8.427%	14.222%	33.829%	10.987%	8.226%	10.094%	6.389%	4.800%
2043	3.026%	8.544%	14.167%	33.750%	10.989%	8.254%	10.098%	6.391%	4.779%
2044	3.034%	8.488%	14.141%	33.723%	11.016%	8.216%	10.128%	6.409%	4.845%
2045	3.040%	8.544%	14.101%	33.706%	11.030%	8.149%	10.146%	6.420%	4.864%
2046	3.042%	8.493%	14.121%	33.692%	11.027%	8.174%	10.155%	6.424%	4.872%
2047	3.036%	8.579%	14.082%	33.715%	11.001%	8.131%	10.159%	6.427%	4.871%
2048	3.027%	8.572%	14.055%	33.824%	10.963%	8.112%	10.155%	6.424%	4.868%
2049	3.012%	8.526%	14.067%	34.005%	10.915%	8.035%	10.155%	6.425%	4.861%
2050	2.998%	8.445%	14.105%	34.192%	10.860%	7.960%	10.157%	6.428%	4.855%

7.4 Zone-wise Power Development Plan

Locations of power sources to be newly established after 2035 are assumed to be unknown.

GW Capacity	1	3			
	Barishal	Chattogram	The Other Zones	Unknown	Total
2021	2.045	2.297	17.161	0.000	21.503
2022	1.957	2.297	17.152	0.000	21.406
2023	2.264	2.460	20.640	0.000	25.364
2024	2.886	4.148	21.824	0.000	28.858
2025	4.130	4.712	23.817	0.000	32.659
2026	4.712	4.942	24.584	0.000	34.238
2027	4.712	6.002	25.231	0.000	35.945
2028	4.712	6.002	25.149	0.000	35.863
2029	4.712	5.952	24.964	0.000	35.628
2030	4.712	5.844	24.856	0.000	35.412
2031	4.602	7.044	25.746	0.000	37.392
2032	5.802	8.244	25.772	0.000	39.818
2033	5.802	8.818	27.619	0.000	42.239
2034	5.802	9.513	29.267	0.000	44.582
2035	7.002	10.449	29.695	0.000	47.146
2036	8.052	11.406	29.647	0.800	49.906
2037	8.052	11.664	30.257	2.550	52.524
2038	7.859	11.601	30.297	4.950	54.707
2039	8.309	11.701	30.155	7.500	57.665
2040	8.309	12.001	30.062	10.050	60.422
2041	8.759	12.801	29.908	11.650	63.118
2042	8.759	12.801	30.003	14.200	65.763
2043	8.539	13.332	30.501	16.050	68.422
2044	8.539	13.332	29.482	19.300	70.653
2045	8.539	13.932	28.768	21.900	73.139
2046	8.539	15.032	28.683	23.350	75.604
2047	8.539	15.032	27.658	27.000	78.229
2048	8.539	14.442	26.246	30.750	79.977
2049	8.539	13.782	25.737	34.400	82.458
2050	8.539	13.782	26.737	35.800	84.858

Appendix E

Primary Energy Supply Plan

Contents

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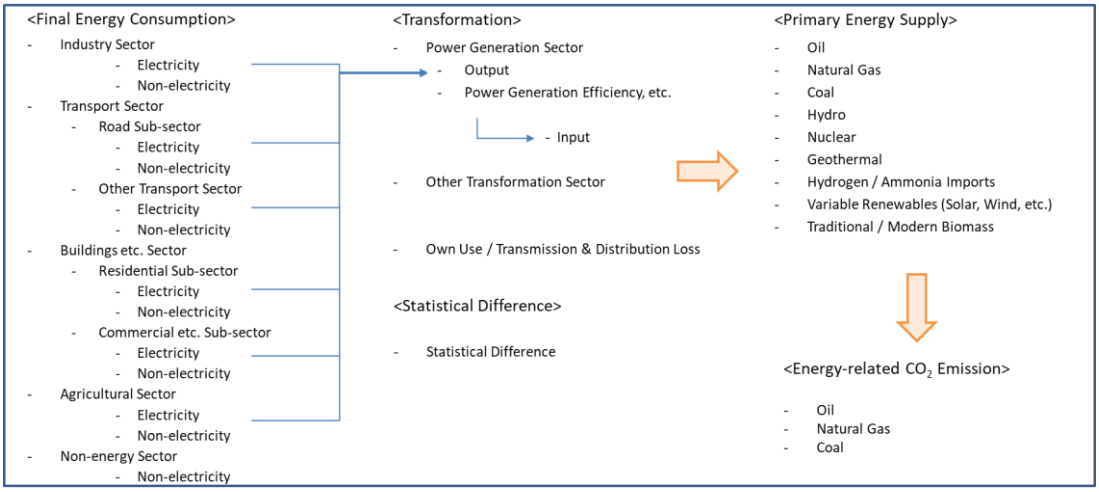
1. Primary Energy Supply Plan

Total primary energy supply (TPES) of Bangladesh is the entire volume of energy supplied in the country. TPES is calculated by summing i) each demand sector's final energy consumption, which was elaborated in Chapter 4, ii) the fuel and energy inputs to the power generation sector, and iii) other conversion sectors such as fuel inputs at refinery and natural gas field production (Figure 1-1).



Source: IEPMP Study Team

Figure 1-1 Compositions of Total Primary Energy Supply

The total primary energy supply (TPES) plan to accommodate the increasing energy demand of Bangladesh is summarized in Table 1-1. TPES is a sum of i) each demand sector's final energy consumption, which is elaborated in Chapter 4, ii) the fuel and energy inputs to the power generation sector, and iii) energy use in other energy transformation sectors such as refineries and natural gas fields.

In the course of economic development, the requirement on TPES will expand 3.9-fold between 2019 and 2050 for the PP2041 GDP case of the Advanced Technologies Scenario (ATS), and 3.1-fold for the In-Between Case. Consumption of traditional fuels such as coal, oil and gas will keep steadily increasing while traditional biomass, notably firewood, will phase out. Fossil energies will continue to be the reliable energy source for economic development with stable availability and established technologies. Among energy sources, natural gas will keep the top share though its share declines sharply giving way to new clean energies. Oil consumption maintains the second position mainly due to increasing demand for motor fuel. Coal consumption may remain in relatively small quantity, though domestic coal supply is expected to play a role in diversifying the supply sources.

Along with the country's commitment to tackle global climate change, clean new energies need to be introduced rapidly; they are non-carbon emission energies such as solar PVs, wind turbines,

modern biomass, ammonia/hydrogen, and fossil fuel burning with CCS. The clean energy ratio including CCS and green power import will exceed 40% of the power generation mix by 2041 as declared by the Prime Minister at COP26 in 2021[1].

Table 1-1 Total Primary Energy Supply Requirement

	otal Primary Energy Supply (million toe				Composition				Average Growth Rate			2019 to
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	2050
PP 2041					%	%	%	%	%	%	%	times
Traditional Biomass	7.9	6.0	3.4	1.5	18.1	8.0	2.9	0.9	-2.5	-4.9	-7.3	0.19
Coal	4.0	13.2	15.2	10.5	9.0	17.8	12.8	6.2	11.6	1.3	-3.3	2.64
Oil	5.7	17.6	30.7	43.4	13.0	23.7	25.9	25.7	10.8	5.2	3.2	7.61
Natural Gas	25.5	30.1	43.7	62.2	58.3	40.4	36.9	36.9	1.5	3.4	3.3	2.44
Power Import (Trad Fuel)	0.4	0.4	0.4	0.4	1.0	0.6	0.4	0.3	0.0	0.0	0.0	1.01
Traditional Fuel	43.5	67.4	93.4	118.0	99.4	90.5	78.9	69.9	4.0	3.0	2.2	2.71
Nuclear	0.0	4.4	8.8	13.1	0.0	5.9	7.4	7.8	-	6.5	3.8	-
Natural Gas - CCS	0.0	0.0	3.7	10.1	0.0	0.0	3.2	6.0	-	-	9.5	-
Hydro	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	2.4	0.0	0.0	1.30
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar PV	0.0	0.7	1.3	2.5	0.1	1.0	1.1	1.5	32.9	5.7	5.9	79.09
Wind - Onshore	0.0	0.1	0.3	0.9	0.0	0.2	0.3	0.6	56.8	7.0	11.1	941.53
Wind - Offshore	0.0	0.0	1.3	3.4	0.0	0.0	1.1	2.0	-	-	8.8	-
Modern Biomass	0.0	0.2	0.3	0.4	0.0	0.2	0.2	0.2	-	4.4	4.0	-
Ammonia	0.0	0.2	1.2	0.6	0.0	0.3	1.0	0.3	-	15.5	-6.4	-
Hydrogen	0.0	0.0	4.9	14.3	0.0	0.0	4.2	8.5	-	-	10.2	-
Power Import (Clean Energy)	0.1	2.4	5.3	5.3	0.3	3.2	4.5	3.2	29.0	7.5	0.0	36.64
Clean Energy	0.2	8.1	27.2	50.8	0.6	10.9	23.0	30.1	37.5	11.6	5.8	207.65
Total	43.8	74.4	118.4	168.9	100.0	100.0	100.0	100.0	4.9	4.3	3.3	3.86
In-Between												
Traditional Biomass	7.9	6.3	4.1	2.2	18.1	8.7	3.8	1.6	-2.1	-3.9	-5.5	0.28
Coal	4.0	16.7	20.4	22.2	9.0	23.0	19.1	16.1	14.0	1.8	0.8	5.60
Oil	5.7	17.3	28.8	39.7	13.0	23.8	26.9	28.9	10.6	4.7	3.0	6.96
Natural Gas	25.5	25.6	32.9	30.3	58.3	35.2	30.7	22.0	0.0	2.3	-0.7	1.19
Power Import (Trad Fuel)	0.4	0.4	0.4	0.4	1.0	0.6	0.4	0.3	0.0	0.0	0.0	1.01
Traditional Fuel	43.5	66.4	86.6	94.8	99.4	91.3	80.9	68.9	3.9	2.4	0.8	2.18
Nuclear	0.0	4.1	8.2	8.2	0.0	5.7	7.7	6.0	-	6.5	0.0	-
Natural Gas - CCS	0.0	0.0	1.9	10.1	0.0	0.0	1.7	7.4	-	-	16.6	-
Hydro	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	2.4	0.0	0.0	1.30
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar PV	0.0	0.7	1.3	2.5	0.1	1.0	1.3	1.8	32.9	5.7	5.9	79.09
Wind - Onshore	0.0	0.1	0.3	0.9	0.0	0.2	0.3	0.7	56.8	7.0	11.1	941.53
Wind - Offshore	0.0	0.0	1.3	3.4	0.0	0.0	1.3	2.5	-	-	8.8	-
Modern Biomass	0.0	0.2	0.3	0.4	0.0	0.2	0.2	0.3	-	4.4	4.0	-
Ammonia	0.0	0.0	1.2	1.6	0.0	0.0	1.1	1.2	-	-	3.2	-
Hydrogen	0.0	0.0	3.1	10.5	0.0	0.0	2.9	7.6	-	-	11.7	-
Power Import (Clean Energy)	0.1	1.9	4.2	0.0	0.3	2.7	3.9	0.0	26.6	7.3	-100.0	0.00
Clean Energy	0.2	7.2	21.9	37.8	0.6	9.9	20.4	27.5	35.9	10.7	5.1	154.38
Total	43.8	72.7	107.0	137.6	100.0	100.0	100.0	100.0	4.7	3.6	2.3	3.14

Source: IEPMP Study Team

It will be a significant challenge for Bangladesh to expand its energy infrastructure to enable this Master Plan on both traditional fossil fuels as well as emerging new energies. To expand both supply and demand of conventional fuels such as coal, oil and natural gas, substantial investment must be made steadily by securing a large amount of funds. In addition, new energies should also be introduced proactively and at high speed although some of them are still in the infancy stage. To enable this, not only the fund and land but also a wide range of new technologies must be introduced. In addition to preparation of attractive business circumstance, human capacity development will be another key to materialize this plan.

Energy supply plans, anticipated issues and necessary policies toward 2050 are discussed below on each energy source, while assessment on necessary investment amount is discussed in Chapter 7.

[1] https://unfccc.int/sites/default/files/resource/BANGLADESH_cop26cmp16cma3_HLS_EN.pdf

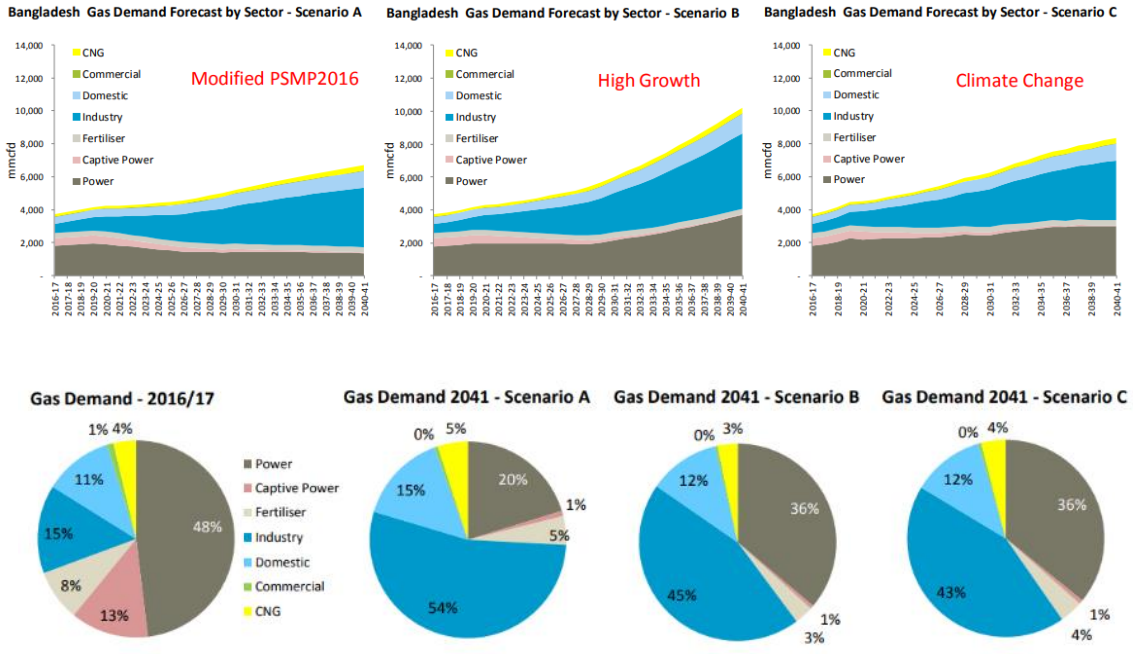
2. Natural Gas

2.1 Review of GSMP 2017

In this section, the GSMP 2017 is reviewed, and later the current supply plan is described in each of the following sections.

a. Gas demand forecast

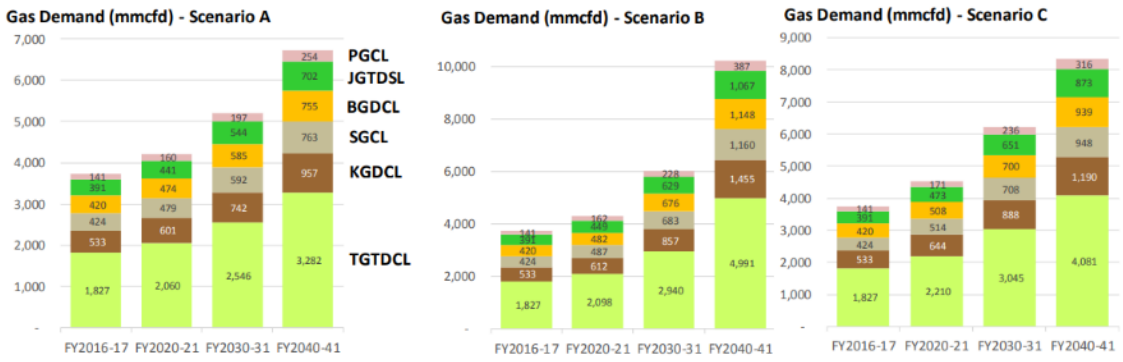
In the Gas Supply Master Plan (GSMP) 2017, three scenarios are set for demand forecast. Scenario A is the "PSMP 2016 Review", Scenario B is the "High Growth Scenario", and Scenario C is the "Climate Change Scenario". Gas demand in 2041 is estimated for Scenario A at 6,713 million cubic feet per day (MMcfd) based on the PSMP 2016, for Scenario B at 10,208 MMcfd, and for Scenario C at 8,346 MMcfd. Figure 2-1 shows the gas demand forecast for each regional gas company. GSMP considered that there was a great deal of uncertainty regarding the economic development of each demand sector and geographical regions, which would impact their demand outlook.



Source: GSMP 2017

Figure 2-1 Gas Demand Forecast by Sector: GSMP 2017

Figure 2-2 shows the gas demand forecast for each regional gas company. They consider that there is a great deal of uncertainty regarding the economic development of each sector and region that impacts their outlooks compiled here.

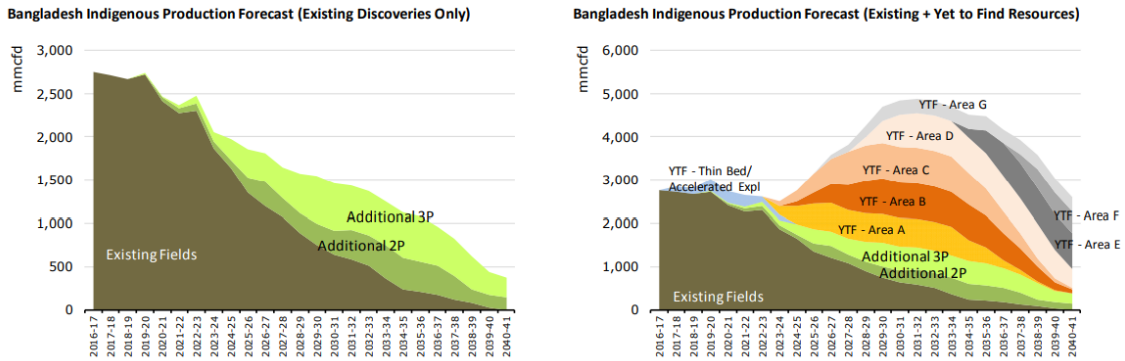


Source: GSMP 2017

Figure 2-2 Gas Demand Forecast by Regional Gas Company: GSMP 2017

b. Domestic natural gas production

With regard to the potential of domestic production, GSMP2017 also sets multiple production scenarios. The plan points out that if the development of new gas fields is not successful, a large amount of natural gas import will become necessary. For instance, in Scenario C, where gas demand evolves moderately, about 4,500 MMcfd of gas import will be required in 2030 if new gas field development is not successful. Such large amount of import will require precise analysis on the future LNG availability, gas infrastructure development and legislative and regulatory arrangements.



Source: GSMP 2017

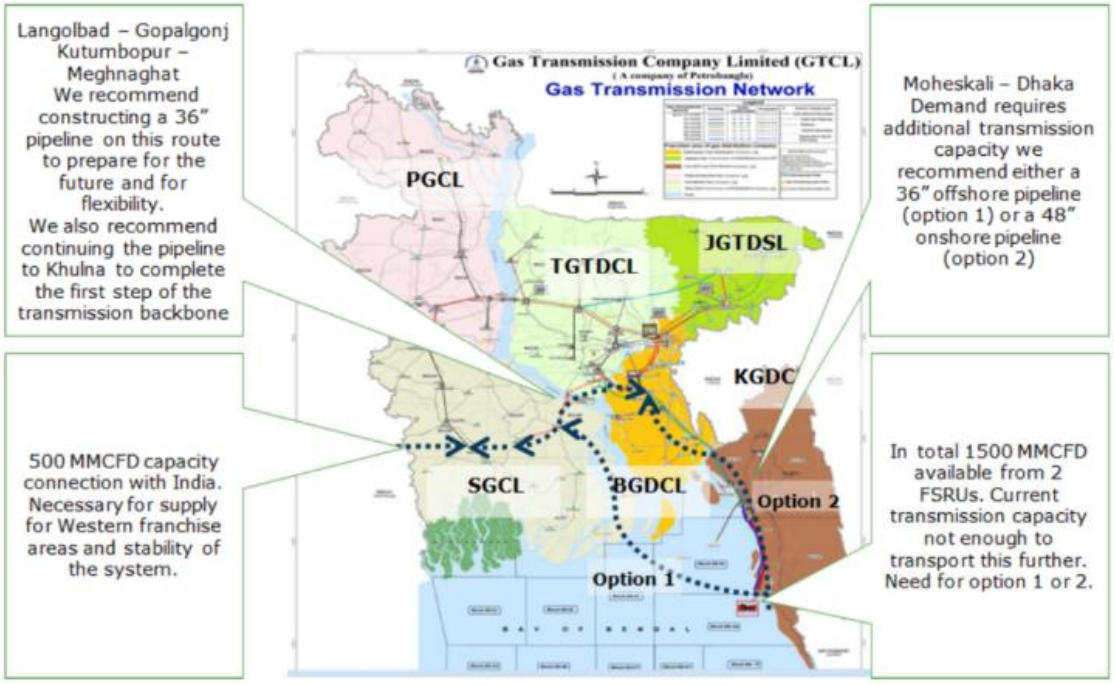
Figure 2-3 Gas Production Potential: GSMP 2017

c) Infrastructure Plan for Gas Transmission

On infrastructure planning, GSPM2017 notes that the existing pipeline transportation capacity is around 2,500 MMcfd, and the capacity needs to be expanded to meet the increasing demand in the country as a whole, especially in the western part, in view of the substantial introduction of LNG. The plan also states that the pipe diameter should be increased as much as possible because the capacity of a gas pipe is proportional to the 2.5 power of the pipe diameter, whereas the cost is simply proportional. It should also be noted that, because there are numerous river crossings in

Bangladesh, installing large diameter pipes may turn out to be a costly challenge.

The GSMP 2017 recommends the following short-, medium- and long-term pipeline development plans based on the gas transportation model developed and analyzed.



Source: Rambol, GSMP2017

Figure 2-4 Short Term Pipeline Enhancement Recommendations of GSMP (short term)

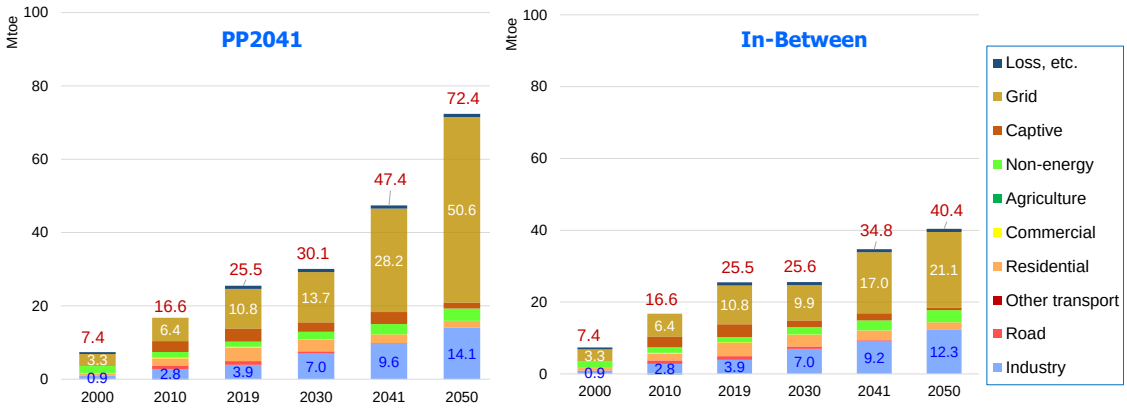
An offshore pipeline directly from Matarbari to the west is favored because (i) gas can be pressurized there to send a large volume, and (ii) it can be used as a hub for future development of offshore gas fields. A 36-inch offshore and 42-inch onshore extension from Moheskhali to Gopalgonj, Khulna is proposed.

There is also an issue on the locations for gas-fired power plants. Natural gas can be transported by pipeline to the demand site and used as a generation fuel, or natural gas can be converted to electricity at a natural gas fired power plant near the LNG receiving site and the generated electricity can be transmitted to the demand site. For example, a 42-inch pipeline can carry 1,000 MMcfd of gas, which can supply gas to a 15,000 MW gas-fired power plant. On the other hand, a 400 kV transmission line is capable of transmitting 500 to 1,000 MW of electric energy. Geographical conditions and the relative difficulty to develop such different types of infrastructure should be considered in making an infrastructure development plan.

2.2 Natural Gas Demand Outlook

Natural gas demand in Bangladesh is forecasted to increase significantly. It will expand 2.8-fold between 2019 and 2050 for the PP2041 GDP case, and 1.7-fold for the In-Between case.

Power generation will be the largest demand sector followed by the industry sector. This is because the high economic growth will be driven by accelerating industrial development and the sophisticated future industries will be mainly powered by electricity. In addition, natural gas is preferred among fossil energies as a low carbon fuel.



Source: IEPMP Study Team

Figure 2-5 Natural Gas Demand Outlook

It is noteworthy that natural gas consumption is projected to decrease in the transport, residential and commercial sectors in accordance with the policy of the Bangladesh government to curb city gas consumption for CNG vehicles, domestic and commercial use. By improving energy efficiency of gas appliances, this movement will be even accelerated.

In addition, in the In-Between case, natural gas demand for power generation will be stagnant through 2030 because new coal-fired power plants and nuclear power plants will start operation one after another. They are all large plants, so their start-up timing must be carefully monitored to finetune the fuel requirement of other type of power plants.

As Bangladesh pushes forward modernization of the country, traditional biomass, notably firewood used at household, will be replaced by gaseous fuels. Under the above policy, the rapidly increasing demand for modern fuel may be supplied with LPG, but a large number of LPG cylinders needs to be delivered in the congested metropolitan areas which will be enlarging along with urbanization. To avoid problems of traffic congestion and safety caused by such cylinder deliveries, it will be more prudent to consider rehabilitation and new construction of city gas systems in the metropolitan areas as a part overall city development plan. This issue must be looked into more in detail on the technical and socio-economic aspects of various options to set out an appropriate balance of city gas, community gas, and LPG.

In the non-energy sector, natural gas will also be used as the feedstock for fertilizer and chemical industries.

All in all, natural gas requirement will exceed 5.3 billion standard cubic feet per day (scfd) in 2041 in the PP2041 GDP growth case, and 4.0 billion scfd in the In-Between GDP growth case.

Table 2-1 Natural Gas Demand Outlook

	FY2030-31	FY2040-41	-	FY30-31	FY40-41	-	19-30	30-40	-	-
Petrobangla (Scenario-3)	Mmtoe	Mmtoe	Mmtoe	%	%	%	%	%	%	
Power	22.9	32.9	-	41.2	48.2	-	4.0	3.7	-	-
Fertizer	2.8	2.8	-	5.1	4.1	-	0.0	0.0	-	-
Captive Power	12.4	13.9	-	22.4	20.3	-	6.5	1.1	-	-
Industry	11.5	12.7	-	20.7	18.6	-	6.8	1.1	-	-
Domestic	4.0	4.0	-	7.2	5.8	-	0.0	0.0	-	-
CNG	1.6	1.6	-	2.9	2.3	-	0.6	0.1	-	-
Commercial	0.3	0.3	-	0.5	0.4	-	0.8	0.0	-	-
Tea	0.0	0.0	-	0.1	0.0	-	2.1	0.0	-	-
Total	55.5	68.2	-	100	100	-	4.2	2.1	-	-
billion scfd	6.24	7.68	-	(NCV @ 8,600kcal/m3)						
	Total Primary Energy Supply			Composition			Average Growth Rate			2019 to 2050
	2030	2041	2050	2030	2041	2050	19-30	30-41	41-50	
PP 2041	Mmtoe	Mmtoe	Mmtoe	%	%	%	%	%	%	times
Industry (incle. Tea)	7.0	9.6	14.1	23.2	20.2	19.5	5.4	2.9	3.5	3.59
Transport (CNG, etc.)	0.6	0.2	0.0	2.1	0.4	0.0	-4.5	-10.2	-100.0	0.00
Residential (Domesctic)	3.2	2.4	1.8	10.6	5.1	2.5	-1.4	-2.5	-2.7	0.48
Commercial	0.1	0.1	0.1	0.4	0.2	0.1	-4.3	-3.0	-2.8	0.32
Agriculture	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	1.00
Non-Energy (Fertilizer, etc.)	2.0	2.8	3.3	6.7	5.8	4.6	3.5	2.9	1.7	2.43
Power	16.3	31.5	52.2	54.2	66.4	72.2	1.1	6.2	4.7	3.63
Grid	13.7	28.2	50.6	45.7	59.5	70.0	2.2	6.8	5.5	4.67
Captive	2.5	3.3	1.6	8.5	6.9	2.2	-3.0	2.3	-6.3	0.45
Loss, etc.	0.9	0.9	0.9	2.9	1.8	1.2	0.0	0.0	0.0	1.00
Total	30.1	47.4	72.4	100	100	100	1.5	4.2	3.9	2.84
billion scfd	3.38	5.33	8.14	(NCV @ 8,600kcal/m3)						
In-Between										
Industry (incle. Tea)	7.0	9.2	12.3	27.3	26.6	30.4	5.4	2.6	2.6	3.14
Transport (CNG, etc.)	0.6	0.2	0.0	2.4	0.5	0.0	-4.5	-10.2	-100.0	0.00
Residential (Domesctic)	3.3	2.6	2.1	12.8	7.6	5.1	-1.2	-2.0	-2.2	0.56
Commercial	0.1	0.1	0.1	0.4	0.2	0.1	-4.3	-3.2	-2.9	0.31
Agriculture	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	1.00
Non-Energy (Fertilizer, etc.)	2.0	2.8	3.3	7.8	7.9	8.2	3.5	2.9	1.7	2.43
Power	11.7	19.0	21.8	45.7	54.6	53.9	-1.9	4.5	1.3	1.51
Grid	9.9	17.0	21.1	38.6	48.9	52.2	-0.8	5.1	2.0	1.95
Captive	1.8	2.0	0.7	7.1	5.7	1.7	-5.9	0.7	-9.4	0.19
Loss, etc.	0.9	0.9	0.9	3.4	2.5	2.1	0.0	0.0	0.0	1.00
Total	25.6	34.8	40.4	100	100	100	0.0	2.8	1.4	1.58
billion scfd	2.88	3.91	4.55	(NCV @ 8,600kcal/m3)						

Note: 1 MMcfd: 1,000,000cf*365days/35.3147(cf/m3)*(8,600/10,000 kcal/m3)/1,000,000(kt/kg) → 1 MMcfd= 8.8887ktoe

Source: IEPMP Study Team, Petrobangla "Committee Report on Gas Demand and Supply Forecast", 21 March 2019

It should be noted that the above projections for ATS PP2041 case and In-Between case are significantly lower than the projections made by Petrobangla as shown in Table 2-1. While the ATS cases assume very strong energy efficiency and conservation efforts aiming at a lower carbon economy, demand estimations made by Petrobangla and Hydrocarbon Unit as explained later may be business as usual (BAU) projections. However, since the difference is significant, in addition to the database, every aspect of the gas demand trend needs to be carefully reviewed in the course of formulating the natural gas development plan.

Table 2-2 Natural Gas Demand Outlook by year (PP2041 case)

	PP2041 case (in mmcfd)													
	Power	Grid	Captive	Industry	Road	Other transp	Residential	Commercial	Agriculture	Non-energy	Loss, etc.	total	Others	Total
2019	1,620	1,219	401	441	116	0	419	21	3	154	97	2,870	0	2,870
2020	1,543	1,191	352	453	115	0	436	20	3	151	97	2,819	-0	2,819
2021	1,545	1,196	349	473	115	0	440	19	3	151	97	2,842	0	2,842
2022	1,636	1,286	350	532	114	0	427	18	3	159	97	2,987	0	2,987
2023	1,476	1,129	347	588	114	0	421	18	3	168	97	2,884	0	2,884
2024	1,145	800	345	636	109	0	412	17	3	176	97	2,595	-0	2,595
2025	1,088	759	329	672	101	0	403	16	3	185	97	2,566	-0	2,566
2026	1,192	879	313	701	94	0	394	16	3	193	97	2,690	-0	2,690
2027	1,300	1,001	299	725	88	0	385	15	3	201	97	2,814	-0	2,814
2028	1,467	1,182	285	747	82	0	376	15	3	209	97	2,995	-0	2,995
2029	1,648	1,376	272	766	76	0	367	14	3	217	97	3,188	-0	3,188
2030	1,833	1,573	260	786	69	0	358	13	3	226	97	3,384	-0	3,384
2031	1,911	1,657	255	804	64	0	350	13	3	234	97	3,474	-0	3,474
2032	2,117	1,868	249	822	58	0	341	12	3	241	97	3,691	-0	3,691
2033	2,195	1,952	242	840	53	0	333	12	3	249	97	3,782	-0	3,782
2034	2,281	2,045	236	860	48	0	324	12	3	257	97	3,882	-0	3,882
2035	2,389	2,160	229	882	43	0	316	12	3	265	97	4,008	-0	4,008
2036	2,623	2,401	222	907	39	0	308	11	3	273	97	4,261	-0	4,261
2037	2,780	2,565	216	934	35	0	301	11	3	280	97	4,440	-0	4,440
2038	3,052	2,843	209	964	31	0	293	10	3	288	97	4,739	-0	4,739
2039	3,358	3,156	202	998	28	0	285	10	3	295	97	5,074	-0	5,074
2040	3,234	3,039	196	1,037	24	0	278	10	3	303	97	4,985	-0	4,985
2041	3,542	3,353	189	1,079	21	0	271	9	3	310	97	5,333	-0	5,333
2042	3,774	3,593	181	1,127	18	0	263	9	3	317	97	5,609	-0	5,609
2043	4,106	3,942	164	1,177	16	0	256	9	3	325	97	5,988	-0	5,988
2044	4,184	4,039	145	1,232	13	0	248	9	3	332	97	6,117	-0	6,117
2045	3,837	3,712	125	1,288	11	0	241	8	3	339	97	5,823	-0	5,823
2046	4,267	4,161	105	1,347	8	0	233	8	3	346	97	6,308	-0	6,308
2047	4,631	4,546	85	1,406	6	0	225	8	3	353	97	6,729	-0	6,729
2048	5,182	5,119	63	1,466	4	0	217	7	3	360	97	7,337	-0	7,337
2049	5,517	5,474	43	1,526	2	0	209	7	3	367	97	7,727	-0	7,727
2050	5,877	5,855	22	1,584	0	0	201	7	3	374	97	8,142	-0	8,142

Note 1: Demand for 2020 and after are estimated result rather than actual data.

Note 2: Agriculture sector represent the demand for tea industry.

Source: IEPMP Study Team

Bangladesh economy bounced back quickly after the downturn caused by Covid-19. As a result, natural gas demand, particularly for power generation, recovered faster than estimated. Taking this into consideration, Table 2-2A shows the adjusted natural gas demand for the ATS/PP2041 case. In this table, estimated results for 2022 is replaced by the actual data recorded in 2022. After 2023, differences between the estimated results and the actual data observed in 2022 are simply added on to the estimated results for each year. The adjusted total natural gas demand will reach 6,397 MMcfd in 2041 which is 1,064 MMcfd larger than that of the previously estimated results (Table 2-2).

Table 2-2A Adjusted Natural Gas Demand Outlook by year (PP2041 case)

	PP2041 (mmcfd)									
	Power	Grid	Captive	Industry (incl. Tea)	Road	Other transport	Residential	Commercial	Non-energy	total
2022	2,500	1,817	683	818	131	0	375	24	203	4,051
2023	2,340	1,660	681	874	130	0	369	24	212	3,949
2024	2,009	1,331	679	922	125	0	360	23	220	3,659
2025	1,952	1,290	662	958	118	0	351	22	228	3,630
2026	2,056	1,409	647	987	111	0	342	22	237	3,755
2027	2,164	1,532	632	1,011	105	0	333	21	245	3,878
2028	2,331	1,712	619	1,032	98	0	324	20	253	4,059
2029	2,512	1,907	606	1,052	93	0	315	19	261	4,253
2030	2,697	2,103	593	1,072	86	0	306	19	269	4,448
2031	2,776	2,188	588	1,090	80	0	297	18	277	4,538
2032	2,981	2,399	583	1,108	75	0	289	18	285	4,756
2033	3,059	2,483	576	1,126	70	0	280	18	293	4,846
2034	3,145	2,576	569	1,146	65	0	272	18	301	4,946
2035	3,254	2,691	562	1,168	60	0	264	17	309	5,072
2036	3,487	2,931	556	1,192	56	0	256	17	316	5,325
2037	3,644	3,095	549	1,220	52	0	248	17	324	5,505
2038	3,916	3,374	542	1,250	48	0	241	16	331	5,803
2039	4,222	3,686	536	1,284	45	0	233	16	339	6,138
2040	4,098	3,569	529	1,322	41	0	226	15	346	6,049
2041	4,406	3,884	522	1,365	38	0	219	15	354	6,397
2042	4,639	4,124	514	1,412	35	0	211	15	361	6,673
2043	4,970	4,472	498	1,463	32	0	204	14	368	7,052
2044	5,048	4,570	478	1,517	30	0	196	14	376	7,182
2045	4,701	4,243	458	1,574	27	0	189	14	383	6,887
2046	5,131	4,692	439	1,632	25	0	181	14	390	7,373
2047	5,495	5,077	418	1,692	23	0	173	13	397	7,793
2048	6,046	5,650	397	1,752	21	0	165	13	404	8,401
2049	6,381	6,005	376	1,811	19	0	157	13	411	8,792
2050	6,741	6,386	355	1,870	17	0	149	12	417	9,206

Note 1: Demand previously estimated for 2022 is adjusted to the actual data observed for 2022.

Note 2: “Agriculture”, “Losses, etc.” and “Others” are omitted since there is no such categories in given actual data in 2022.

Source: IEPMP Study Team

Previous Forecast of Domestic Gas Demand

The Committee Report on Gas Demand and Supply Forecast (March 2019) of Petrobangla forecasts the long-term gas demand in three scenarios as shown in Table 2-3~5. According to the Scenario-1 of the projection, gas demand would increase by 6.0% annually over 10 years from FY 2020-21 and 3.9% annually over 20 years through FY2040-41, for a total increase of 4,730 MMcfd. The electricity and industrial sectors contribute significantly to the demand increase, with the former estimated to increase by 1,970 MMcfd for the grid power and 1,354Mmcfd for the captive power, and the latter by 1,344 MMcfd.

Table 2-3 Domestic Gas Demand Forecast: Petrobangla (2019) Scenario 1

Unit: MMscfd

Year	Power	Fertilizer	Captive Power	Industry	Domestic	CNG	Commercial	Tea	Total
2018-19	1,605	317	573	519	448	165	29	2.6	3,658
2019-20	1,667	317	697	626	448	167	31	2.7	3,955
2020-21	1,731	317	779	699	448	168	33	3,4	4,178
2021-22	2,078	317	899	804	448	169	34	3.4	4,752
2022-23	2,078	317	1,008	899	448	171	34	3.4	4,957
2023-24	2,225	317	1,130	1,006	448	172	34	3.4	5,335
2024-25	2,054	317	1,240	1,122	448	179	34	3.4	5,397
2025-26	2,205	317	1,359	1,247	448	186	34	3.4	5,800
2026-27	2,448	317	1,481	1,374	448	193	34	3.4	6,298
2027-28	2,609	317	1,595	1,494	448	200	34	3.4	6,700
2028-29	2,576	317	1,701	1,608	448	207	34	3.4	6,895
2029-30	2,572	317	1,801	1,717	448	214	34	3.4	7,107
2030-31	2,572	317	1,899	1,825	448	221	34	3.4	7,319
2031-32	2,670	317	1,999	1,934	448	228	34	3.4	7,633
2032-33	2,836	317	2>017	1,949	448	228	34	3.4	7,833
2033-34	2,953	317	2,038	1,966	448	228	34	3.4	7,988
2034-35	3,065	317	2,057	1,982	448	228	34	3.4	8,134
2035-36	3,069	317	2,077	1,998	448	228	34	3.4	8,174
2036-37	3,033	317	2,091	2,009	448	228	34	3.4	8,163
2037-38	3,147	317	2,105	2,021	448	228	34	3.4	8,303
2038-39	3,342	317	2,114	2,028	448	228	34	3.4	8,515
2039-40	3,552	317	2,124	2,036	448	228	34	3.4	8,742
2040-41	3,701	317	2,133	2,043	448	228	34	3.4	8,908

Source: Petrobangla “Committee Report on Gas Demand and Supply Forecast”, 21 March 2019

Table 2-4 Domestic Gas Demand Forecast: Petrobangla (2019) Scenario 2

Unit: MMscfd

Year	Power	Fertilizer	Captive Power	Industry	Domestic	CNG	Commercial	Tea	Total
2018-19	1,605	317	573	519	448	165	29	2.6	3,658
2019-20	1,667	317	697	626	448	167	31	2.7	3,955
2020-21	1,731	317	779	699	448	168	33	3.4	4,178
2021-22	2,078	317	899	804	448	169	34	3.4	4,752
2022-23	2,078	317	1,006	899	448	171	34	3.4	4,957
2023-24	2,225	317	1,130	1,006	448	172	34	3.4	5,335
2024-25	2,054	317	1,151	1,023	448	172	34	3.4	5,203
2025-26	2,205	317	1,183	1,048	448	172	34	3.4	5,411
2026-27	2,448	317	1,215	1,075	448	172	34	3.4	5,713
2027-28	2,609	317	1,241	1,096	448	172	34	3.4	5,921
2028-29	2,576	317	1,259	1,111	448	172	34	3.4	5,920
2029-30	2,572	317	1,271	1,120	448	172	34	3.4	5,937
2030-31	2,572	317	1,280	1,128	448	172	34	3.4	5,954
2031-32	2,670	317	1,292	1,137	448	172	34	3.4	6,074
2032-33	2,836	317	1310	1,153	448	172	34	3.4	6,274
2033-34	2,953	317	1,331	1,170	448	172	34	3.4	6,429
2034-35	3,065	317	1,350	1,135	448	172	34	3.4	6,575
2035-36	3,069	317	1,370	1,201	448	172	34	3.4	6,615
2036-37	3,033	317	1,384	1,213	448	172	34	3.4	6,504
2037-38	3,147	317	1,398	1,224	448	172	34	3.4	6,744
2038-39	3,342	317	1,407	1,232	448	172	34	3.4	6,556
2039-40	3,552	317	1,416	1,240	448	172	34	3.4	7,123
2040-41	3,701	317	1/426	1,247	448	172	34	3.4	7,349

Source: ditto

Table 2-5 Domestic Gas Demand Forecast: Petrobangla (2019) Scenario 3

Unit: MMscfd

Year	Power	Fertilizer	Captive Power	Industry	Domestic	CNG	Commercial	Tea	Total
2018-19	1,605	317	573	519	448	165	29	2.6	3,658
2019-20	1,667	317	697	626	448	167	31	2.72	3,955
2020-21	1,731	317	779	699	448	168	33	3.42	4,178
2021-22	2,078	317	899	804	448	169	34	3.42	4,752
2022-23	2,078	317	1,008	899	448	171	34	3.42	4,957
2023-24	2,225	317	1,130	1,006	448	172	34	3.42	5,335
2024-25	2,054	317	1,168	1,046	448	173	34	3.42	5,243
2025-26	2,205	317	1,217	1,094	448	174	34	3.42	5,492
2026-27	2,448	317	1,266	1,144	448	175	34	3.42	5,835
2027-28	2,609	317	1,309	1,188	448	175	34	3.42	6,084
2028-29	2,576	317	1,344	1,226	448	176	34	3.42	6,124
2029-30	2,572	317	1,372	1,258	448	177	34	3.42	6,182
2030-31	2,572	317	1,398	1,289	448	178	34	3.42	6,240
2031-32	2,670	317	1,427	1,322	448	179	34	3.42	6,400
2032-33	2,836	317	1446	1,337	448	179	34	3.42	6,600
2033-34	2,953	317	1,467	1,354	448	179	34	3.42	6,755
2034-35	3,065	317	1,485	1,369	448	179	34	3.42	6,901
2035-36	3,069	317	1,505	1,385	448	179	34	3.42	6,941
2036-37	3,033	317	1,519	1,397	448	179	34	3.42	6,930
2037-38	3,147	317	1,533	1,408	448	179	34	3.42	7,070
2038-39	3,342	317	1,542	1,416	448	179	34	3.42	7,282
2039-40	3,552	317	1,552	1,424	448	179	34	3.42	7,509
2040-41	3,701	317	1,561	1,431	448	179	34	3.42	7,675

Source: ditto

Hydrocarbon Unit (HCU) developed a medium- to long-term gas demand outlook for Bangladesh for the decade 2020 to 2030 in its “Energy Scenario of Bangladesh 2019-20” report. As of 2020, the domestic gas demand was about 3,508 MMcfd and it was expected to increase by 1,114 MMcfd over the decade to 4,622 MMcfd in 2030.

Table 2-6 Domestic Gas Demand Projection: HCU Version

(Unit: MMcfd)

Year	Power	Fertilizer	Captive Power	Industry	Domestic	CNG	Commercial & Tea	**Total**
2019	1,284	316	480	710	425	139	38	**3,392**
2020	1,334	316	480	776	425	139	38	**3,508**
2021	1,384	316	480	842	425	139	38	**3,624**
2022	1,662	316	432	908	425	130	38	**3,911**
2023	1,786	316	389	974	420	125	38	**4,048**
2024	1,780	316	350	1,040	431	120	38	**4,075**
2025	1,803	316	315	1,106	442	110	38	**4,130**
2026	1,844	317	283	1,172	453	100	38	**4,207**
2027	1,958	319	255	1,238	465	100	38	**4,373**
2028	2,087	321	230	1,304	476	75	38	**4,531**
2029	2,060	323	207	1,370	488	75	38	**4,561**
2030	2,058	325	186	1,440	500	75	38	**4,622**

Source: Hydrocarbon Unit

2.3 Domestic Production Prospect

As mentioned in Appendix-A, domestic exploration activities are mostly limited to the eastern fold belt and its surrounding areas, but the Fore deep region in the central part of the country is also considered to have high potential for hydrocarbon resource exploration. Therefore, according to the Hydrocarbon Unit (HCU) report (2021), deep hydrocarbon geological potential exploration in the Fore deep region, where exploration has been lagging, is being planned; two 2D seismic projects have been approved by the government through the Gas Development Fund. In addition, 3D seismic data is being collected in the Fenchuganj and Rupganj gas fields in 2018-19 with the objective of identifying suitable areas for drilling new gas fields. Furthermore, a joint study by BAPEX and Japan's Mitsui Oil Exploration Company Ltd (MOECO) has identified 20 potential gas structures in Blocks 8 and 11.

Various forms of unconventional domestic gas resources and technology, such as coal bed methane (CBM), shale gas, and underground coal gasification (UCG), are also being explored; Petrobangla is conducting a project to assess the CBM potential of the Jamalgonj coal mine, the country's largest and deepest coal deposit. Petrobangla is implementing a project to assess the CBM potential of the Jamalgonj coal mine, the largest and deepest coal deposit in the country. And the Hydrocarbon Unit (HCU) is conducting a feasibility study on shale gas potential in the country. However, as discussed in Chapter 4, CBM at Jamalgonj is now deemed not viable.

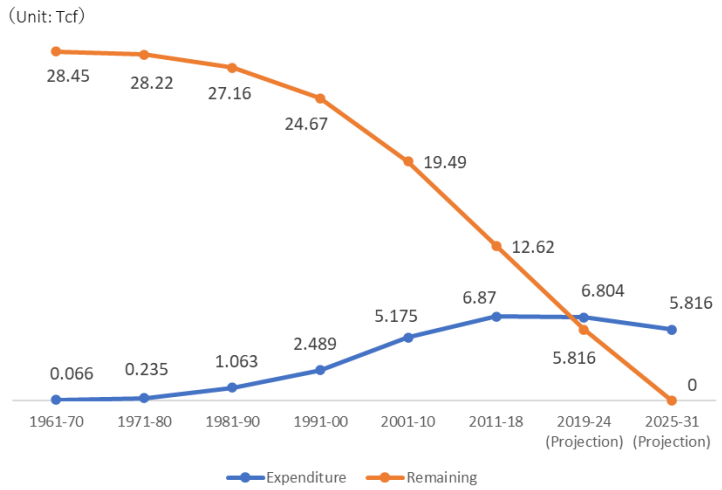
As of the end of December 2020, Gas Initially in Place (GIIP) is estimated to be 39.8 trillion cubic feet (Tcf) and Proven and Probable (2P) gas reserves are estimated to be 28.3 Tcf.

Table 2-7 Domestic Gas Reserves: As at December 2020

	GIIP	Recoverable Reserves			
		1P	2P	3P	Total
	Tcf	Tcf	Tcf	Tcf	Tcf
Producing	36.9	20.5	6.1	1.3	27.9
Non-Producing	0.7	0.05	0.00	0.0	0.05
Production Suspended	2.2	1.0	0.3	0.2	1.5
Total	39.8	21.5	6.8	1.2	29.5

Source: Hydrocarbon Unit

If no new gas fields are discovered and additional gas reserves are not secured, it is estimated that gas resources will be exhausted by 2025-2031 (Figure 2-6).



Source: Hydrocarbon Unit (HCU)

Figure 2-6 Forecast of future gas resources

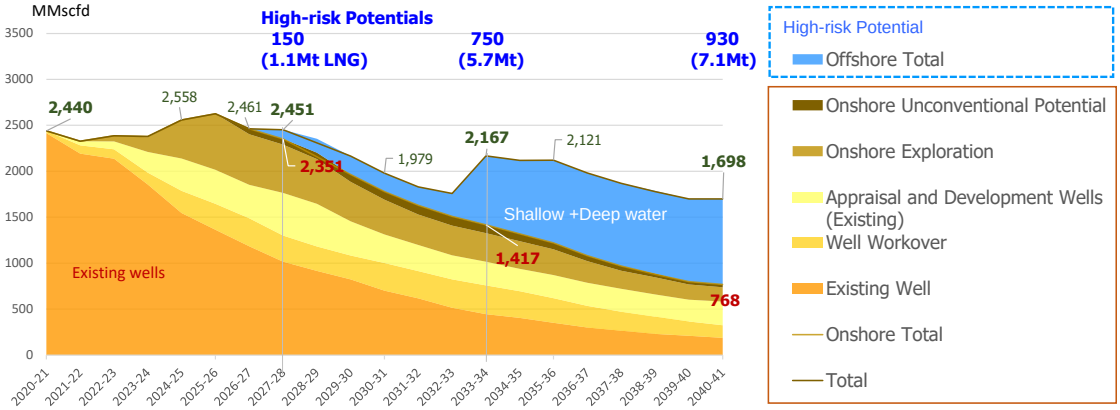
Domestic natural gas production is forecasted by Petrobangla (up to FY 2040-41) as shown in Figure 2-7. Gas production is projected to decrease from the present 2.4 billion scfd to 2.2 billion scfd in 2041. Production from the existing gas fields will decline as the reserves depletes with production. Activities such as workover on the existing wells and drilling of appraisal and development wells on the existing gas fields as well as the onshore thin-bed formation, an unconventional play, will bring some additional production to mitigate this declining trend, but far less than enough to reverse it.

Gas production is also expected from offshore shallow and deepwater blocks. These plays have not been tested by drilling and verified as commercially viable through feasibility study. Such activities will require sophisticated technology on seismic analysis, drilling and production and hence huge fund. Thus, they may be ranked as high-risk potential. With production from offshore blocks, natural gas production is projected to almost recover to the present level in the 2030s.

Table 2-8 Forecast of Domestic Natural Gas Production

	2020-21	2030-31	2040-41	2050-51
	MMcfd	MMcfd	MMcfd	MMcfd
Existing Well	2,415	701	188	40
Well Workover	25	301	136	140
Appraisal and Development Wells (Existing)	0	311	258	160
Onshore Exploration	0	377	156	100
Onshore Unconventional Potential	0	90	30	30
Onshore Total	2,440	1,779	768	470
Offshore: Shallow Water	0	200	250	250
Offshore: Deepwater	0	0	680	980
Offshore Total	0	200	930	1,230
Total	2,440	1,979	1,698	1,700

Source: Petrobangla, see notes to Figure 2-6-



Note: Natural gas production up to 2040 (FY2040-41) is made by Petrobangla, and the trend is extended to 2050 by the Study Team.

Figure 2-7 Forecast of Domestic Gas Production

Table 2-9 Natural Gas Production Outlook by year

Year	Existing Well	Well Workover	Appraisal and Development Wells (Existing)	Onshore Exploration	Onshore Unconventional Potential	Onshore Total	Offshore: Shallow Water	Offshore: Deepwater	Offshore Total	Total
	MMcfd	MMcfd	MMcfd	MMcfd	MMcfd	MMcfd	MMcfd	MMcfd	MMcfd	MMcfd
2020-21	2,415	25	0	0	0	2,440	0	0	0	2,440
2021-22	2,191	90	45	0	0	2,326	0	0	0	2,326
2022-23	2,137	103	85	60	0	2,386	0	0	0	2,386
2023-24	1,856	130	224	159	0	2,379	0	0	0	2,379
2024-25	1,546	240	353	419	0	2,558	0	0	0	2,558
2025-26	1,364	281	372	608	0	2,625	0	0	0	2,625
2026-27	1,183	306	363	550	60	2,461	0	0	0	2,461
2027-28	1,015	285	464	527	60	2,351	100	0	100	2,451
2028-29	916	265	464	488	70	2,158	150	0	150	2,308
2029-30	824	260	372	429	80	1,965	200	0	200	2,165
2030-31	701	301	311	377	90	1,779	200	0	200	1,979
2031-32	617	296	285	332	100	1,630	200	0	200	1,830
2032-33	514	310	262	323	100	1,509	250	0	250	1,759
2033-34	446	311	258	312	90	1,417	250	500	750	2,167
2034-35	404	291	244	299	80	1,319	250	550	800	2,119
2035-36	351	267	252	281	70	1,221	250	650	900	2,121
2036-37	300	236	250	235	60	1,081	250	650	900	1,981
2037-38	266	206	250	196	50	968	250	650	900	1,868
2038-39	231	188	240	188	40	879	250	650	900	1,779
2039-40	209	156	238	166	30	799	250	650	900	1,699
2040-41	188	136	258	156	30	768	250	680	930	1,698
2041-42	170	140	250	150	30	740	250	710	960	1,700
2042-43	150	140	240	140	30	700	250	740	990	1,690
2043-44	130	140	230	130	30	660	250	770	1,020	1,680
2044-45	110	140	220	120	30	620	250	800	1,050	1,670
2045-26	90	140	210	110	30	580	250	830	1,080	1,660
2046-47	80	140	200	100	30	550	250	860	1,110	1,660
2047-48	70	140	190	100	30	530	250	890	1,140	1,670
2048-49	60	140	180	100	30	510	250	920	1,170	1,680
2049-50	50	140	170	100	30	490	250	950	1,200	1,690
2050-51	40	140	160	100	30	470	250	980	1,230	1,700

Source: Petrobangla, see the notes to Figure 2-6.

With regard to the natural gas potential, experts of international oil companies operating in Bangladesh view that there are various potential gas resources such as offshore deep water and onshore unconventional resources, though it is necessary to mobilize every modern technology developed recently and being adopted worldwide. Once proper conditions are prepared to introduce these leading-edge technologies, it will be possible to find a considerable amount of gas resources.

2.3 LNG import plan

Under the circumstance that indigenous gas production would not be able to suffice the demand, the balance must be made up with import of LNG (liquefied natural gas). As of 2022, the international LNG market has been globally established and integrated and the LNG utilization in Asia has also rapidly expanded. Bangladesh started import of LNG in 2018 facing insufficient natural gas production. To support economic development of the country, LNG import was expected to inevitably increase, but the demand growth may not be as large as expected because of the start-ups of new power generation units, and the demand outlook has been revised in this master plan.

Table 2-10 shows the natural gas supply plan up to 2050. Under the most-likely case of the indigenous gas production plan, LNG import will increase to 33 million tons (Mt) in 2030 and 46 Mt in 2040 for the Petrobangla case, 9 million tonnes (Mt) in 2030, 21 Mt in 2040 and 46 Mt in 2050 for the PP2041 GDP case and 5 Mt in 2030, 12 Mt in 2040 and 19 Mt in 2050 for the In-Between case, respectively. However, if exploration on the high-risk potential resources is not be successful, additional import of LNG will become necessary on top of the projection by 7.1 Mt in 2040 and 9.4 Mt in 2050. On the other hand, if the natural gas demand follows the projection made by Petrobangla, gas supply balance will become tight at an earlier time. To cope with this, LNG import needs to be increased earlier.

In line with these increasing requirements, the LNG import facility as well as gas transmission system must be reinforced simultaneously.

Table 2-10 Outlook of Natural Gas Supply Balance

	2030	2035	2040	2045	2050
Gas Demand	mmcfd	mmcfd	mmcfd	mmcfd	mmcfd
Petrobangla (Scenario-3)	6,240	6,941	7,675	-	-
PP2041	3,384	4,008	4,985	5,823	8,142
In-Between	2,879	3,213	3,717	3,982	4,545
Production					
Low Risk Potential	1,779	1,221	768	580	470
High Risk Potential	200	900	930	1,080	1,230
Total	1,979	2,121	1,698	1,660	1,700
LNG Demand (mmscfd)	mmscfd	mmscfd	mmscfd	mmscfd	mmscfd
Petrobangla: Base	4,261	4,820	5,977		
Without High Risk Potential	4,461	5,720	6,907		
PP2041: Base	1,405	1,887	3,287	4,163	6,442
Without High Risk Potential	1,605	2,787	4,217	5,243	7,672
In-Between: Base	900	1,092	2,019	2,322	2,845
Without High Risk Potential	1,100	1,992	2,949	3,402	4,075
LNG Demand (million tonnes)	Mt	Mt	Mt	Mt	Mt
Petrobangla: Base	32.7	36.9	45.8		
Without High Risk Potential	34.2	43.8	52.9		
PP2041: Base	10.8	14.5	25.2	31.9	49.4
Without High Risk Potential	12.3	21.4	32.3	40.2	58.8
In-Between: Base	6.9	8.4	15.5	17.8	21.8
Without High Risk Potential	8.4	15.3	22.6	26.1	31.2

Source: Petrobangla/IEPMP Study Team

As LNG import is expected to increase further, it is also desirable to increase control on the LNG operation such as chartering LNG carriers to open a way for LNG procurement on FOB basis.

a. LNG Import Terminal

Table 2-11 LNG Terminal Plan

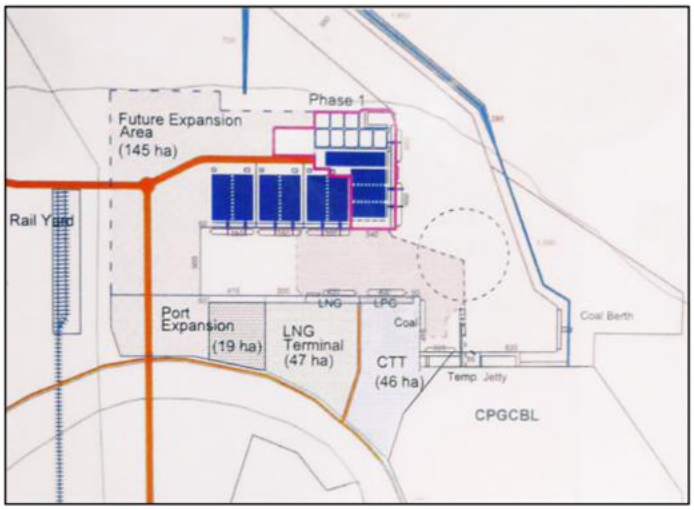
Location	Terminal	Capacity/Expansion	Start-up
		MMcfd	
Moheskhali	#1 FSRU (Operating)	500 → 630	Expnasion to be discussed
	#2 FSRU (Operating)	500 → 630	Expnasion to be discussed
	#3 FSRU	500-750	2026
Payra	#4 FSRU	630-1,000	2028
Matarbari	Land-based	1,000	2030
Total	3,430~4,010 MMcfd (24.0~30.7 million tonnes)		

Source: Petrobangla

Presently two floating storage and regasification units (FSRUs) are in operation in the southeastern part of Bangladesh offshore Moheskhali; Their expansion is being considered pending the gas demand trend. In addition, preparation is being made to introduce two more FSRUs and one onshore LNG terminal as shown in Table 2-11. Located at estuaries of big rivers, very shallow water areas extend far offshore along the seashore of Bangladesh prohibiting voyages of world class large tankers. For this reason, FSRUs were selected to start with LNG import. LNG is received from ocean-going tankers and regasified there and sent to the onshore gas pipeline system. FSRUs can be introduced with shorter lead time and, in case a lease contract is applied, with less upfront expenditure. However, they may need to be replaced after use of certain period. On the other hand, a land terminal offers much more flexible

operation to receive world-class larger LNG carriers (170,000m$^{3)}$, to ship LNG for small-lot local use and to utilize cryogenic heat for cold storage and industrial activities. A land terminal will have a long life, be less affected by the sea conditions, and be more economic in the long run.

Thus, the first onshore LNG terminal in Bangladesh is planned at Matarbari, which is expected to add an additional 3.8 million tons in the second phase and 7.6 million tons in the future. If LNG requirements increase further, the Matarbari LNG terminal may be expanded further. The biggest challenge for this project is dredging of the fairway to secure the water depth for world-class LNG carriers and cargo-ships to enter the port.



Source: RPGCL

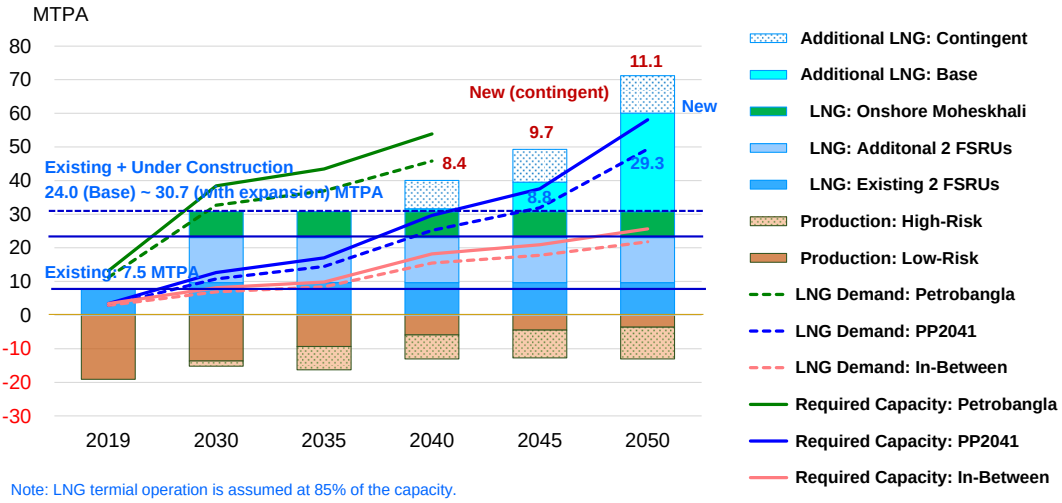
Figure 2-8 Matarbari Port Development Plan

The required total capacity of LNG import terminals, calculated at an annual average load factor of 85%, is likely to exceed 30 million tons per year after 2040. However, if high-risk potential does not materialize, such consideration must be advanced 5 years or so. The Requirement for LNG import terminals[2] is illustrated in Figure 2-8 based on the gas demand projection and natural gas production as shown in Table 2-10.

In case the high-risk potential does not materialize, LNG import capacity needs to be expanded around 2040. As construction/expansion of an LNG terminal may need a lead time of 3-5 years, it is necessary to decide on this issue around 2035. On one hand, if natural gas demand evolves along with the projection for the In-Between case, such decision can be made 10 years later. On the other hand, however, if natural gas demand grows faster as indicated in the projection by Petrobangla, the additional import capacity will become necessary around 2035 and the decision on this needs to be made before 2030.

It is quite challenging to predict the pace of energy consumption growth when an economy is going to take-off. Therefore, the natural gas demand trend must be carefully monitored, and projections should be reviewed periodically in order to guide the industry in the right direction.

[2] Calculated applying an annual average re-gas availability at 85%, according to the information provided by Petrobangla.



Source: IEPMP Study Team

Figure 2-9 Requirement for LNG Import Terminals

b. Cross border LNG import

Due to a lack of deepwater ports in Bangladesh, import of vaporized LNG via pipeline is being considered. Feasibility of this plan has not yet been examined, while, likewise with electricity, a well-designed international connection is expected to enhance stability of the entire gas supply network.

2.4 National Gas Pipeline Plan

The gas trunk pipeline is operated by Gas Transmission Company Limited (GTCL). A list of GTCL's ongoing and planned pipelines is provided below.

Table 2-12 GTCL's ongoing and planned pipeline list

	Name	Size	Length	Project Period
1	Bogura – Rangpur – Saidpur Gas Transmission Pipeline Project	30 -inch	150 km	2018/10 - 2023/6
2	Bakhrabad-Meghnaghat-Haripur Gas Transmission Pipeline Project	42 -inch	50 km	2021/7 – 2024/6
3	Installation and Modification of Gas Stations at Off-Transmission Points of GTCL	–	–	2021/7 – 2024/6
4	Gas Transmission Pipeline along Bangabandhu Sheikh Mujib Railw ay Bridge Project	36 -inch	10 km	2021/7 – 2025/6
5	Langolbandh- Maow a and Janjira-Tekerhat Gopalganj Gas Transmission Pipeline Project	36 -inch	110km	2024/7 – 2028/6
6	Kuakata-Payra-Barishal-Gopalganj-Fakirhat-Khulna Gas Transmission Pipeline Project	42 -inch 36 -inch	190km 60km	2024/7 – 2029/6
7	Satkhira (Bhomra) – Khulna (Aronghata) Gas Transmission Pipeline Project	30 -inch	65 km	2024/7 – 2028/6
8	Shahbazpur Gas Field-Bhola North Gas Field-Laharhat-Barishal Gas Transmission Pipeline Project	30 -inch	65 km	2024/7 – 2028/6
9	Matarbari-Langolband (3rd Parallel) Gas Transmission Pipeline Project	48 -inch	330km	2024/7 – 2029/6

Source: GTCL

Currently, the JICA Technical Cooperation Project W/G (Gas Technology Cooperation Project) is working on improvement of the gas supply business in Bangladesh. As discussed in Chapter 2, the present configuration of the national gas pipeline is incomplete. It is one-sided pressurizing system with a fish-bone structure resulting in inefficient operation. In addition, due to shortage of indigenous gas production, the system is not operated efficiently. To improve the situation, the national gas pipeline network should be upgraded with lager diameter pipes, measuring system and, in particular, a new pipeline connecting Matarbari and Dhaka and loops with multiple input points to stabilize gas supply in the central areas around Dhaka and the western region.

The draft plan presently considered by the project team is shown in Figure 2-10. The regasified LNG supply will come in mainly from Moheskhali and Matarbari. Because of the shallow water depth in the western part of the country, import terminals are mostly located in the east. As LNG import increases, it will become increasingly difficult to accommodate them only with the existing pipeline from Moheskhali. Therefore, at the time when the Matarbari onshore LNG terminal is constructed, an additional pipeline for gas evacuation from the Matarbari terminal will become necessary. This 48-inch new pipeline extending for 360 km may be laid down partly subsea and connected to the western part of the Dhaka loop. It should also play a role for gas storage and pressure adjustment for the whole system to mitigate operational problems being caused by rigid and sizable LNG supply contracts.

To provide a resilient gas system, a 36-inch loop will be built in the central metropolitan area around Dhaka and another loop to widely cover the western region. They will also play an important role to secure stable gas pressure in the whole system and thus enable efficient gas supply.

To supplement this, it is desirable to have a gas import point in the west of the country to stabilize the whole national gas system and accommodate the local gas demand in the west. Thus, the offshore Payra FSRU is planned. However, due to the shallow water depth and fast sedimentation in this area, many issues need to be overcome before the project is given a green light. It is necessary to implement such study well ahead of the project implementation.

Source: JICA Study Team

Figure 2-10 National Gas Pipeline Network Plan

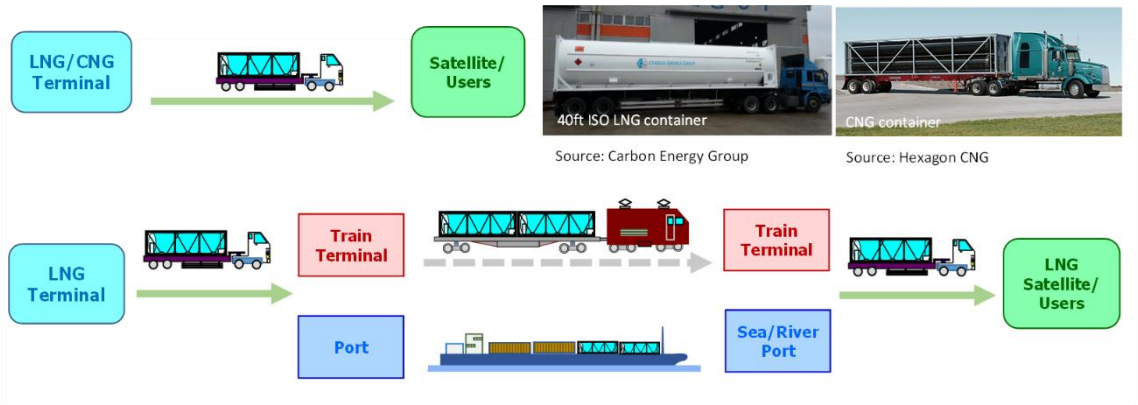
In order to properly manage the entire system as described above, it is necessary to have a centralized operation center such as a Gas Dispatch Center. It will monitor, direct and control operation of the entire gas system. To enable this, it is necessary to install gas metering systems at custody transfer points and automatic control valves and fittings to respond to the operation directives together with the centralized information system applying the modern digitization technology. The existing system must be upgraded as well in order to enable such operation management.

The above concept will be further refined and fine tuned through the ongoing techno-economic study.

Additionally, if supplemental gas supply is required at local satellites particularly for gas pressure stabilization, as well as gas users not connected to the pipeline system such as industrial parks and community gas, delivery of LNG or CNG in a small lot may be considered. Such system

is called a “virtual pipeline”, which is being adopted worldwide where a pipeline connection is impracticable.

For example, LNG is filled in 40ft containers (18 tonnes of LNG each) at an onshore LNG terminal, and transported by trailers, railways and river barges as shown in Figure 2-11. This system is beneficial as it does not require a complicated transshipment facility in-between the origin and destination. However, storage tank(s) and vaporization system are necessary at the destination terminal. On the other hand, if an isolated customer is located in a short distance from a truck pipeline, CNG will more beneficial than LNG because a vaporization system is not necessary. However, CNG application may be limited to small-medium size users as high-pressure gas storage is difficult. Pending the demand size, lay down of a branch pipeline may be practical for large users. Feasibility of such a system may be examined in the course of national gas system development.



Source: IEPMP Study Team

Figure 2-11 Virtual Pipeline by LNG

2.5 Issues and Challenges

In this IEPMP, natural gas demand is projected under the Advanced Technology Scenario (ATS) where utmost efforts should be made on energy efficiency and conservation. However, in the early stage of economic development, such efforts may take time to flourish, and natural gas demand may grow much faster as projected by Petrobangla. To cope with this, it is necessary to closely monitor the demand trend and fine-tune the medium-term gas development plans, accordingly.

As shown in Table 2-8, the outlook of indigenous gas production is particularly important for the country as the deficit must be made up by import. Though the global LNG market is developed today, LNG import means straight outflow of foreign currencies placing substantial burden on the economy. Increasing domestic production, on the other hand, gas supply will be more stabilized, the economy will be stimulated with investment, and technologies will be accumulated. Ensuring

modern technologies and exploration funds, both of which are not available in Bangladesh, is a key to success in enabling production of the high-risk potential gas. To this end, it is crucial for the country to prepare appropriate conditions to invite foreign investment and technologies.

The present gas system in Bangladesh is overloaded with problems due to its relatively old-fashioned system. Gas leakages observed in many points of the system must be fixed in view of safety, energy saving, and reduction of GHG emissions. Proper measurement and control measures must be adopted in the natural gas supply system for efficient management.

Modernization of the city gas system, in particular on measuring and pricing, is essential to revitalize the gas business and rationalization of urban development. Because of the obsoletion of the supply system, city gas is currently being phased out. However, in order to substitute the city gas supply in the residential and commercial sectors, a large number of LPG cylinders needs to be delivered, and/or electricity supply needs to be increased. To this end, it is necessary to consider a policy on appropriate distribution of cooking fuel among, city gas, LPG and electricity.

3. Oil Supply

3.1 Oil Demand Outlook

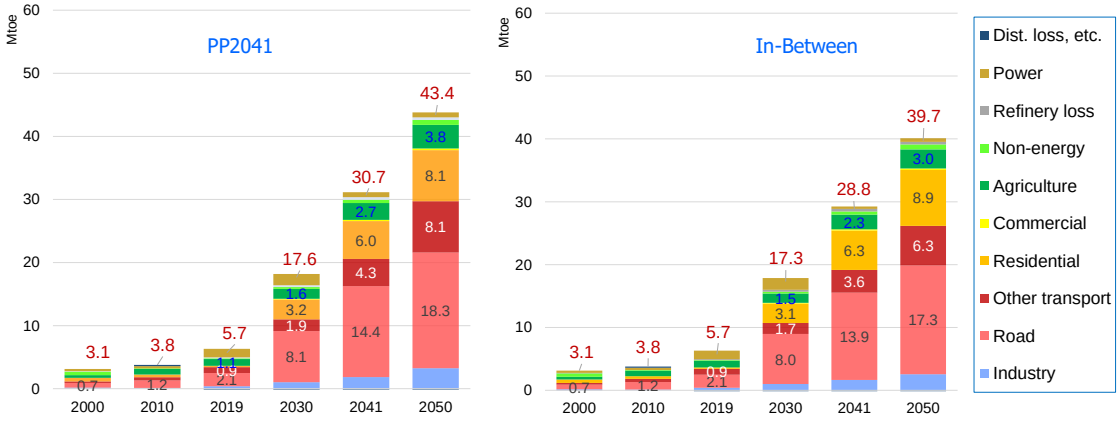
Consumption of petroleum products is forecast to expand 7.6-fold between 2019 and 2050 for the PP 2041 GDP case and 7.0-fold for the In-Between Case as shown in Table 3-1. The increase will be mainly led by motor fuel such as gasoline and diesel oil in response to increasing demand for mobility. Diesel and fuel oil are also used for sea and river water transport. The share of the overall transport sector will exceed 60% of the oil demand in the 2030s.

Table 3-1 Oil Demand Outlook by Sector

	Total Primary Liquid Supply (million toe)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Industry	0.4	1.0	1.8	3.2	7.0	5.8	6.0	7.5	8.9	5.6	5.2	8.13
Road	2.1	8.1	14.4	18.3	36.3	45.9	47.0	42.3	13.2	5.4	2.2	8.84
Other Transport	0.9	1.9	4.3	8.1	16.5	10.5	14.0	18.7	6.3	7.9	5.9	8.60
Residential	0.2	3.2	6.0	8.1	3.6	17.9	19.6	18.7	28.3	6.1	2.7	39.75
Commercial	0.0	0.1	0.2	0.2	0.1	0.7	0.6	0.6	33.0	4.7	2.4	49.74
Agriculture	1.1	1.6	2.7	3.8	18.7	8.9	8.7	8.7	3.5	5.0	3.2	3.52
Non-Energy	0.1	0.3	0.5	0.8	2.0	1.6	1.7	1.8	8.8	5.7	3.5	6.79
Power	1.4	1.8	0.8	0.8	23.7	10.1	2.6	1.8	2.5	-7.2	0.0	0.58
Refinery Loss	0.1	0.3	0.4	0.4	2.6	1.7	1.3	1.0	6.5	2.5	0.8	2.85
Distribution Loss, etc.	-0.6	-0.5	-0.5	-0.4	-10.6	-3.0	-1.5	-0.9	-1.1	-1.3	-1.2	0.68
Total	5.7	17.6	30.7	43.4	100.0	100.0	100.0	100.0	10.8	5.2	3.2	7.60
thousand barrels per day	112	347	603	852	(kb @ 5840MJ)							
In-Between												
Industry	0.4	1.0	1.7	2.5	7.0	5.7	5.8	6.4	8.6	4.8	4.0	9.6
Road	2.1	8.0	13.9	17.3	36.3	46.1	48.2	43.6	13.0	5.2	2.0	7.0
Other Transport	0.9	1.7	3.6	6.3	16.5	10.0	12.6	15.9	5.7	6.9	5.1	9.2
Residential	0.2	3.1	6.3	8.9	3.6	17.8	21.7	22.4	28.0	6.6	3.3	-8.0
Commercial	0.0	0.1	0.2	0.2	0.1	0.7	0.7	0.6	32.9	4.6	2.3	-8.8
Agriculture	1.1	1.5	2.3	3.0	18.7	8.6	8.1	7.7	3.1	4.2	2.4	18.0
Non-Energy	0.1	0.3	0.5	0.8	2.0	1.6	1.8	1.9	8.8	5.7	3.5	9.0
Power	1.4	1.9	0.4	0.6	23.7	10.8	1.3	1.4	2.9	-13.3	3.7	40.3
Refinery Loss	0.1	0.3	0.4	0.4	2.6	1.7	1.4	1.1	6.5	2.5	0.8	17.9
Distribution Loss, etc.	-0.6	-0.5	-0.5	-0.4	-10.6	-3.1	-1.6	-1.0	-1.1	-1.3	-1.2	34.4
Total	5.7	17.3	28.8	39.7	100.0	100.0	100.0	100.0	10.6	4.7	3.0	6.95
thousand barrels per day	112	340	565	780	(kb @ 5840MJ)							

Diesel is widely used for power generation at present at small rural power stations as well as at some larger thermal stations. Diesel for power will gradually phase out during modernization and rationalization of the power supply system being replaced by other sources. The residential sector will be the next largest user of oil products represented by increasing demand for LPG. Traditional biomass typically firewood for cooking and hot water supply will be switched to gaseous fuel during the course of modernization. Fuel switching is expected to improve domestic air quality and then in turn people's health condition. For the supply of clean gaseous fuel, however, the question "city gas or LPG" must be discussed deliberately as discussed in 6.3.2. There is a possibility that city gas would be used more widely substituting the LPG import projected here.

While diesel is used in the agricultural sector for irrigation and agricultural machines, a certain amount of them used for irrigation will be switched to grid power and solar PV system.



Source: IEPMP Study Team

Figure 3-1 Oil Demand Outlook by Sector

Pending discussion on the future transport system and mode of cooking fuel, consumption of petroleum products is projected to expand greatly and how to supply them, in quantity and quality, is the issue for the oil sector. Should they be supplied by expansion of the domestic refining capacity or import of products?

3.2 Breakdown of Petroleum Demand

Bangladesh Petroleum Corporation (BPC) expects petroleum demand of its marketing companies from 2022FY to 2031FY as shown in Table 3-2.

Table 3-2 BPC's Demand Outlook

Million T

	2022FY	2023FY	2024FY	2025FY	2026FY	2027FY	2028FY	2029FY	2030FY	2031FY
Gasoline	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.2
Kerosene,Jet A-1	0.4	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.8	0.8
Diesel	4.9	5.3	5.7	6.0	6.3	6.6	7.0	7.4	7.9	8.4
HSFO and others	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9
Total	6.7	7.2	7.6	8.0	8.5	9.0	9.5	10.0	10.6	11.3

Taking into account 1.4 million tons of LPG import made by private companies in 2021, High Speed Diesel and Fuel Oil import by Independent Power Providers (IPP), and the outlook of Bangladesh Petroleum Corporation (BPC) up to 2030, breakdown of the demand till 2050 is forecast as shown in the table below.

Table 3-3 Breakdown of Petroleum Demand

	2021FY	2030FY	2041FY	2050FY
	million tons			
BPC	6.0	13.5	24.9	32.6
Private Refinery	0.5	0.5	0.5	0.5
LPG (private)	1.4	2.5	5.0	10.0
HSD & FO (IPP)	4.4	1.0	0.0	0.0
Total	12.3	17.5	30.4	43.1

Source: JICA Study Team

The sales volume of the three sales

companies under the umbrella of BPC (Padma Oil Company Ltd, Jamuna Oil Company Ltd, and Meghna Oil Company Ltd) will be 10.6 million tons in 2030, increasing to 33.1 million tons in 2050. The total sale of 23 private LP gas operators will be 2.5 million tons in 2030 and will expand to 10 million tons in 2050, pending discussion on the selection of cooking fuel in the residential and commercial sectors. The amount of fuel consumed by IPPs for power generation will be 1.0 million tons in 2030 and will phase out before 2040.

3.3 Supply Plan of Petroleum Products

Along with progress in expansion of refineries and installation of Single Point Mooring Systems (SPMs), supply capacity of petroleum products will reach 27.6 million tons per year by 2030 including LPG import. Main expansions expected are; 1) 3 million tons per year by construction of the distillation unit 2 at the Eastern Refinery Limited (ERL-U2) in Chittagong starting operation in December 2027, 2) 4.5 million tons per year by the new SPM for petroleum products to start in December 2023 which will be constructed together with the SPM for crude oil handling, and 3) 1.0 million tons per year by construction of an LPG import terminal. In the northern part of the country, import of petroleum products from Numaligarh Refinery Limited of India via India Bangladesh Friendship Pipeline (IBFPL) will start at the end of 2022.

Table 3-4 Petroleum Supply Plan

Unit: million tons per year	2021FY	2030FY	2041FY	2050FY
Total liquid fuel demand	**12.3**	**17.5**	**30.4**	**43.1**
Refinery production	**2.0**	**5.0**	**15.0**	**13.5**
ERL-1	1.5	1.5	1.5	
ERL-2		3.0	3.0	3.0
ERL-3 (replace ERL-1)			10.0	10.0
Other small refineries	0.5	0.5	0.5	0.5
Product import (excl LPG)	**8.9**	**10.0**	**10.4**	**19.6**
BPC@Chittagong	4.5	5.0	5.0	5.0
IBFPL		1.0	1.0	1.0
SPM-1@Chittagong		3.0	4.5	4.5
New SPM@TBD (excl crude oil)				9.1
HSD/FO for IPP	4.4	1.0	0.0	0.0
LPG	**1.4**	**2.5**	**5.0**	**10.0**
Existing LPG terminal	1.4	1.5	2.0	2.0
ERL	0.0	0.1	0.4	0.4
New LPG Terminals@TBD		0.9	2.6	7.6

Source: JICA Study Team

Once the SPM currently under construction offshore Moheskhali is put in operation, its additional construction cost may become lower compared to construction of a new port or an artificial island. So, to accommodate increasing demand, the first priority is given to construction of two additional SPMs dedicated for petroleum products import.

Under the rationalization plans of crude oil import and petroleum products distribution, Moheskhali SPM and IBFPL will start operation at the end of 2023. Then, Dhaka Chittagong Pipeline (DCPL) and two airport pipelines in Dhaka and Chittagong will start operation at the end of 2024 and 2025, respectively. Approximately 40% of the petroleum demand is centered in the Dhaka region. In line with start of the DCPL, it is necessary to increase the capacity of connected oil depots and also to construct new regional oil depots.

In 2041, one new SPM unit, tank and double pipelines will be built for oil import. This will assure stable distribution of petroleum products to meet the domestic demand. The western regions of Khulna, Rajshahi, and Rangpur account for about 30% of the national demand. Taking into account the efficiency of supply to these regions, it is necessary to set out an appropriate site plan of the two SPM, their storage capacities and the route of the product pipelines to cover the regional oil demand.

Table 3-5 Development of Major Oil Projects

	Capacity (mtpa)	COD	Project cost ($ billion)
SPM (Moheshkali)	4.5 x 2	Dec 2023	0.75
IBFPL	1.0	End of 2022	0.33
DCPL	2.7	End of 2024	0.35
JETA1	0.9	June 2024	0.37
JETA1-2 (SAIA)	0.4	End of 2025	0.15
ERL-2	3.0	Dec 2027	2.20

Source: JICA Study Team

3.4 Points to Note

The first point to note is the size of refining capacity. Petroleum demand is expected to increase further beyond 2030. Its growth will be 25 million tons per year or 500 thousand barrels per day (kbd) from 2030 to 2050. Against this backdrop, expansion of the national refining capacity is projected with 5.0 million tons per year or 100 kbd as the ERL Unit-3 with deep conversion capacities to yield more lighter products. This expansion of refining capacity will help to maintain a certain level of independence on product supply, but the size of assumed capacity expansion is relatively small compared with the recent world trends that typically build around 200 kbd of distillation units. In addition to the economics, issues on supply security, operational flexibility, and resilience of the petroleum supply system should be considered on a sound balance between the domestic refinery and product import with a deliberate study.

The second is the supply infrastructure to the western part of the country. In consideration of the increasing demand in the western regions and improvement of supply security through dispersion of supply sources, the location of the new SPM and the new refinery should be decided carefully.

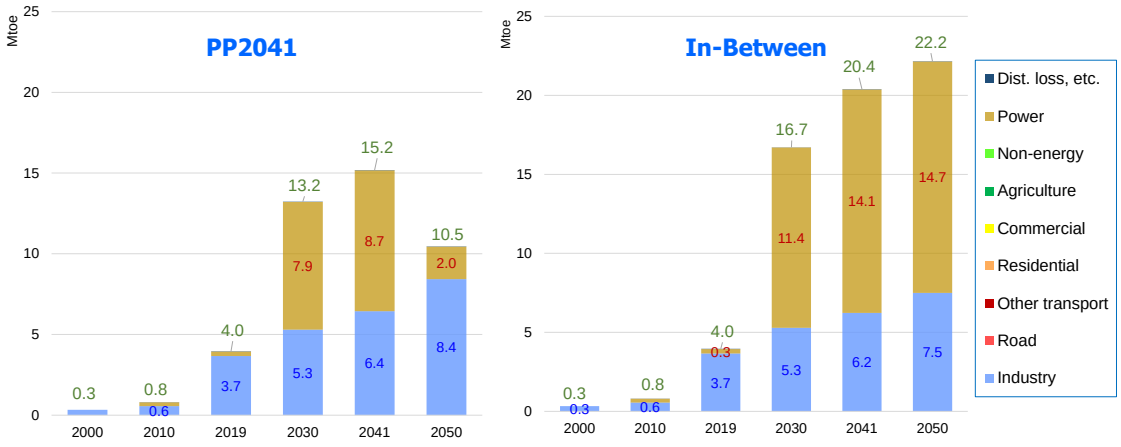
The third is about LPG supply. In this plan, after construction of the Moheskhali LPG import terminal with a handling capacity of 1.0 million tons per year, LPG import is projected to grow significantly. This is mainly caused by increasing use of LPG for cooking. As discussed earlier, it is necessary to consider the appropriate distribution of cooking fuel among city gas, LPG and electricity evaluating pros and cons of them.

4. Coal Supply

At present, domestic natural gas accounts for the main base power of Bangladesh, but this is anticipated to decline in the foreseeable future up to 2041. This study will require a certain amount of coal-fired power plant capacity for the primary energy of base power, but it will also be necessary to consider the balance between imported and domestic coal.

4.1 Coal Demand Outlook

In Bangladesh, coal is mainly used in the industry and power sectors. Industry coal consumption is not as large as other countries, as general coal consuming industries such as cement and large-scale blast furnace steel production do not present broadly in Bangladesh. This is mainly because carbonate rocks as feedstock for the cement industry is scarce and clinker is imported for production of final cement products. Instead, imported coal has been used for production of bricks as the major construction material in Bangladesh. In view of the environmental problems incurred by the industry, burnt bricks will be gradually replaced by non-burnt type stressed concrete blocks. Domestic steel production is not significant and only electric furnaces are used to turn scraps to steel. As such, industrial coal consumption will remain relatively small in the course of economic development.



Source: IEPMP Study Team

Figure 4-1 Coal Demand Outlook

In Bangladesh, power supply with imported coal started at the Payra power station in 2020 and additional coal power plants are under construction in Matarbari. Coal consumption for power will continue to increase during the 2030s but will gradually move to ammonia-cofiring to control GHG emissions. Eventually, coal consumption for power is scheduled to start decreasing during the 2040s in the In-Between case, meanwhile, the phase out of coal-fired plants may be deferred due to the lower economic growth.

At present, ammonia co-firing is still in the experimental stage. Selection of low carbon technologies must be investigated carefully including technologies yet to emerge, and an

appropriate guideline for use of coal as one of the primary energies must be set out in view of economics, energy security and environmental considerations.

Table 4-1 Coal Demand Outlook

	Total Primary Energy Supply (million toe)				Composition				Average Growth Rate			2019 to
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	2051
PP 2041					%	%	%	%	%	%	%	times
Industry	3.7	5.3	6.4	8.4	92.4	40.1	42.4	80.6	3.4	1.8	2.5	2.30
Power	0.3	7.9	8.7	2.0	7.2	59.8	57.5	19.3	35.3	0.9	-12.5	7.06
Loss, etc.	0.0	0.0	0.0	0.0	0.4	0.1	0.1	0.1	0.0	0.0	0.0	1.00
Total	4.0	13.2	15.2	10.5	100.0	100.0	100.0	100.0	11.6	1.3	-3.3	2.64
In-Between												
Industry	3.7	5.3	6.2	7.5	92.4	31.6	30.5	33.8	3.4	1.5	1.7	2.05
Power	0.3	11.4	14.1	14.7	7.2	68.3	69.4	66.1	39.9	2.0	0.3	51.42
Loss, etc.	0.0	0.0	0.0	0.0	0.4	0.1	0.1	0.1	0.0	0.0	0.0	1.00
Total	4.0	16.7	20.4	22.2	100.0	100.0	100.0	100.0	14.0	1.8	0.8	5.60

Source: IEPMP Study Team

Coal-fired power plants expected to be in operation during the project period are listed in Table 4-2 with features on operational parameters. However, the total Installed Capacity and Annual consumption totals are indicative figures, as the operating periods are different.

Table 4-2 Coal-fired Power Plants and Coal Consumption

Power Plant	Start-up	Installed Capacity (MW)	Ownership	Plant Efficiency (Gross) (%)	Load Factor (%)	Calorific Value of designed coal (HHV, kcal/kg)	Annual coal consumption (1,000t/y)
Barapukuria 250 MW (1st & 2nd Unit) (BPDB SBU)	Operating	250	BPDB	32.0%	50%	6,130	480
Barapukuria Replace	2036	600		41.0%	70%	6,130	1,259
Barapukuria 275 MW (3rd Unit) (BPDB)	Operating	274	BPDB	32.0%	50%	6,130	526
Payra, Potuakhali 1320MW CFPP (1st Phase)	2020	1,320	BCPCL (NWPGCL)	41.0%	70%	5,050	3,362
Maitri Super Thermal PP (Rampal)	2023	1,320	BIFPCL	41.0%	70%	5,500	3,087
Payra, Patuakhali 1320MW CFPP (2nd Phase)	2025	1,320	BCPCL (NWPGCL)	41.0%	70%	5,050	3,362
Matarbari 1200 MW USC CFPP (Unit-1)	2025	600	CPGCBL	41.3%	70%	4,700	1,630
Matarbari 1200 MW USC CFPP (Unit-2)	2026	600	CPGCBL	41.3%	70%	4,700	1,630
Patuakhali 1320 (2x660) MW USCPP (Phase-1) (Unit-1)	2024	660	RNPL	41.0%	70%	5,000	1,698
Patuakhali 1320 (2x660) MW USCPP (Phase-1) (Unit-2)	2025	660	RNPL	41.0%	70%	5,000	1,698
Barishal 307 MW CFPP	2023	307	IPP	41.0%	70%	5,000	790
Chittogram 2 x 612 MW CFPP (S.Alam Group)	2024	1,224	IPP	41.0%	70%	5,000	3,149
Dhaka Orion	2027	635		41.0%	70%	5,000	1,634
Moheskhali 1200 MW USCPP (ECA)	2032	1,200		41.0%	70%	5,000	3,087
Matarbali 1200 MW USC CFPP (Phase 2: Unit 3&4)	2031	1,200	CPGCBL	41.3%	70%	4,700	3,261
		12,170					**30,652**

Source: IEPMP Study Team

Table 4-3 shows the projected coal demand for general industry and coal-fired power plants. Case-A shows the coal demand with 20% ammonia blending for two 660 MW units in 2030 and four 660 MW units in 2035, while Case-B shows the projected demand without ammonia blending as a reference case. Note that the demand is calculated in domestic coal equivalent at 6,130 kcal/kg basis rather than the international marker of 7,000 kcal/kg.

Table 4-3 Coal Demand with/without Ammonia cofiring

ATS In-between	Coal Deamand (million tce)			
	2019	2030	2041	2050
Case-A				
Coal-fired power plants without ammonia co-firing	0.4	22.6	27.9	28.9
General Industry, Loss, etc.	6.0	8.6	10.2	12.2
Total	6.4	31.2	38.1	41.2
Case-B				
Coal-fired power plants without ammonia co-firing	0.4	22.6	30.2	32.2
General Industry, Loss, etc.	6.0	8.6	10.2	12.2
Total	6.4	31.2	40.4	44.4

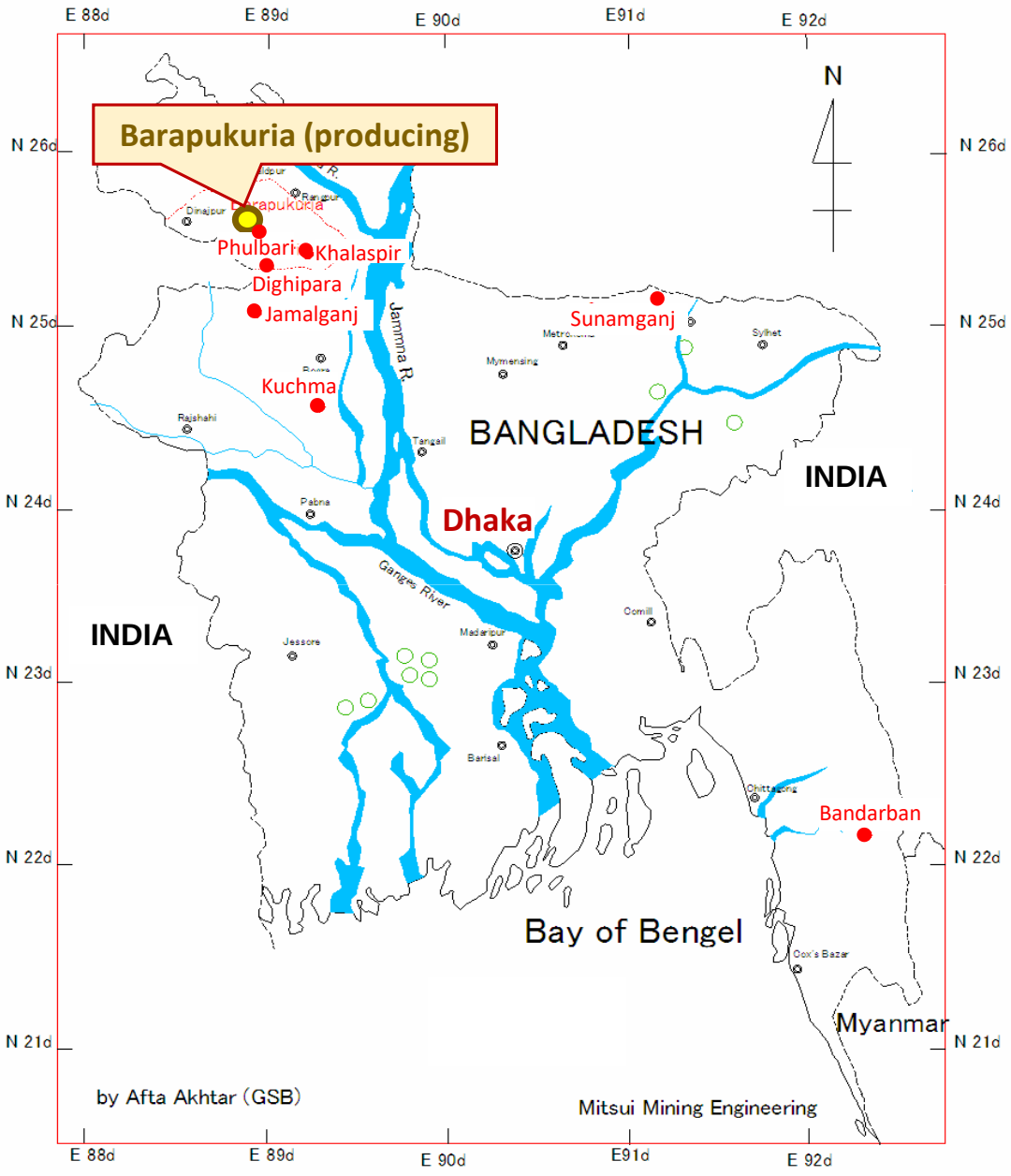
Source: IEPMP Study Team

4.2 Domestic Coal Resources

There are many challenges in development and use of coal as a domestic resource. Nevertheless, domestic coal is an important primary energy source for Bangladesh in view of the energy security, economic development and job creation. Prudent utilization of coal must be considered in a fair and equitable manner.

1) Coal resources

Coal resources in Bangladeshi are mostly located in the northwest part of the country, except for Sunamganj and Bandarban, as shown in Figure 4-2. Coal is generally featured as high-quality coal with low ash and low sulphur content. Some are classified as coking coal, which has extremely high commercial value. Six coal fields have been explored to date; their development status is summarized in Table 4-5. Of these, Barapukuria is the only operating coal mine in Bangladesh; it is a fully mechanized underground mine. A plan to develop an open pit coal mine at Phulbari has been abandoned due to strong opposition by the local community. Impact of this abandonment of the open-pit development plan is large and affects the future decision making of the development method of coal mines in Bangladesh.



Source: GSB

Figure 4-2 Location Map of Coal Felds[3] in Bangladesh

[3] Red circles indicate coal fields. However, the exploration information of Sunamuganj and Bandarban is not disclosed.

Table 4-4 Coalfield Resources and Development Status in Bangladesh (as of 2021)

	Coal field name	Explore-ration year	Explorer (Number of exploration)	Depth	Coal field name	Explore-ration year	Explorer (Number of exploration)	Depth	Coal field name
1	Barapukuria (Dinajpur)	1985 - 87	7 (GSB)	130-507 (GSB)	7 (GSB)	51 (GSB)	101 (GSB)	410 (Revised by Petrobangla	✓ In 1994, Petrobangla and China Machinery Corporation (CMC) signed a development contract, and BCMCL was established in 1998. Design capacity: 1 million tons per year. ✓ In the 16 years leading up to June 2021, 12.54 million tons have been produced. ✓ F/S for expansion of mining areas in the north and south was completed in August 2018. 860,000t/year, an increase of 6 million tons is expected. ✓ F/S for open pit mining is currently being proposed.
2	Phulbari, (Dinajipur)	1997	BHP (107)	141 - 270	2	15-70	572	572	✓ The project was abandoned in August 2006 due to opposition from local residents. ✓ Global Coal Management took over the project, but the current status is unknown.
3	Khalaspir, (Rangpur)	1989 - 90	4 (GSB)	257-483 (GSB)	8 (GSB)	50.0 (GSB)	143 (GSB)	685 (GSB)	✓ Proved reserves are 143 million tons. ✓ F/S is under consideration for the production plan of 2 million tons per year.
4	Dighipara, (Dinajipur)	1994 - 95	5 (GSB)	323 - 455 (GSB)	7 (GSB)	58.0 (GSB)	402 (GSB)	706 (Revised by Petrobangla)	✓ F/S report to be completed in February 2020; 67 drill holes totaling 30,034m to be completed in 2018-2019 ✓ Coal reserves of 89 million tons to be mined over 35 years at 3 million tons per annum
5	Jamalgonj, (Bogra)	1962	10 (GSP)	640-1,158	7	64	1,053	5,450 (Revised by Petrobangla)	✓ Largest coalfield in Bangladesh ✓ CBM (Coal Bed Methane) feasibility study conducted in 2015-16, but CBM production was not feasible due to low gas saturation.
6	Kuchma, (Bogra)	1959	SVOC	2,380 -2,876	5	51.82			✓ CBM (Coal Bed Methane) is targeted due to the depth of the area, but this is under consideration.

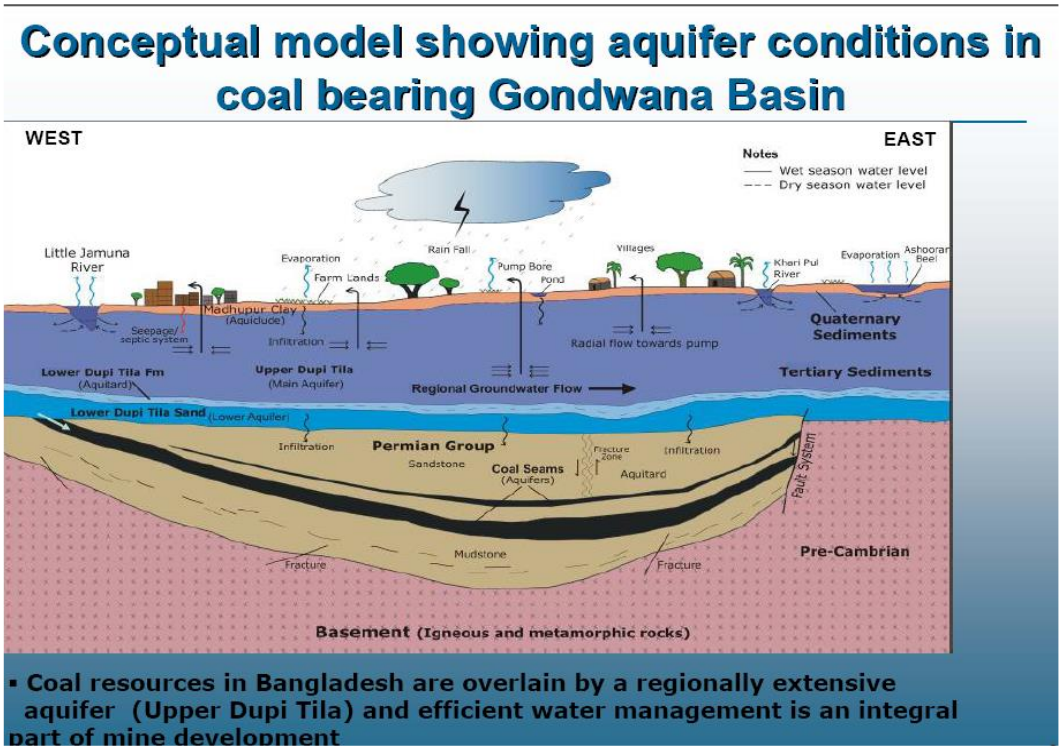
Source: Geological Survey of Bangladesh, March 2022

As shown in Table 4-5, the actual minable coal reserve is estimated by Petrobangla at 637.7 million tons. The schematic diagram of coal seam and upper aquifer conditions in Bangladesh is shown in Figure 4-3.

Table 4-5 Minable Coal Reserve depending on Mining Method

Sl. No	Coal Field	Depth(m)	Estimated Geological Reserves (Million ton)	Mining method (Mining availability %)	Actual Minable coal reserve (million t)
1	Barapukuria	118-509	410	U/G(10%)	41
2	Dighipara	328-455	706	U/G(10%)	70.6
3	Phulbari	141-270	572	O/C(80%)	457.6
4	Khalaspir	222-516	685	U/G(10%)	68.5
5	Jamalganj	640-1158	5,450	(Not available)	
Total			7,823		637.7

Source: Prepared by the IEPMP Study Team based on data from Petrobangla



Source: Asia Energy Corporation (Bangladesh) Pty Ltd (AEC), 2005

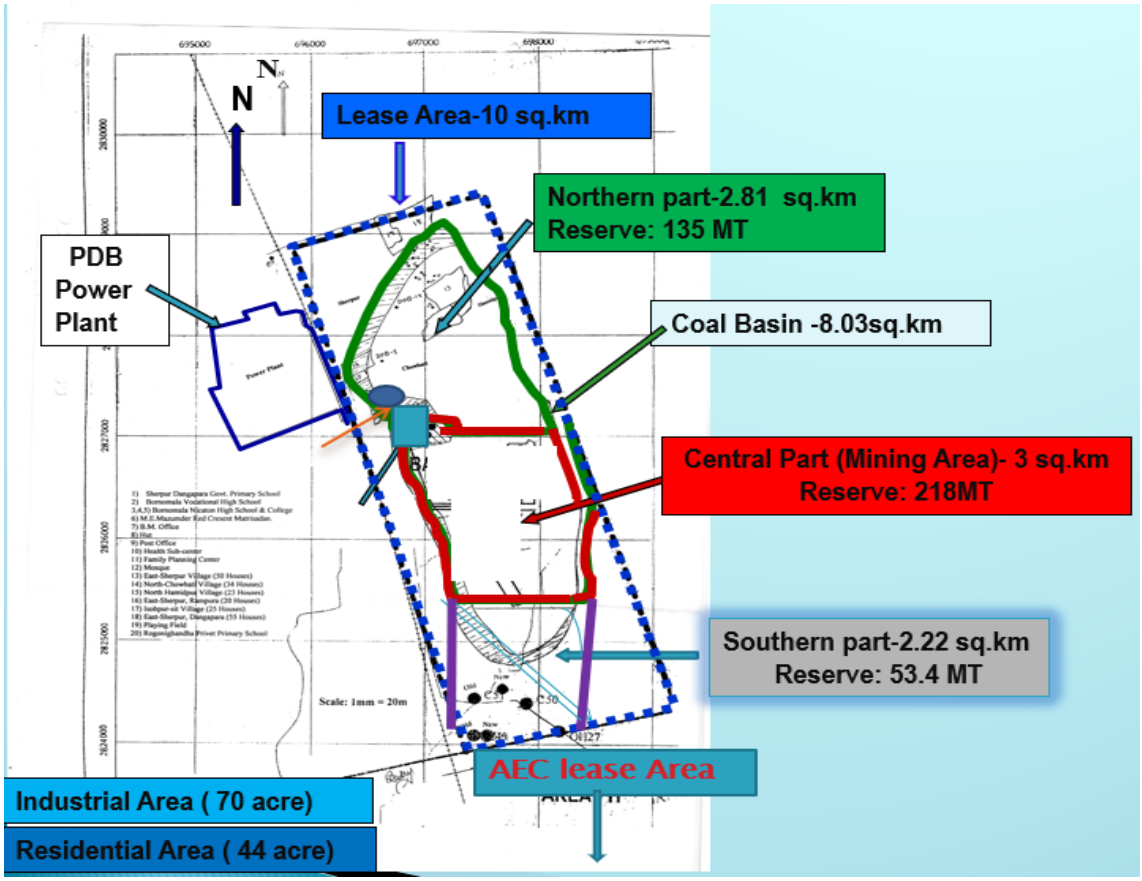
Figure 4-3 Schematic Diagram of Coal Seam and Upper Aquifer Conditions in Bangladesh

2) Issues and Challenges for New Coal Development

Current status of plans for F/S on new coal development is summarized below, which illustrates issues and challenges facing the coal industry in Bangladesh.

a. Expansion of underground mining at Barapukuria coal field

According to the report on the F/S on the expansion of mining operations in the northern and southern parts of the Barapukuria coal field, in the south, the mining rate is assumed at 13% using the LWCT mining method and production will be at an average production of 860,000 tons per year for eight years. In the north, the room-and-pillar mining method will be used; production will be an average of 640,000 tons per year at a mining rate of 4% for six years. Figure 4-4 shows the location of these areas. The central area of the field is currently being mined. Additional investments will be made mainly for the upgrading of exhaust fans, construction of exhaust shafts, and expansion of drainage pumps. Total coal production during the project period is estimated at 10.7 million tons (Mt) (both in the south and north). In addition, the life of the expanded mine is 14 years.



Source: B Presentation of Barapukuria Coal Mining Company Limited (BCMCL), March 2022

Figure 4-4 Planned Southern and Northern Expansion Areas of Barapukuria Coal Mine

b. Barapukuria Coal Mine Open Pit

The Barapukuria coal mine will start mining coal from the northern part of the Barapukuria Basin using the (LTCC) method starting in December 2023 under the fourth contract with the XMC-CMC consortium in China. Coal extraction in the north will require approximately 5,800 m of underground passages. On the other hand, underground mining in the south is very difficult due to the absence or very thin thickness of the impermeable LDT between the coal seam and the upper Dupitira aquifer. Therefore, mining from the south requires a more detailed investigation. In addition, reaching the southern part of the Barapukuria Basin would require an underground passage of more than 10 km, which will require a huge investment. Therefore, the Barapukuria Coal Mine proposed open pit F/S in the northern and southern parts of the basin. The consultant who carried out the F/S for the field's expansion as noted in the previous section also recommends that another F/S should be carried out for open cut mining because the mining rate of underground mining is low.

The feasibility study (F/S) made by Barapukuria Coal Mine proposes implementing open pit mining in the south and north of the mine, particularly in the north where the coal seam depths range from 118m to 330m, and which was expected to be more suitable for open pit mining. The study expects the aggregated production volume over twenty-eight to thirty years will be 170 Mt at an annual output of six million tons, if economically viable.

The proposed study for open pit mining has not yet been approved by the concerned government authority, the Energy and Mineral Resources Division (EMRD). This is because there are several issues to be considered for the government for open pit mining in Bangladesh. The first is that Bangladesh is a densely populated country and securing land for the local community is of the highest priority. Land acquisition and resettlement are very difficult tasks from administrative and operational perspectives. The second is that the land in the mining areas is very fertile and used to grow three crops a year. The land is very important for the local economy as well as for the food supply. The third is oppositions from the local community. In August 2006, there was a large dispute with the local community over the large-scale open pit mining project in Phulbari. The Bangladesh government has frozen the open pit development of the field since then. These multiple issues make the government cautious about open-pit mining in Bangladesh.

Although the underground mining operations at the Barapukuria coal mine have been successful so far, if open-pit mining becomes possible instead of underground mining, which has restricted the mine's production rate, it will play a major role in securing a stable supply of coal in Bangladesh. The company's employment and Corporate Social Responsibility (CSR) activities are highly regarded by local residents. If Bangladesh will need to rely on coal supply for its future energy supply, conducting F/S and examining whether adopting open pit mining in the field is technically, economically, socially, and environmentally feasible are recommended.

c. Dighipara Coalfield

The Dighipara coalfield is the second largest coalfield discovered in Bangladesh, with more than twice as much coal in reserve as the Barapukuria coalfield. Dighipara field, like Barapukuria, has a low-ash, low-sulphur, and highly volatile bituminous coal characterized by moderate to high calorific value. The Dighipara coal mine is also strategically located in the northwestern part of the country where there is no accessible alternative or conventional energy sources for power generation in Bangladesh. The F/S report for the Dighipara field was completed in February 2020, and its outcomes were discussed within the government in September 2020. The next steps for the field's development are currently under consideration by the government. It is reported that this F/S notes the following:

1) The basin has a high-quality coal resource comprising three major coal seam units with an average ash content of about 14.5% (adb) and an average energy of 6,650 kcal/kg (adb).
2) Mining conditions are influenced by a series of large aquifers in the Dupi Tila Formation.
3) Hydrogeological investigations indicate that the runoff associated with mining is 96.7 m^3/min (5,800 m3/h).
4) It is technically feasible to mine the coal using multi-slice LTCC technology to achieve a nominal production rate of over 3 million tonnes per annum.
5) A total of 89 million tonnes of coal could be mined, with mining planned for 35 years.
6) The production schedule included a pre-production construction period of 7 years and a production start-up period of 3 years, giving a total of 10 years from the development decision to production.
7) If the mine is opened, the coal will be used to build a 1,000MW ultra-supercritical (USC) power station operated by North-West Power Generating Company Limited (NWPGCL). The construction site is at Dighipara, with a COD of 2025 and completion in December 2032.

The F/S report for the Dighipara field points to the high initial investment in its development and notes the challenge of water management, which may make the field's development not economically viable at current coal prices. Barapukuria Coal Mining Company Limited (BCMCL) therefore has started to review the F/S and further decisions on the Dighipara's development will be made after the company's review. The following issues were discussed by the IEPMP Study Team as part of this F/S report:

1） The production plan is based on multi-slice LTCC technology as the mining method, but it is not clear whether stable coal production is possible or not.

2) LTCC mining was introduced in May 2013 and is currently being implemented at the Barapukuria coal mine. Currently, a total of 12 coal faces are being mined using the LTCC method. Multi-slice LTCC is suitable for thicker coal seams. 3 to 4 meters of coal seams can be cut in one slice, and an additional 3 meters of coal can be recovered as top caving. This is why multi-slice LTCC is suitable for higher production volumes in mines with coal seams averaging 36 m thick, such as Barapukuria. However, multi-slice LTCCs have a higher risk of subsidence and roof falls than single-slice LTCCs.

3) It is not known at present whether the Dighipara coal mine will be developed or not, although it is possible that it will be supplied to a new power station or general industrial use.

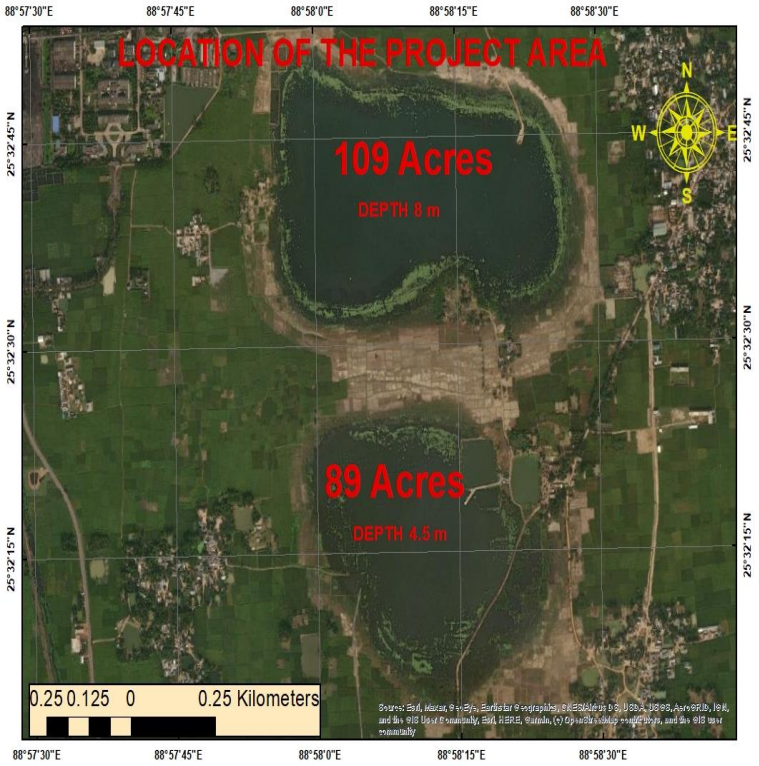
d. Khalaspir Coalfield Development F/S

Barapukuria Coal Mining Corporation Limited (BCMCL) has a plan to conduct an F/S for development of the Khalaspir coal mine. Under the plan, BCMCL is to conduct a feasibility study by 2027. (Currently under investigation)

e. F/S of CBM in Jamalgonj coalfield

F/S was conducted about the potential of coal bed methane (CBM) production from Jamalgonj coalfield in November 2016. Because the coal seam at the field is deep (640-1,158m) and underground mining of the field is costly, the production of CBM was examined. The study drilled 3,343.30 meters in three wells, and the coal core samples were tested for gas content, near infrared analysis, and coal lithology. Geophysical logging was carried out in all wells, followed by Injection I falloff tests to determine the permeability of the reservoir. The study results show that the coal seams are highly cleaved and fractured and good permeability is achieved. However, the amount of desorbed gas is very low, with a very low gas saturation of less than 10%. CBM cannot be produced from such low gas saturation, and the gas resource in the field was classified as Gas-in-Place (GIP) that is not recoverable.

In Barapukuria Coal Mine, as a result of underground coal mining, land subsidence has resulted in the formation of two ponds, covering an area of 109 acres and 89 acres, with water depths of 8 meters and 4.5 meters (Figure 4-5). SREDA, in collaboration with ADB, conducted an F/S to determine the suitability of the two ponds for the installation of floating solar panels with capacity of 46 MW. During the process of the study, a number of discussions and review meetings have been held among BCMCL, Petrobangla, SREDA, BPDB, and Ministry of Power, Energy and Mineral Resources Division. BCMCL showed an interest to set up the proposed floating solar power plant on its own initiative acquiring two ponds land. The company's management and SREDA have given an initial consent to the installation. In general, it is not possible to construct houses and other buildings in the areas of subsidence anticipated by underground mines or in the covered areas of mining sites in open cut mines. But it will be possible to install solar panels in the future, which is a promising way to use such land effectively.



Source: Barapukuria Coal Mining Company Limited(BCMCL), March 2022

Figure 4-5 Prospective Area for Solar Power Plant

5. Hydrogen and Ammonia supply

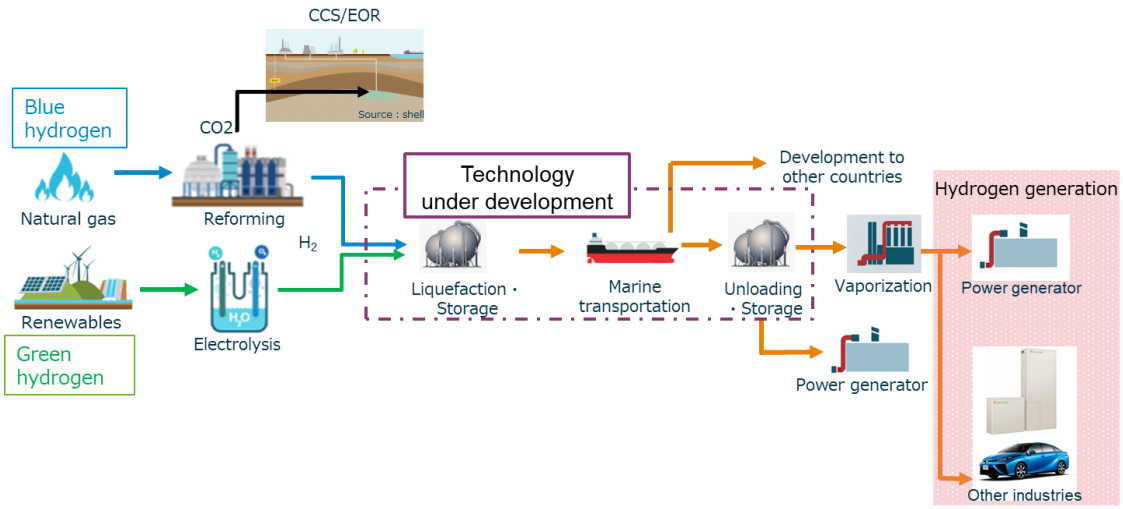
To realize a decarbonized society, it is essential to conduct the maximum introduction of renewable energy and new decarbonization technologies using ammonia, hydrogen, and CCUS. However, in Bangladesh, which has the world's highest population density, renewable energy with low energy density seems not to supply sufficient energy. Under these circumstances, it is rational to consider the options of hydrogen and ammonia as clean energy with high energy density.

5.1 Hydrogen and ammonia supply chain

Hydrogen and ammonia, which can be generated from natural gas, renewable energy, etc. is one of the clean fuels that do not generate CO2 when burned. Ammonia, as well as hydrogen, is promising decarbonized fuel because ammonia is already widely used in industrial processes and used as a fertilizer, furthermore ammonia can also be used as fuel and has potential as a hydrogen carrier.

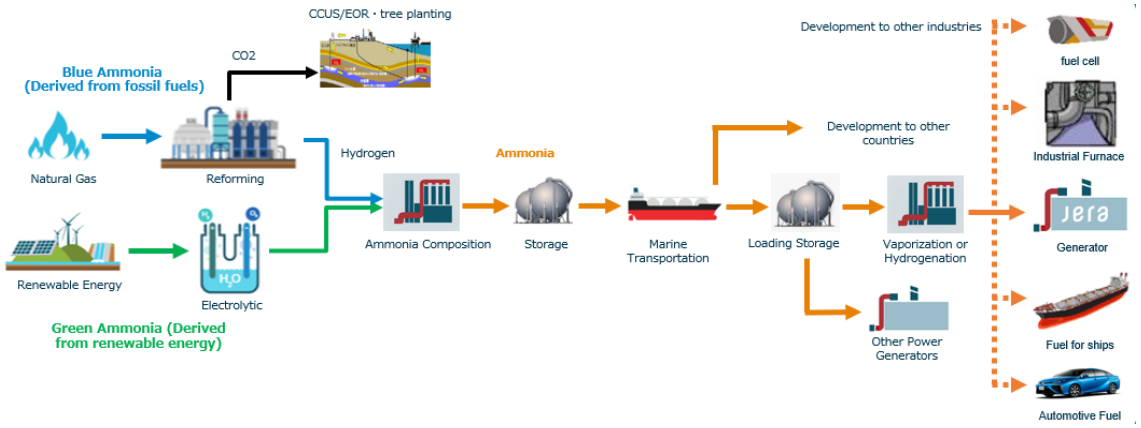
Since hydrogen is relatively similar to the combustion characteristics of natural gas, co-firing in gas-fired power plants is being considered. Ammonia, on the other hand, is similar to the combustion characteristics of coal, so co-firing in coal-fired power plants is being considered.

The figure 5-1 and figure 5-2 shows an example of supply chain for hydrogen and ammonia.



Source: IEPMP Study Team

Figure 5-1 Example of Supply Chain for Hydrogen

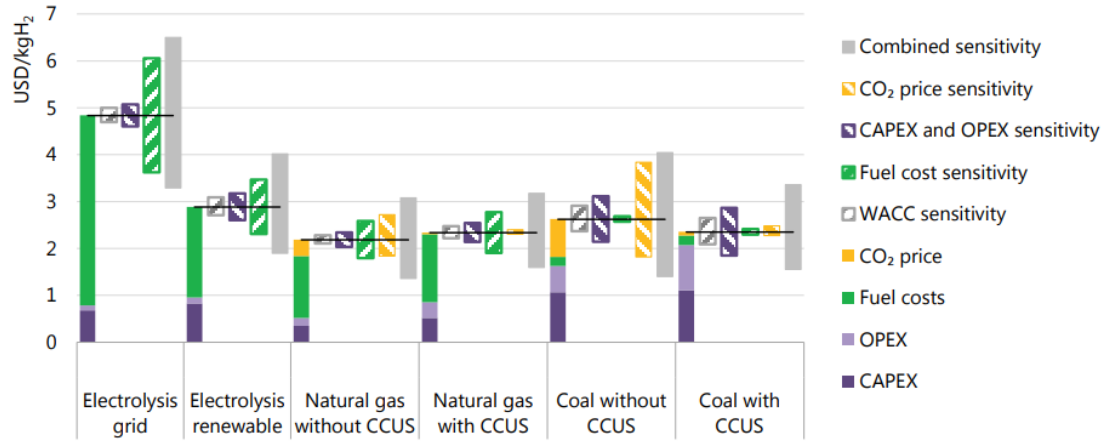


Source: IEPMP Study Team

Figure 5-2 Example of Supply Chain for Ammonia

5.2 Cost differences by production method

The types of hydrogen and ammonia are broadly classified into blue and green. Blue hydrogen and ammonia are derived from fossil fuels, such as natural gas, and is generated CO2 from the production process is captured and utilized or stored. Green hydrogen and ammonia are derived from electrolysis of water with renewable electricity. “The Future of Hydrogen,” which was published by the International Energy Agency (IEA) in 2019, suggests that in the short term until around 2030, hydrogen production from fossil fuels will be the most competitive option. The trend is the same for ammonia, because it is produced from hydrogen by the Haber-Bosch process.



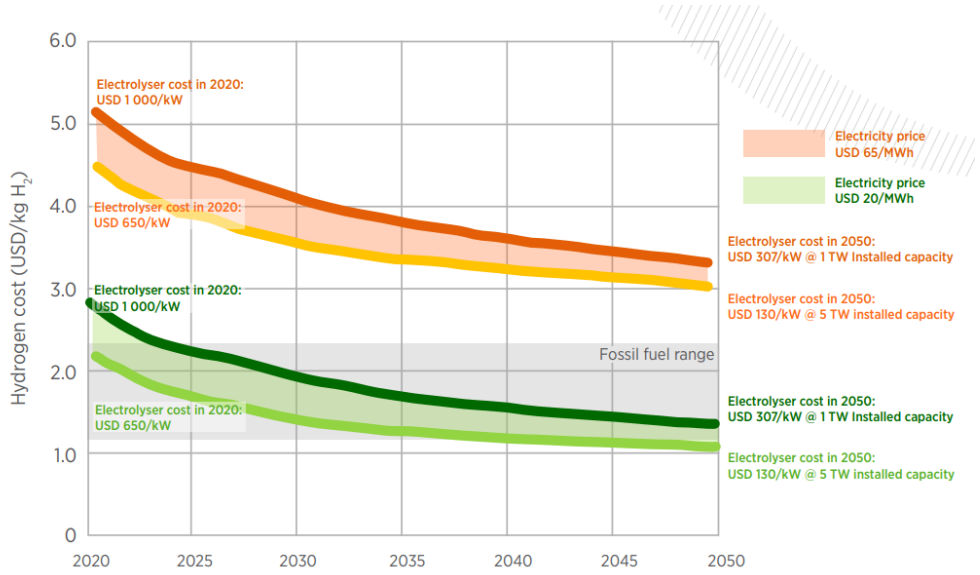
Notes: WACC = weighted average cost of capital. Assumptions refer to Europe in 2030. Renewable electricity price = USD 40/MWh at 4 000 full load hours at best locations; sensitivity analysis based on +/-30% variation in CAPEX, OPEX and fuel costs; +/-3% change in default WACC of 8% and a variation in default CO_2 price of USD 40/tCO_2 to USD 0/tCO_2 and USD 100/tCO_2. More information on the underlying assumptions is available at www.iea.org/hydrogen2019.

Source: IEA 2019. All rights reserved.

Source: “The Future of Hydrogen”, IEA

Figure 5-3 Hydrogen Production Costs for Different Technology Options in 2030

On the other hand, according to the "Quarterly Q1 2021" report published by the International Renewable Energy Agency (IRENA), in the mid to long term, the competitiveness of green hydrogen derived from water using renewable energy sources will improve, and the production cost is assumed in some cases to be 20% cheaper in 2040 and 30% cheaper in 2050 comparing to 2030. It also suggests that the cost of green hydrogen will be equivalent to that of blue hydrogen in 2040 and will even be lower thereafter. Therefore, when introducing hydrogen and ammonia in Bangladesh, it is realistic to initially use blue hydrogen and gradually shift to green hydrogen based on the cost trend of green hydrogen. In this study, the procurement plan is formulated assuming that the introduction of green hydrogen will start in 2040, and the amount of green hydrogen will be same as blue hydrogen in 2050. (Although green hydrogen may be cheaper in 2050, a certain amount of the blue hydrogen which has been contracted earlier will remain in the procurement portfolio.)



Source: "Quarterly Q1 2021", IRENA

Figure 5-4 How Electrolyzer Scale-up Drives Down Costs

5.3 Hydrogen and Ammonia Introduction Plan in Bangladesh

In the power supply plans in this study, hydrogen is planned to be co-fired in 2035 and ammonia in 2030. Table 5-1 shows the amount of hydrogen and ammonia procured.

Table 5-1 Procurement Volume of Hydrogen and Ammonia

ATS PP 2041 Scenario

Fuel type	Item	2030	2035	2041	2050
Hydrogen	Amount (t)	-	260,000	1,507,000	4,404,000
	Blue (%)	-	100	90	50
	Green (%)	-	0	10	50
Ammonia	Amount (t)	521,000	2,603,000	2,603,000	1,301,000
	Blue (%)	100	100	90	50
	Green (%)	0	0	10	50

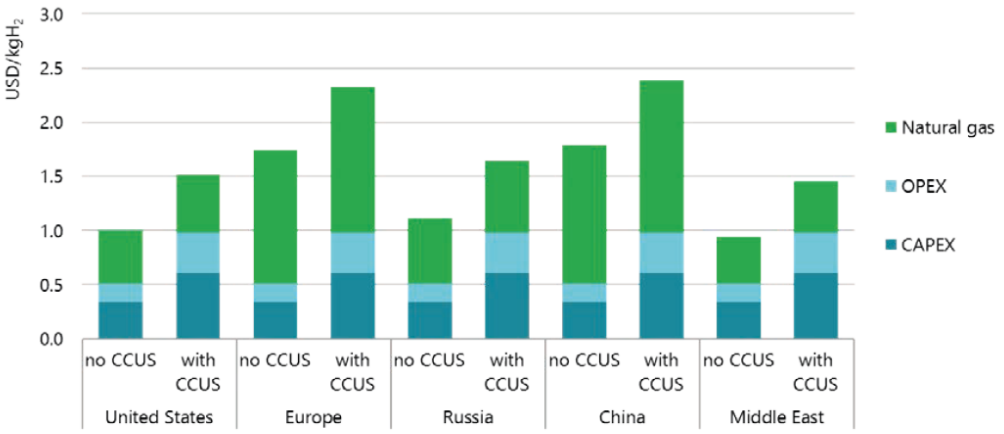
ATS In-between Scenario

Fuel type	Item	2030	2035	2041	2050
Hydrogen	Amount (t)	-	260,000	1,507,000	2,781,000
	Blue (%)	-	100	90	50
	Green (%)	-	0	10	50
Ammonia	Amount (t)	521,000	2,603,000	2,603,000	1,301,000
	Blue (%)	100	100	90	50
	Green (%)	0	0	10	50

Source: IEPMP Study Team

5.4 Suppliers

According to the IEA's "The Future of Hydrogen," natural gas prices account for the largest portion of blue hydrogen production costs. The Middle East and the United States, where the gas prices are low, are the most cost-competitive producers. Considering the transportation cost, it seems to be more feasible to procure from the Middle East, which is geographically close to Bangladesh. Figure 5-5 shows Hydrogen production costs by region.



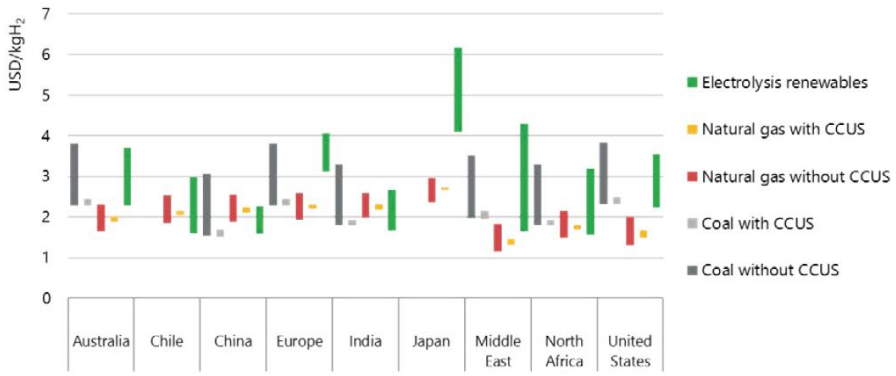
Notes: kgH_2 = kilogram of hydrogen; OPEX = operational expenditure. CAPEX in 2018: SMR without CCUS = USD 500–900 per kilowatt hydrogen (kW_{H2}), SMR with CCUS = USD 900–1 600/kW_{H2}, with ranges due to regional differences. Gas price = USD 3–11 per million British thermal units (MBtu) depending on the region. More information on the underlying assumptions is available at www.iea.org/hydrogen2019.

Source: IEA 2019. All rights reserved.

Source: "The Future of Hydrogen", IEA

Figure 5-5 Blue Hydrogen Production Costs by Region

Pertaining to green hydrogen, Figure 5-6 shows that Chile, China, India, the Middle East, and North Africa are cost competitive in green hydrogen production. Considering transportation costs, procurement from India or Middle East seems a promising option.



Notes: Bars indicate range between near- and long-term hydrogen production costs, which include a CO_2 price of USD 25/t CO_2 in the near term and USD 100/tCO_2 in the long term. For options from coal and natural gas, the higher value indicates the long-term costs (due to the increasing CO_2 price), whereas for hydrogen from renewable electricity the lower value indicates the long-term costs.

Source: IEA 2019. All rights reserved.

Source: "The Future of Hydrogen", IEA

Figure 5-6 Hydrogen Production Costs by Region

5.5 Hydrogen and ammonia strategy in Saudi Arabia

In October 2021, Saudi Arabia announced the plan to achieve CN by 2060. As a means of achieving CN, it considers the production of blue hydrogen and ammonia from natural gas using

existing infrastructure and the production of green hydrogen and ammonia using abundant solar radiation and wind power. It will result in the creation of domestic demand and export to Asia and Europe is also considered. In September 2020, Saudi Aramco, the Institute of Energy Economics of Japan, Mitsubishi Corporation and others conducted supply chain demonstrations to transport blue ammonia produced in Saudi Arabia to Japan. In March 2021, Saudi Aramco and ENEOS began FS to build a supply chain for blue hydrogen and ammonia. The NEOM project, which envisions to build a renewable energy city, is also underway, and the production of 1.2 million tons of green ammonia per year from renewable energy produced at NEOM starting in 2025 is being considered.

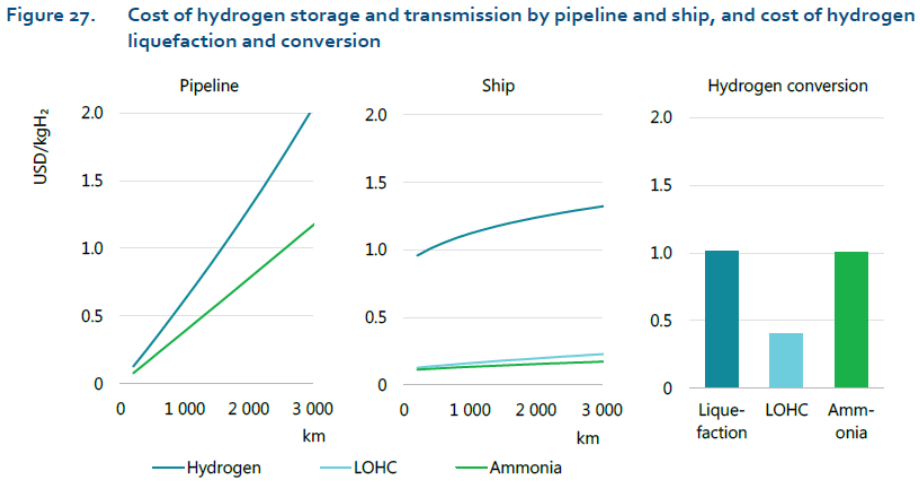
5.6 Hydrogen and ammonia strategy in India

According to the "National Hydrogen Mission (NHM)" published in November 2020, NHM aims to produce 5 million tons of green hydrogen by 2030 in India, making the country a global hub for production and exports. The NHM plans to provide generous support to green hydrogen and ammonia producers by granting priority access to the power grid, allowing the deposit of the generation from renewable energy sources that will not be used immediately for up to 30 days and to be taken out when needed, and providing storage sites for export or use on ships.

5.7 Transportation

Ammonia, mainly for fertilizer, has a global production volume of 200 million tons, 10% of which is imported and exported. Supply chain, including marine transportation, has been already established. Due to a significant increase in demand for power generation, larger production plants and transport ships are being considered and it will result in the cost reduction through economies of scale. It is also expected to be utilized as a hydrogen carrier and it will make it possible to meet the demand for hydrogen by importing ammonia and reconverting it into hydrogen domestically.

Hydrogen is mainly transported by pipelines for short-distance transportation. The IEA's “The Future of Hydrogen” shows that hydrogen gas transport by pipeline is generally the cheapest for distances less than about 1,500 km. [*] It could be applied, for example, when considering importing from India.



Source: "The Future of Hydrogen", IEA

Figure 5-7 Hydrogen / Ammonia Transportation Costs

On the other hand, a marine transportation method has not been established. Therefore, an optimal hydrogen transport medium, called a hydrogen carrier, needs to be developed. Currently, liquid hydrogen, LOHC (Liquid Organic Hydrogen Carrier), and ammonia are being considered candidates, and which will be the most promising will depend on the future progress of technological development. Considering that co-firing in coal-fired thermal power plants also generates demand for ammonia, procuring ammonia for long-distance transportation seems to be a viable option, but it is necessary to closely monitor the future trends in technological development.

It is economical to transport hydrogen and ammonia with large vessels whenever possible. The ammonia carrier that is currently being developed is the same size as a Very Large Gas Carrier (VLGC) with a capacity of about 50,000 tons with 11 to 12 meter draft, which is globally utilized as a carrier of liquefied petroleum gas (LPG). Matarbari, which is being developed as a deep-water port, seems to be the most promising receiving terminal of future ammonia import, but it is necessary to consider whether Matarbari alone can meet the future increase in ammonia procurement volume. It depends on the capacity of berths and receiving tanks, and further detailed studies are needed, including the development of new receiving terminals and the import by pipeline from neighboring countries.

5.8 Procurement costs

Procurement costs of blue and green hydrogen and ammonia in Bangladesh are estimated. The cost is adjusted by the JICA IEPMP Study Team based on highly reliable references, including

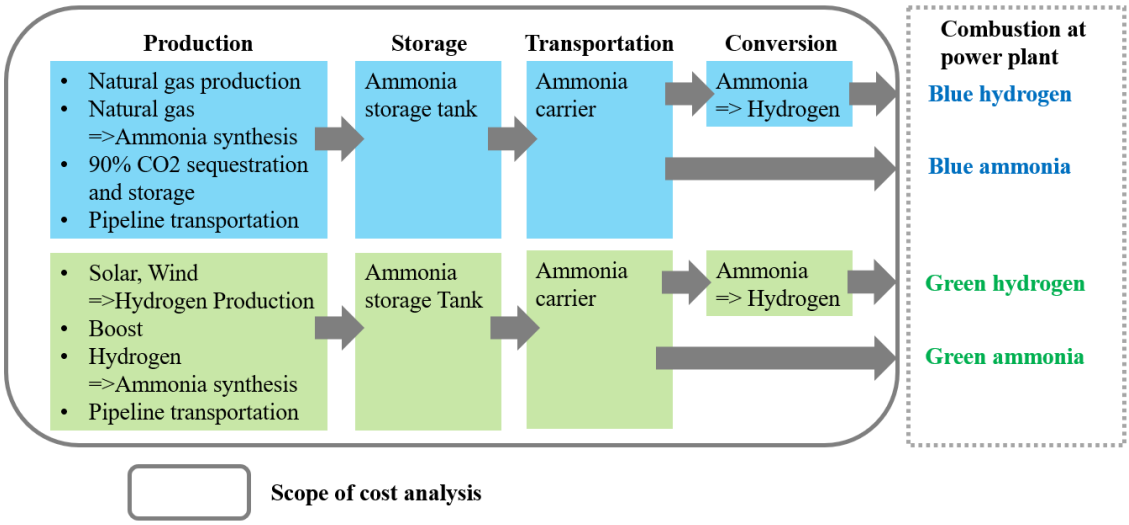
the studies by IEA, other government agencies, and private research firms. The assumptions of the cost calculation of blue/green hydrogen and ammonia are provided in Table 5-2 and the scope of costs analysis is provided as Figure 5-8.

Table 5-2 Assumptions for Cost Calculation

Blue Hydrogen	Raw materials: natural gas Production process: Steam reforming CO2 sequestration rate: 90%
Blue ammonia	Raw materials: natural gas Production process: Steam reforming + Harbor-Bosch process CO2 sequestration rate: 90%
Green hydrogen	Electricity: Solar and onshore wind Production process: Water electrolysis
Green ammonia	Electricity: Solar and onshore wind Production process: Water electrolysis + Harbor-Bosch process

Source: IEPMP Study Team

Each process related to cost calculation is shown in Figure 5-8.



Source: JICA IEPMP Study Team

Figure 5-8 Scope of Cost Analysis

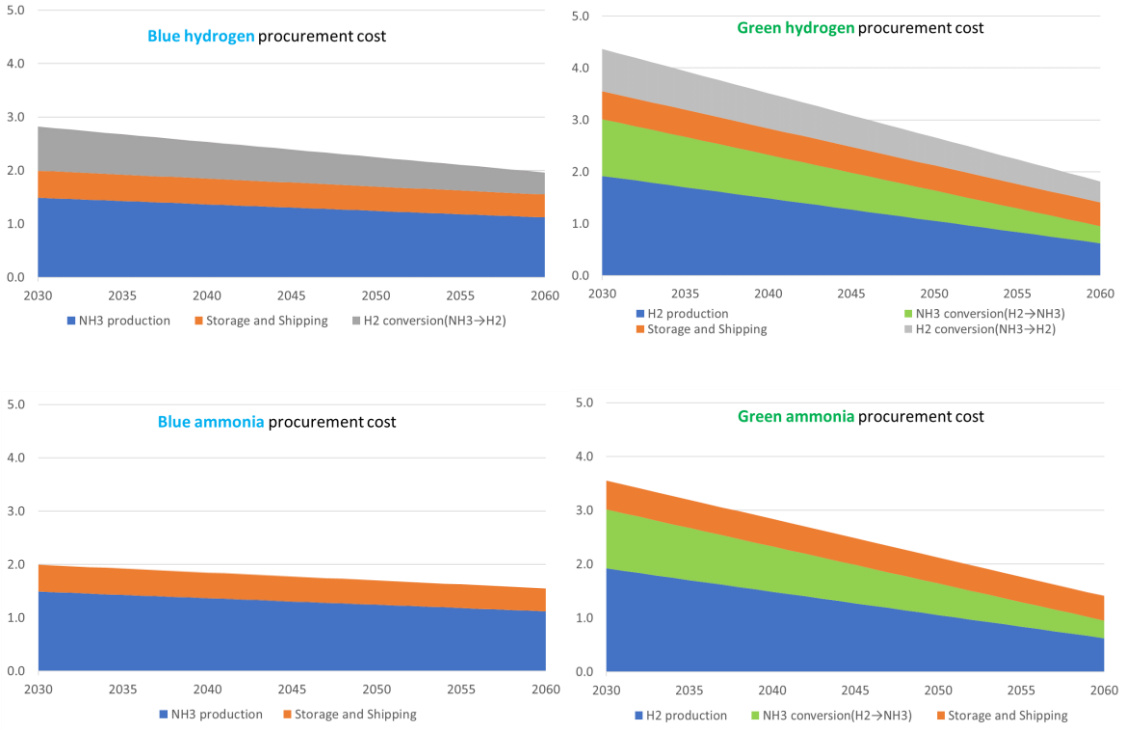
Based on the above assumptions, the cost estimates from 2030 to 2060 are shown in Figure 5-9. In the future, the supply is expected to decline because of the worldwide introduction of hydrogen and evolution of production technologies, particularly that of green hydrogen and ammonia. Although there are many uncertainties regarding long-term estimates, by adopting the cost reduction options as shown in Table 5-3, persistent cost reduction until 2060 is expected to

be realized.

Table 5-3 Cost Reduction Options

Type	Cost reduction option	Cost reduction range	Notes
Blue	Production equipment	▲50%	New ATR technology
	Production operation	▲10%	Efficiency Improvement
	Storage・Transportation	▲15%	Progress of existing technology
	Hydrogen conversion	▲50%	New technology
Green	Electrolytic device	▲70%	New technology
	Storage・Transportation	▲15%	Progress of existing technology
	Hydrogen conversion	▲50%	New technology

Source: IEPMP Study Team



Source: IEPMP Study Team

Figure 5-9 Trend in Hydrogen and Ammonia Prices [USD/kg-H2]

6. Other Energy Sources

6.1 Non-Power Renewable Energy

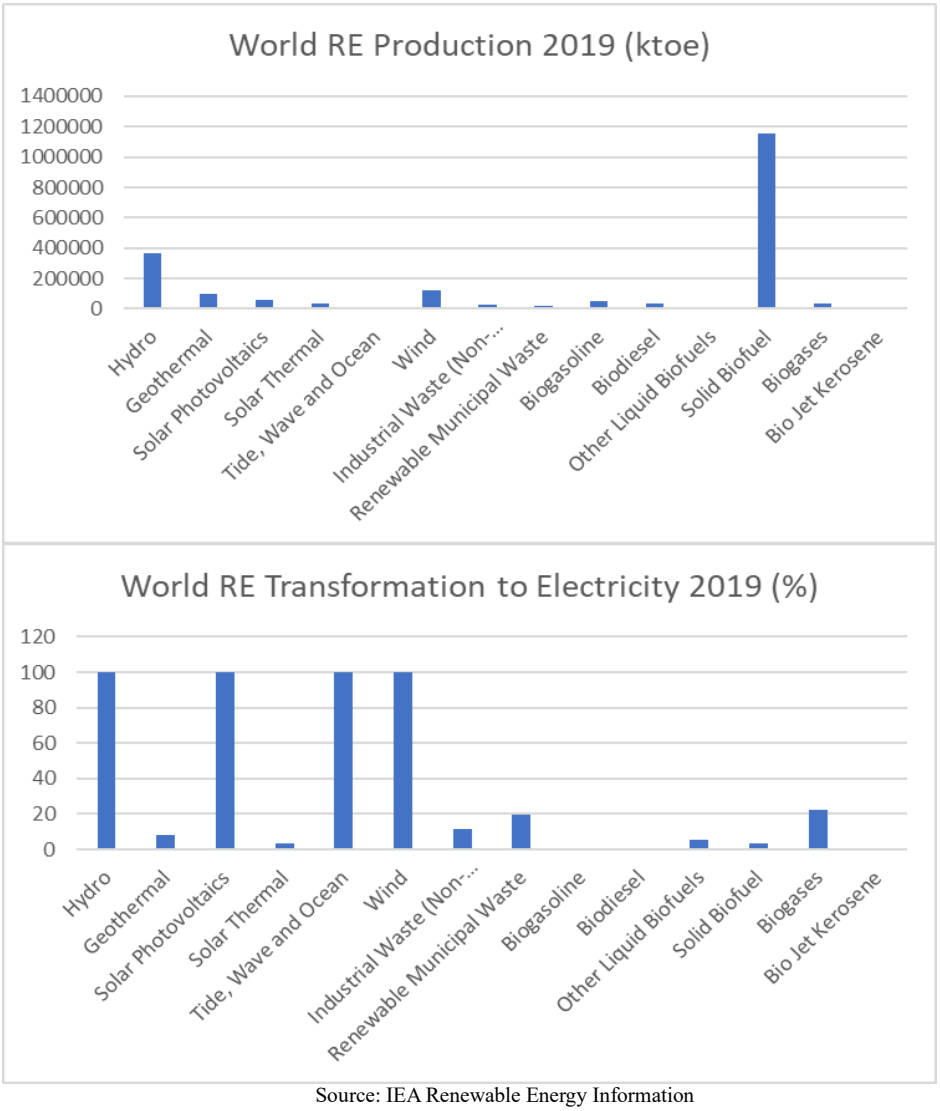
1) Types of non-electrified renewable energy

a. World

Renewable energies can be categorized into 1) those only generating electricity, 2) fuels used for both heat and electric power generation purposes, and 3) those used for heating, cooling, and storage at low temperature. Typical examples of the category 1) are hydro power, solar power by photovoltaic (PV), and wind power. Examples of the category 2) are biomass and biogas. New technologies such as artificial photosynthesis may be included to this category. Examples of the category 3) are the direct use of heat from geothermal and unused heat in nature, such as heat storage using river water.

The amount of energy production and the converted share to electricity of typical renewable energy sources in the world are shown in Figure 6-1. The figure shows that solid biomass, such as firewood and wood chips, still accounts for the majority of renewable energy available in the world, though the share used for electric power is very small.

Although many renewable energies can be converted to electricity, they are still predominantly used as fuels except for hydropower, wind power, PV, and ocean energy. Some technologies, in fact, are suitable for power generation while others are not. For example, about 20% of waste that includes organic materials is used for power generation although other energies such as biofuels are utilized as transportation fuel such as bio-gasoline and biodiesel. Firewood and charcoal, meanwhile, have a very limited share as a source for power generation because they are not efficient as fuel for power generation.



Source: IEA Renewable Energy Information

Figure 6-1 Energy Production by Renewable Energy Technologies and Shares Converted to Electricity

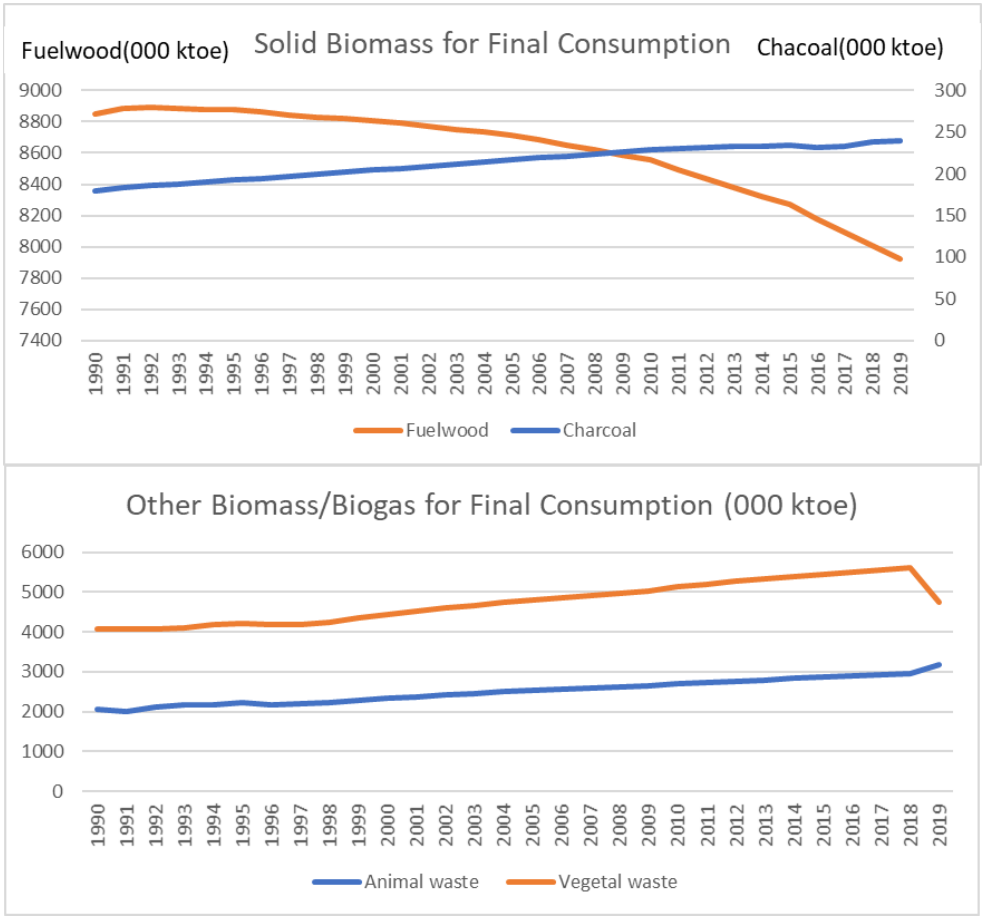
b. Bangladesh

Non-electrified renewable energies that are utilized in Bangladesh are solid biomass (firewood), charcoal, and biogas. Other types of non-electrified renewable energies such as biofuels, geothermal heat, and solar heat have not yet developed in Bangladesh to the extent that the statistics by IEA and the United Nations (UN) can cover.

2) Firewood / charcoal and biogas

According to the statistics of IEA and UN, non-electrified renewable energies in Bangladesh are dominated by firewood and firewood-derived charcoal. Most of the firewood

and charcoal are for residential use (cooking). Figure 6-2 shows that the use of charcoal has increased slightly while the absolute amount of firewood has decreased rapidly in recent years. UN statistics, on the other hand, show that residues derived from livestock and plants have increased rapidly over recent years. Livestock excrement and agricultural residuals were originally used as a substitute during a shortage of firewood. Since the late 1990s, however, the increase in the amount of these residues has coincided with the decrease in firewood. This decline is thought to be because of the expansion of the use of biogas as explained later. Meanwhile, Bangladesh is an agricultural country, and the energy utilization of residues from livestock and crops contributes to the forest conservation and the reduction of methane as by-product of agricultural residues.



Source: UN Statistics Division - Energy Statistics

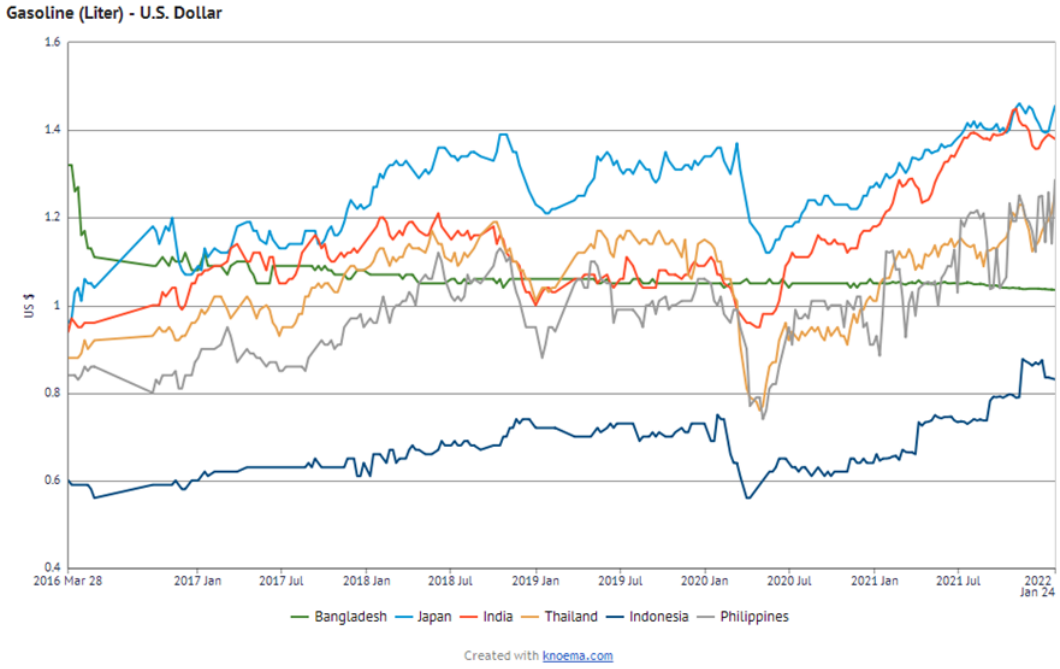
Figure 6-2 Changes in Final Energy Consumption of Solid Biomass, Biomass of Other Types, and Biogas in Bangladesh

3) Biofuel

One of the characteristics of Bangladesh's use of renewable energy compared to its

neighboring countries is that it does not use biofuels. In Asian developing countries, biofuels that are produced from sugar cane or palm oil are widely utilized as a transport fuel. Such biofuels can be domestically produced at low cost as typically seen in biodiesel production in Indonesia and Malaysia. The premise for the success of biofuel utilization is that the fuels can be produced at a lower cost than the international prices of oil products. In Bangladesh, however, due to the climate of Bangladesh, production of the feedstock biofuels such as sugar cane and palm oil are not cost-competitive enough to be converted as a transport fuel.

The pricing policy of transport fuels in Bangladesh is another reason of the lack of progress of biofuels. Figure 6-3 shows the changes in the domestic gasoline prices and those in major Asian countries. It is remarkable that the price in Bangladesh has had less fluctuations and more stabilities compared to other countries. This suggests that the affordability and stability of gasoline price are given higher priority in the Bangladesh's pricing policy. Because of this pricing policy, however, biofuels cannot have cost competitiveness.



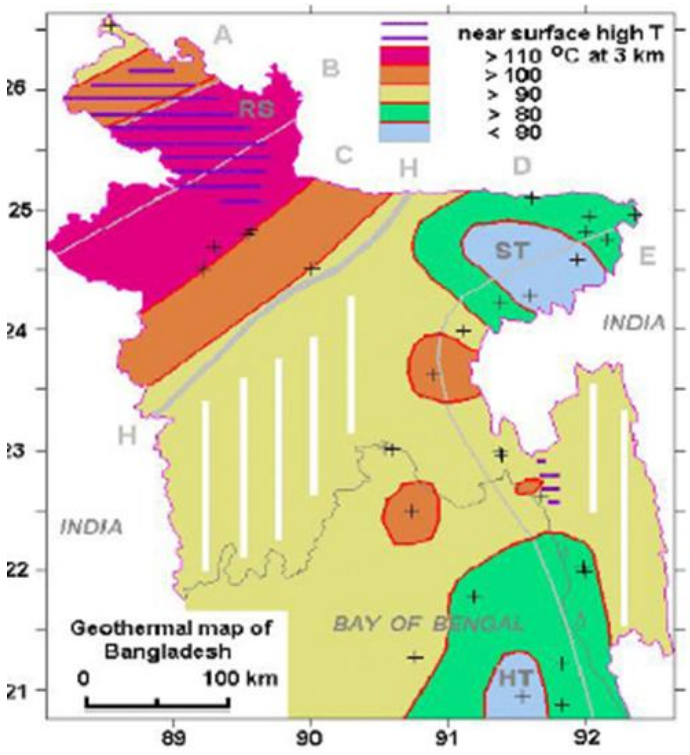
Source: Global Petrol Prices, Weekly Average (https://www.globalpetrolprices.com/)

Figure 6-3 Changes in Gasoline Prices in Bangladesh and Neighboring Countries

4) Geothermal and others

The use of geothermal heat in Bangladesh has not progressed significantly at all. In a cold region or a very warm region, low-cost underground geothermal heat and heat from river water can contribute to heating or cooling of the region. In Bangladesh, however, the demand for heating from geothermal sources and the demand for heat storage by river water are still too small to justify a large-scale deployment for such energies.

It is said that Bangladesh has abundant geothermal heat energy. The temperature depends on the depth. The deeper (the closer to the magma), the higher the temperature can be obtained, though its cost is prohibitive. Figure 6-4 shows the temperature distribution of Bangladesh at the depth of 3 km underground, suggesting that geothermal can be a future option that can be used directly even at low temperatures[4].



Source: Kamruzzaman Khan, 2015

Figure 6-4 Temperature Distribution 3km Depth Underground in Bangladesh

5) Issues of Firewood and SDG7

The United Nations has listed energy as the seventh item of Sustainable Development Goals (SDGs), called "Affordable and Clean Energy". The seventh item of SDGs (SDG7) is divided into three items: 7.1-Access to Energy, 7.2-Renewable Energy, and 7.3-Energy Efficiency. In developing countries such as Bangladesh, 7.1-Access to Energy is especially important from the viewpoint of improving the living standards of the low-income population. Access to “clean” energy, in particular, is of high priority. There is a strong need to switch from firewood to clean energy such as electricity and gas.

Typical problems with firewood are the release of harmful substances including smoke associated with the use of firewood, and the resulting health hazards and adverse effects on forest resources and the natural environment. Therefore, from the viewpoint of SDG 7.1, it is required

[4] Kamruzzaman Khan, “Scope of Geothermal Potential of Bangladesh: A Review”, 2015, https://www.researchgate.net/publication/303590862_Scope_of_Geothermal_Potential_of_Bangladesh_A_Review

to make a policy and technological shift to suppress the use of firewood as much as possible although firewood is categorized as renewable.

In Bangladesh, the direct use of electricity or biogas from biomass / biogas resources have gained increasing attentions in recent year. While the conversion from biomass or biogas to electricity requires a certain level of technology and investments, the direct use of these energy sources is currently expanding thanks to its relatively low supply cost.

In fact, according to the state-owned company Infrastructure Development Company Limited (IDCOL), 57,092 units of biogas plants have been developed since 2006 in Bangladesh, resulting in the saving of firewood by 54,808 tons/year. It means that one unit of biogas plant replaces nearly 1 ton/year of firewood. The potential of biogas from animal residue is estimated to be 4,517 tons/year, most of which derives from cattle (4,510 tons/year). The potential from residues of crops is estimated to be 10,749 tons/year, most of which derives from rice (8,994 tons/year). Combined, the biogas potential of Bangladesh is estimated to be 15,266 tons/year (320,586 TJ in terms of energy (21 MJ/m3) or 7,657 ktoe/year). This is comparable to the total amount of firewood used (7,923 ktoe) in Bangladesh as of 2019.

6) Demand for firewood and the drivers

Firewood is commonly used in developing countries as fuel for cooking. The reasons are 1) there is firewood nearby and it is available for free (self-picking up), 2) there is no clean energy available in rural areas, and 3) clean energies are not affordable even if they are available. Among all reasons, the third reason, or poverty, is the most important driver for the persistent use of firewood[5]. Even if electricity and gas are available from the market, if the lower income population cannot afford to buy such energy, they will be forced to keep collecting the firewood by themselves. Where electricity and gas are not available, in fact, collecting firewood itself is a business, contributing to local employment. It can be said that the demand for firewood and poverty are two sides of the same coin. As long as poverty persists and firewood are cheaply available, the demand for firewood will not go away. Hence, in order to achieve the goals of SDG 7.1, it is necessary to eliminate poverty and clean energy has to be supplied at an affordable cost for lower income population.

One thing to be noted here is that firewood collection creates employment for local lower-income population. If gas and electricity from the grid becomes affordable for the majority of residents, the business of firewood collection, which is a relief for the lower-income population, will be lost. If poverty itself cannot be eliminated, the impacts of the supply of clean energy on the business of lower-income population also needs to be considered and complemented.

[5] "Prospects for Fuelwood-gathering Households", FAO Information Note on Asia-Pacific Forestry Sector Outlook Study, https://www.fao.org/3/w7744e/w7744e08.htm#5.4.4.%20prospects%20for%20fuelwood%20gathering%20households

From this point, it is considered that the promotion of biogas, which creates employment by local production for local consumption, has greater added value than the supply from the grid in areas where poverty and employment problems are large.

6.2 Policy to Promote Non-Power Renewable Energy

Non-power renewable energy competes with renewable power. Thus, the policy to promote non-power renewable power requires extra care to balance relevant factors and interests. In particular, if poverty in local communities cannot be eliminated in the short term, promotion of renewable energy should be designed as a part of a local economic development by promoting local energy production and consumption, which creates employment for the local community.

Pertaining to biomass, biogas, and low-temperature geothermal heat, they can be converted into electricity, or they can be directly utilized as a source of heat supply. It is necessary to balance the market needs in local communities and energy efficiency whether a particular energy source should be used as fuel for electric power or directly as a source of heat supply. The energy conversion efficiency from biomass and biogas to electricity is at best half and typically around 20% to 30%. With the help of the government such as IDCOL, biogas is currently expanding rapidly and is replacing firewood. While this should be promoted and welcomed, it will eventually compete with electricity from the grid as it promotes renewable electricity in its energy infrastructure.

Prioritized policy items in non-power renewable energy are summarized in four ways. The first is to promote renewable energy technologies such as biogas and efficient stoves based on the supply of biogas. The second is to ensure that the promotion renewable energy contributes to local employment, The third is to find an optimal balance of the use of renewable energy wither to be used as fuel for power generation or a source of heat supply. The fourth is to examine the demand location of renewable energy whether the converted electricity should be locally consumed or connected to the grid.

7. Economic analysis

Levelized cost of electricity

Power generation cost is calculated using levelized cost of electricity (LCOE). LCOE is a hypothetical generation cost calculated based on the discounted cash out flow during the entire operational life of certain power generation and the discounted amount of electricity generated.

$$\frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

It = Investment expenditures in year t

Mt = Operations and maintenance expenditures in year t

Ft = Fuel expenditures in year t

Et = Electricity generation in year t

r = Discount rate

n = Life of the system

Figure 6.5.X Formal representation of levelized cost of electricity

Source: IEPMP Study Team

8. Requirement of Clean Energy Supply

8.1 Expected Clean Energy Supply

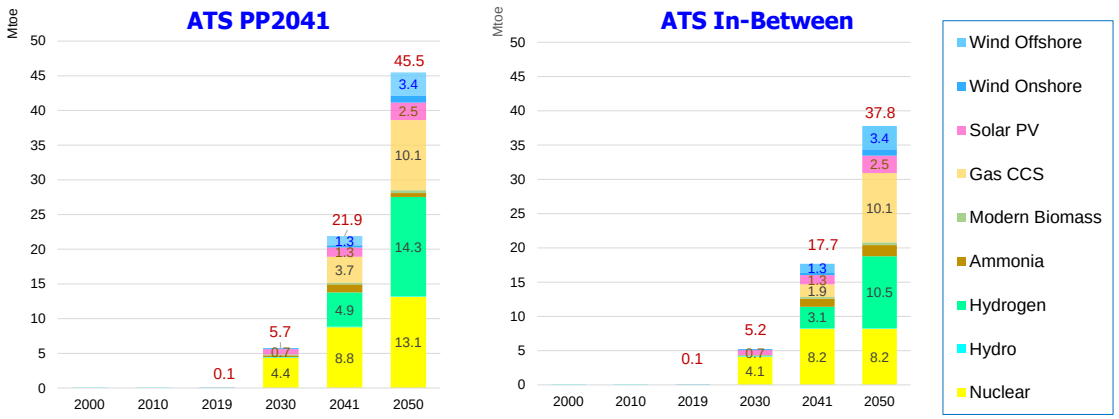
Aiming to build a low carbon economy with clean energy sources amounts to 40% of the power generation mix in 2041, introduction of clean energies must expand rapidly, which include hydro, nuclear, solar PV, wind, modern biomass as well as CCS, ammonia and hydrogen. The total supply of clean energy will amount to 45.5 million toe in 2050 for the PP2041 GDP case and 37.3 million toe for the In-Between case. The share of clean energy will increase from almost zero in 2019 to 27% in 2050 for the PP 2041 case. In addition, power import includes import of hydro power cum green energies from the neighbouring countries.

Table 8-1 Clean Energy Supply in the TPES Mix

	Total Primary Energy Supply (million toe)				Composition				Average Growth Rate			2019 to 2051
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	
PP 2041					%	%	%	%	%	%	%	times
Traditional Fuel	43.1	66.9	93.0	117.6	98.4	89.9	78.5	69.6	4.1	3.0	2.2	2.73
Clean Energy	0.1	5.7	21.9	45.5	0.2	7.7	18.5	26.9	44.6	12.9	6.9	459.40
Power Import	0.6	1.8	3.5	5.8	1.3	2.4	3.0	3.4	10.6	6.5	4.6	9.94
Total	43.8	74.4	118.4	168.9	100.0	100.0	100.0	100.0	4.9	4.3	3.3	3.86
In-Between												
Traditional Fuel	43.1	65.9	86.1	94.3	98.4	90.7	80.5	68.6	3.9	2.5	0.8	2.19
Clean Energy	0.1	5.2	17.7	37.8	0.2	7.2	16.5	27.5	43.4	11.7	7.2	381.67
Power Import	0.6	1.5	3.2	5.5	1.3	2.1	3.0	4.0	9.0	7.1	5.0	9.37
Total	43.8	72.7	107.0	137.6	100.0	100.0	100.0	100.0	4.7	3.6	2.3	3.14

Source: IEPMP Study Team

Among the energy sources, nuclear, hydro and CCS are expected to play important roles. In Bangladesh, geothermal resources are nonexistent. Resources of variable renewable energies notably solar and wind are relatively limited as discussed in Chapter 3, while land available for them is limited with high population density. Their introduction is scheduled at a reasonably maximum level, but the share of these variable new energies will remain below 20% even in 2050.



Source: IEPMP Study Team

Figure 8-1 Outlook of Clean Energy Supply

Table 8-2 Supply Plan of Clean Energy

	Total Primary Energy Supply (million toe)				Composition				Average Growth Rate			2019 to
	2019	2030	2041	2050	2019	2030	2041	2050	19-30	30-41	41-50	2051
PP 2041					%	%	%	%	%	%	%	times
Nuclear	0.0	4.4	8.8	13.1	0.0	76.4	40.0	28.9	-	6.5	3.8	-
Naturlal Gas - CCS	0.0	0.0	3.7	10.1	0.0	0.0	17.0	22.3	-	-	9.5	-
Hydro	0.1	0.1	0.1	0.1	66.7	1.5	0.4	0.2	2.4	0.0	0.0	1.30
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar PV	0.0	0.7	1.3	2.5	32.3	12.8	6.1	5.6	32.9	5.7	5.9	79.09
Wind - Onshore	0.0	0.1	0.3	0.9	1.0	2.5	1.4	2.1	56.8	7.0	11.1	941.53
Wind - Offshore	0.0	0.0	1.3	3.4	0.0	0.0	6.1	7.5	-	-	8.8	-
Variable NREs	0.0	0.9	3.0	6.9	33.3	15.2	13.6	15.1	34.7	11.8	7.9	207.94
Modern Biomass	0.0	0.2	0.3	0.4	0.0	2.8	1.2	0.9	-	4.4	4.0	-
Ammonia	0.0	0.2	1.2	0.6	0.0	4.1	5.3	1.2	-	15.5	-6.4	-
Hydrogen	0.0	0.0	4.9	14.3	0.0	0.0	22.5	31.5	-	-	10.2	-
Clean Fuel	0.0	0.4	6.3	15.3	0.0	6.9	28.9	33.6	-	28.6	8.3	-
Total	0.1	5.7	21.9	45.5	100.0	100.0	100.0	100.0	44.6	12.9	6.9	459.40
In-Between												
Nuclear	0.0	4.1	8.2	8.2	0.0	78.6	46.5	21.7	-	6.5	0.0	-
Naturlal Gas - CCS	0.0	0.0	1.9	10.1	0.0	0.0	10.6	26.8	-	-	16.6	-
Hydro	0.1	0.1	0.1	0.1	66.7	1.6	0.5	0.2	2.4	0.0	0.0	1.30
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-
Solar PV	0.0	0.7	1.3	2.5	32.3	14.0	7.6	6.7	32.9	5.7	5.9	79.09
Wind - Onshore	0.0	0.1	0.3	0.9	1.0	2.7	1.7	2.5	56.8	7.0	11.1	941.53
Wind - Offshore	0.0	0.0	1.3	3.4	0.0	0.0	7.6	9.0	-	-	8.8	-
Variable NREs	0.0	0.9	3.0	6.9	33.3	16.7	16.9	18.2	34.7	11.8	7.9	207.94
Modern Biomass	0.0	0.2	0.3	0.4	0.0	3.1	1.5	1.0	-	4.4	4.0	-
Ammonia	0.0	0.0	1.2	1.6	0.0	0.0	6.5	4.3	-	-	3.2	-
Hydrogen	0.0	0.0	3.1	10.5	0.0	0.0	17.6	27.7	-	-	11.7	-
Clean Fuel	0.0	0.2	4.5	12.5	0.0	3.1	25.6	33.1	-	35.4	9.7	-
Total	0.1	5.2	17.7	37.8	100.0	100.0	100.0	100.0	43.4	11.7	7.2	381.67

Source: IEPMP Study Team

8.2 Points to note

For Bangladesh, the journey to having a low carbon economy is not an easy one as the country is unfortunately not blessed with rich renewable energy resources, notably solar radiation, stable wind flow and/or geothermal power. The country is characterized by flat low land and extremely high population density. The potential of hydro or pumped hydro generation is quite limited. It is said that there are good geological formations suitable for carbon storage, but they have not yet been confirmed technically and commercially. Therefore, it is anticipated that technologies such as nuclear, ammonia/hydrogen and CCS, mainly based on industrial technologies, will play major roles in low carbonization. These technologies are expected to advance significantly in the future. Therefore, it is particularly important to monitor their progress and make decisions at appropriate times in line with the timeline and important milestones of the energy roadmap.

Bangladesh is a country playing catch up with front-running emerging countries such as China and India. In the talk of the energy policy, we should keep in mind that eradication of poverty and improvement of the living circumstances to secure the health of citizens are the most important socio-economic objectives. For example, United Nations has listed energy as one of the items of Sustainable Development Goals (SDGs), and its goal is “Affordable and Clean Energy”. SDG7 is divided into three items: 7.1-Access to Energy, 7.2-Renewable Energy, and 7.3-Energy Efficiency. In developing countries such as Bangladesh, 7.1-Access to Energy is especially

important from the point of improving the living standards of the lower-income population. Particularly “clean” energy should be easily accessed. Thus, there is a need to switch from firewood to modern energies that are said to be clean, such as electricity and gas. Then, how can they be supplied securely at affordable prices, irrespective of climate concerns? We should prudently sort out priorities of goals and measures to achieve under this Energy Master Plan.

9. Summary

To support high economic growth projected to achieve the goals for the PP 2041, the energy supply must be expanded significantly in the coming decades. Major issues and recommendations discussed above are summarized below.

1) Natural Gas

a. Natural gas will continue to be the largest energy source in the future energy mix. However, its medium-term supply-demand balance is exposed to various uncertainties such as rescheduling of large power plant, greater success in industrialization, slow penetration of energy efficiency and conservation, outcome of natural gas exploration, etc. Therefore, trends in these movements must be monitored closely and the natural gas development plan should be fine tuned from time to time.

b. Historically Bangladesh has been dependent on the indigenous natural gas production, but resources are depleting without any remarkable discoveries in recent years. To reverse this trend, potential resources must be discovered and brought into production. All over the world, many sophisticated technologies have been developed in oil and gas exploration, development and production activities during the past two decades. These are expected to greatly change the current stagnant status. To introduce technology and funds for upstream activities from overseas, as they are scarce in Bangladesh, it is necessary to prepare proper business circumstances.

c. To accommodate the increasing gas demand, LNG import will increase. Pending the demand trend, additional expansion of LNG import facilities beyond the present plan will become necessary toward the late 2030s. Proper plans should be developed in accordance with the expected timeline of LNG development. In order to enhance efficient and flexible operation of LNG import as well as materialize long-run economics, upgrading and expansion of land-based LNG import terminals should be given priority.

d. The present national gas grid is incomplete with a fishbone type pressure system and does not cover the western part of the country. This situation will be improved upon completion of the western pipeline system with an FSRU at Payra. For stable operation of the gas system, it is important to create two loop pipelines connecting the eastern system: one in the central part of the country around Dhaka and the other covering the western region with multiple input points. The present gas system is partly obsolete with gas leakages and insufficient monitoring systems. It is necessary to modernize and upgrade the system for safe and efficient management.

e. The city gas supply for the residential and commercial sectors are presently being controlled, enhancing introduction of LPG. It is necessary to examine pros and cons of city gas, LPG and electricity as energy sources for cooking and hot water supply and set

out a balanced policy to achieve an efficient and low-carbon energy utilization.

2) Oil

a. In line with increasing demand for mobility, oil consumption will expand significantly, maintaining the second position in the energy supply mix. As small-scale expansion of the Chittagong refinery is scheduled, but the biggest part of the demand increase is going to be supplied by petroleum product import. A balanced policy should be set out on the roles of domestic refining and product import evaluating not only the amount of the upfront investment, but also long-run economics and national energy supply security.

b. As being considered in the Rationalization Plan of petroleum products distribution to inland markets, oil product import base, inland product pipelines and oil depots should be developed along the timeline.

c. LPG import is projected to expand greatly in the 2030s and onwards. As mentioned for natural gas, it is necessary to set out a balanced policy on how to use city gas, LPG and electricity as the energy for cooking and hot water supply in the residential and commercial sectors.

3) Coal

a. Coal-fired power plants with USC technology started operation in Payra in 2020. The technology is expected to play an important role for the stable supply of electricity at affordable prices and construction of several additional plants is scheduled. At Payra, coal import is facing difficulties due to the shallow water depth of the fairway. To solve the problem, the coal import base being constructed at Matarbari should be equipped with a transshipping facility for river barges. It will make the lightering operation of ocean class vessels and small-lot transportation by river barges easier.

b. Bangladesh is blessed with rich coal resources, but it also has a dense population. With increasing demand, domestic coal production will contribute to develop regional economies, promote energy security and reduce foreign currency outflow. Many challenging problems must be solved before enabling the development of coal mines. Feasibility studies and policy discussions should be implemented as soon as possible in due course.

4) Other Energies

Bangladesh is not blessed with typical resources of renewable energies, notably solar, wind and geothermal energy. Therefore, the country must depend on industry based clean energy technologies such as nuclear, ammonia-hydrogen and CCS. It is important to monitor these fast-developing technologies and make timely investment decisions in line with the overall roadmap toward a low-carbon economy.

The Integrated Energy and Power Master Plan

Appendix F

Environmental and Social Considerations

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1. Methodology and Preliminary Findings

The term "Strategic Environmental Assessment (SEA)" refers to environmental assessment at a higher level of decision-making, as opposed to environmental assessment at a project level. According to JICA's Basic Policy on Environmental and Social Considerations, environmental and social impacts associated with development plans shall be addressed at an early stage or at the policy stage even before the planning stage. When a project carries out a study in the above-mentioned project stage (such as master plan study), the Strategic Environmental Assessment (SEA) shall be applied.

This Project is entitled *Integrated Energy and Power Master Plan* (IEPMP) development, which is a national energy and power plan projecting a long-term trajectory of the energy and power supply by 2050, and it is considered that the Project itself does not anticipate significant adverse impacts as it is a master plan development; hence, it is classified as Category B in accordance with the JICA guideline.

In Bangladesh, SEA is not legally required as the local laws and regulations do not stipulate the specific procedures, on the other hand, the application of SEA is encouraged in National Environmental Policy (NEA) (2018). In this study, the SEA is prepared, based on JICA's Environmental and Social Considerations in consultation with the Ministry of Power, Energy and Mineral Resources, and Department of Environment (DoE) of the Ministry of Environment of Bangladesh and other relevant Ministries.

1.1 Approach and Methodology

Experience of implementing the SEA is still limited in Bangladesh and the DoE and the JICA Study Team have also worked along with the Power Division and the Energy and Mineral Resources Division. To carry out the SEA, the approach and methodology to prepare SEA are presented as follows:

- Identification of overall Sustainability Objectives − Ensures that environmental and social issues associated with the nature of the Plan are incorporated at the earliest stage of decision making in the process;
- Identification of Targets and Indicators − Determines whether the objectives of the strategic action are achieved;
- Description of Environmental Baseline − Illustrates the existing environmental/sustainability conditions in the context of the strategic action;
- Prediction and Evaluation of Impacts − Determines the potential impacts and the strategic management plan including alternatives and identifies opportunities for mitigation; and
- Mitigation of Impacts − An ongoing process to ensure the strategic action is sustainable and the impacts of the proposed actions are minimized.

1.2 Findings from the Inception and Scoping Stages

The SEA is developed, based on the IEPMP and identifies potential environmental and social impacts which may be incurred from the sub project activities. The SEA then addresses appropriate mitigation measures and the management plan at an early stage of the subproject development.

Under this Project, the JICA Study Team and the Government counterparts held the Inception meeting and SEA scoping meeting on November 23, 2021 and July 3, 2022 respectively to consult with various stakeholders concerning environmental and social issues in Bangladesh. The JICA Study Team received various comments from the stakeholders, addressing their concerns about technical specifications and institutional arrangement of the energy and power development and associated environmental and social impacts at subproject activities.

During the inception meeting held in November 2021 (total of 247 participants, of which 31 were female), the JICA Study Team presented the SEA development plan and schedule, based on progress of the power and energy development plan, including transmission and distribution. The principles of SEA, approach and methodology, and scope of work were presented at the meeting. The detailed findings of the inception meeting can be found in Annex A Minutes of Meetings for the Inception Meeting.

During the SEA Scoping meeting held in July 2022 (total of 148 participants), identification of environmental and social impacts associated with the project activities was presented as illustrated below. The detailed findings of the SEA scoping meeting can be found in Annex B. Minutes of Meetings for the SEA Scoping Meeting. Based on the proposed energy and power systems, the following type of energy power mix was proposed. In response, initial identification of environmental and social considerations associated with the infrastructure development were presented.

1) Natural gas

All natural gas operations in Bangladesh are governed and operated by Petrobangla and its affiliated state-owned companies. Although Bangladesh has gas fields (20 fields as of December 2020), domestic natural gas supply is on a downward trend due to declining production at existing gas fields and stagnant development of new gas fields. On the other hand, LNG imports are on the rise, as two offshore LNG receiving terminals have been in operation since the start of LNG imports in FY 2018.

In SEA, with regard to natural gas, it is necessary to evaluate upstream, such as gas field development and LNG procurement (e.g., receiving terminal and pipeline construction), as well as downstream, such as construction of power plants and transmission/distribution networks. Although natural gas-fired power plants emit less greenhouse gases than coal-fired power plants and other types of power plants, it is necessary to pay attention to environmental aspects such as

air quality, water quality, and ecosystems, as well as to resettlement and accidents that may occur when securing land for the plants.

2) Coal

Bangladesh's coal supply comes from the Barapukuria coal mine, the only domestic coal mine, and the rest is imported. In 2021 the Bangladeshi government cancelled a plan to build 10 coal-fired power plants and is now seeking to promote renewable energy. In addition, the introduction of co-firing technology with ammonia and hydrogen is expected to be considered for coal-fired power plants. In accepting coal carriers from overseas, it may be necessary to improve port facilities, etc.

In the SEA, the evaluation will take into account the following points: (1) development of port facilities, (2) construction of coal-fired power plants, and (3) construction of power transmission and distribution networks. Particular attention will be paid to the climate change impacts and air pollution associated with coal-fired power generation.

3) Oil

Domestic crude oil production is limited; imported crude oil is processed at Eastern Refinery Limited, the only refinery in Bangladesh. Oil-fired power generation is relatively expensive from an economic standpoint and is on the decline.

SEA will pay attention to climate change, air and water pollution, ecosystems, land acquisition and resettlement, accidents, etc.

4) Wind

There are no wind farms in operation as of November 2021. Suitable sites for wind power development are unevenly distributed in coastal areas in terms of wind conditions. While the introduction of onshore wind power would be limited, the higher potential for offshore wind power has been identified. One of the challenges is to develop a power transmission and distribution network from coastal wind power development sites to power supply destinations such as Dhaka.

In the SEA, environmental and social impacts, especially on ecosystems, fisheries, and protected areas, need to be taken into account. Bangladesh is located on two migratory bird routes: the East Asian-Australasian Flyway (EAAF) and the Central Asian Flyway (CAF), and the impacts on migratory birds associated with wind farms will be considered. In Bangladesh, as one of the measures to protect and manage migratory hilsa fishery, hilsa sanctuaries have been established. There is also a marine protected area designated in the Bay of Bengal. From a livelihood perspective, the impact on inland and marine fisheries, as well as aquaculture and other industries in coastal areas, should be taken into account. Since cyclones occur in Bangladesh before and after the monsoon season (April-May and October-November), natural disaster risks

will also be considered.

5) Solar

Solar power is positioned as a renewable energy generation technology that the Bangladeshi government plans to expand the most. Of the approximately 777 MW of electricity generated from renewable energy sources, about 70% comes from solar power (about 543 MW (347 MW off-grid and 196 MW grid-connected)) (as of December 2021). Suitable sites for solar power generation are concentrated in the Chittagong hills, in southeastern Bangladesh.

SEA will be carried out with particular attention to land acquisition and associated resettlement for large-scale solar power generation. Bangladesh's high population density and restrictions on the conversion of agricultural land to solar parks have created barriers to land acquisition. Since Bangladesh is surrounded by many rivers and the average elevation is less than 5 m above sea level, the risk of disaster such as flooding will be considered.

6) Nuclear

In Bangladesh, the construction of the Rooppur nuclear power plant (installed capacity of 2,400 MW; to be operational from 2025), which is located inland, is underway by the Russian state-owned company, Rosatom.

In SEA, nuclear power generation emits less greenhouse gases than coal-fired power generation, etc.; however, the evaluation will take into account safety aspects, especially accidents during nuclear power plant operation, and management of radioactive materials (waste, exhaust gas, wastewater, etc.).

7) Hydrogen

Hydrogen power generation is a relatively new technology, and it is assumed to be increasingly utilized.

SEA will consider environmental and social impacts of hydrogen production, hydrogen power generation, and transmission and distribution. Hydrogen emits no greenhouse gases during power generation. However, if CO_2 is emitted during the production process of hydrogen used for power generation (especially in the case of gray hydrogen made from fossil fuels), the impact on climate change should be considered. In addition, for green hydrogen made from renewable energy sources, etc., environmental and social impacts at the electricity procurement stage, such as wind and solar power generation, will also be examined. In addition, from a social perspective, hydrogen is an extremely flammable and combustible gas, so as an environmental and social risk related to hydrogen, attention must be paid to safety management during storage and transportation.

8) Ammonia

In this master plan, the introduction of power generation by co-firing and mono-firing of ammonia is considered. The utilization of ammonia is expected to be introduced in the future.

For ammonia, it is necessary to consider the impact of the production process, such as the procurement of hydrogen as a raw material. In addition, while no greenhouse gases are emitted during combustion, NOx is emitted, so the impact on air pollution, etc. will be considered.

9) Others

The following points which are common to all power sources will be taken into consideration.

a. Protected areas/ Ecosystem

In Bangladesh, the Wildlife (Conservation and Security) Act (2012) defines wildlife sanctuaries, marine protected areas, etc. The Environmental Conservation Act defines Ecologically Critical Areas (ECAs). SEA will examine information on protected areas and critical habitats to ensure that no significant negative impacts occur.

b. Natural disaster

Bangladesh is surrounded by many rivers and is prone to flooding due to inflows from upstream catchments and localized heavy rainfall; the country is located on the route through which cyclones pass each year. SEA will consider the risk of disasters, in consideration of changes in flood frequency and magnitude due to climate change, as well as sea level rise, etc.

c. Institutional arrangement related to environmental and social considerations

Toward 2050, which is the scope of this master plan, the current systems related to environmental and social considerations will be reviewed, issues will be sorted out, and recommendations on institutional aspects that need to be considered will be compiled. In particular, it is necessary to review institutional arrangements for renewable energy in order to promote wind power generation, etc., as envisioned in energy and power supply scenario (e.g., zoning and environmental impact assessment provisions for wind power generation and a mechanism to manage cumulative impacts should be established).

The items to be taken into initial consideration for SEA are described below. As of September 2022, the details of each scenario are under preparation, SEA is conducted for the final version of the power mix.

Table 1.2-1 Items to be Taken into Consideration During SEA Scoping

No.	Items to be taken into considerations for SEA	Thermal			Wind	Solar	Nuclear	Hydrogen	Ammonia
		Natural Gas	Coal	Oil					
1	Climate change	○	◎	○	-	-	-	○	○
2	Air pollution	○	◎	○	-	-	-	-	○
3	Water pollution	○	○	○	-	-	○	-	-
4	Waste	-	○	-	-	-	◎	-	-
5	Protected areas	△	△	△	△	△	△	△	△
6	Ecosystem	○	○	○	◎	○	○	○	○
7	Land aquistion/ Involuntary resettlement	○	○	○	○	◎	○	○	○
8	Accidents	○	○	○	-	-	◎	◎	◎
9	Natural disaster	△	△	△	△	△	△	△	△

Note: ◎ (significant impacts are expected), ○ (impacts are expected to some extent), △ (impacts are largely subject to locations, etc.), - (minor impacts are expected/ almost no impacts are expected)
Source: Prepared by JICA Study Team

2. Project Description and Evaluation of Three Scenarios

In view of the future energy and power supply to cope with global climate change, three energy scenarios are developed, considering the variable factors such as GDP growth potential, and international energy price assumptions.

In terms of GDP, the PP2041 case, which is the perspective plan of Bangladesh, projecting the target GDP per capita of US$16,000 in nominal terms in 2041.

(1) Scenario Approach on Energy Outlook

In this study, three scenarios are categorized as Reference Scenario (REF), Advanced Technology Scenario (ATS), and Net-Zero Scenario (NZS) as shown in Table 2.1-1 and its detailed projection of Scenarios is found in Chapter 4.

Table 2.1-1 Scenario Approach on Energy Outlook

	Reference Scenario (REF)	Advanced Technology Scenario (ATS)	Net Zero Scenario (NZS)
Characteristics	The past trends will continue based on the existing energy and environmental policies. Radical changes will not take place on energy efficiency and low carbonization policies.	Energy and environmental policies to ensure stable energy supply and strengthen climate action will be successful to a certain extent. Introduction of advanced technologies will progress.	Greenhouse gas emissions will be net zero in 2050. The transition path toward 2050 is estimated by backcasting approach.
Policy	Progressively strengthen low-carbon policies as observed in the past developments.	Significant progress in international cooperation along with strengthening domestic policies.	Extremely strong energy and environment policies are necessary to achieve net zero by 2050.
Technology	Efficiency improvement follows past trends. Cost reduction like past trends. Spread of low-carbon technologies through regulation and policy.	Technology progress accelerates cost reduction. Strengthening regulations and guidances accelerates dissemination.	Assume technologies to reduce greenhouse gas emissions to net zero in 2050. Timing and amount of introduction of each technology are assumed by backcasting approach.

Source: JICA Study Team

REF simply follows the past development trends, while NZS focuses on extremely strong policies to achieve net-zero carbon emissions in 2050. ATS aims at pursuit of a low-carbon society mobilizing practicable and affordable means to a maximum extent. A three-scenario outlook is shown in Figure 2.1-1 and technology settings are described in Table 2.1-2.

REF follows the past trends, reduction of carbon emissions will be also pursued, though it will not significantly deviate from the historical trend. In terms of assumed technologies, moderate progress will be observed in the efficiency improvement, cost reduction of energy supply, and adoption of low carbon technologies.

In NZS, carbon emissions are set at net zero in 2050 and a back cast approach is applied to find the pathway to 2050. Technology development and international cooperation should be pursued at an extreme pace. Energy conservation, electrification and hydrogen utilization must be also introduced at maximum in the industry sector. Thorough energy conservation and electrification

must be expanded in the residential and commercial sectors. In the road sector, most cars must become electric vehicles (EVs) except for some hydrogen-driven trucks and buses (TRBS).

As shown in Table 2.1-3, a roadmap for the timing of start-up and investment decision of critical energy supply infrastructures is proposed. In the power system development, one critical decision in the short- to mid-term is for the third and fourth unit of additional nuclear units.

Feasibility study of the first offshore wind farm may be undertaken around 2028. Detailed study for natural gas with CCS and the hydrogen mono-firing power generation will be started around 2030. Feasibility studies for coal mines should also be started in 2024.

In the oil sector, the expansion project needs to be approved for the existing Eastern Refinery and the installation of single point mooring system in Moheskhali by 2025. In addition, LPG import facility also needs to be on stream by 2030 and the feasibility study to be started in 2025.

In the natural gas and LNG sector, the third FSRU will need to be done in a short period of time, its feasibility study by 2023 or 2024. The fourth FSRU plans (Payra) to be installed in the western part of the country may need to take extra time to complete. In addition, development of the domestic pipeline network, particularly the network from Matarbari to Dhaka, should also be pursued and the study for the network development is to be initiated by 2024.

Table 2.1-2 Technology Setting: Power Generation Sector by Scenario

		Net-Zero Scenario (NZS)		Advanced Technology Scenario (ATS)	
Power Sector	Renewables	Solar PV (Solar Park, Irrigation)	16 GW in 2050 with land use restrictions	Solar PV (Solar Park, Irrigation)	6 GW in 2050 without land use restrictions
		Solar PV (Rooftop)	12 GW in 2050 on rooftops of the buildings	Solar PV (Rooftop)	12 GW in 2050 on rooftops of the buildings
		Onshore wind	5 GW in 2050, mainly coasts	Onshore wind	5 GW in 2050, mainly coasts
		Offshore wind	50 GW (near seas + EEZ) in 2050 excl. heritages	Offshore wind	15 GW (only near seas) in 2050 excl. heritages
	Nuclear	Eight (8) units by 2050		Six (6) units by 2050	
	Coal-fired	50% ammonia co-firing around 2030 and 100% ammonia single-firing around 2042		20% ammonia co-firing around 2030 and 50% ammonia co-firing around 2035	
	Gas-fired	100% hydrogen single-firing will start around 2035 and replace 70% of gas-fired power through 2050. Gas-fired with CCS will start around 2036 and achieve 30% of the gas-fired power in 2050.		20% hydrogen co-firing will start around 2035, 50% hydrogen co-firing around 2040 and 100% hydrogen single-firing around 2045. Gas-fired with CCS will start around 2036 and achieve 77 TWh (IMF Ext 26 TWh) in 2050.	
	Oil-fired	For about 1% of grid net power generation in 2041, oil-fired power will remain through 2050.		For about 1% of grid net power generation in 2041, oil-fired power will remain through 2050.	
	Captive	Conventional captive power will be zero in 2050.		Conventional captive power will remain a little in 2050, while high-efficiency co-gen system will be introduced from 2031 and reach 300 MW (app. 30 MW*10 towns) in 2050 nationally.	
	Import	15% of total electricity demand through 2050		10% of total electricity demand through 2050	

Table 2.1-3 Roadmap for Critical Energy Supply Infrastructure Development

Energy	Facility	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Power development	Solar park (first plant on the Bangladesh Delta Plan)	Construction of committed and planned prjects		Potential Survey										FS		FID			On stream											
	Offshore wind (first plant)			Potential Survey			FS			FID					On stream															
	Nuclear	*Constructoin*	On stream		FS		FID Roopoor #3&#4						On stream				FS		FID #5&#6					On stream						
	Gas w/CCS (first plant)										FS		FID			On stream														
	Ammonia co-firing (first plant)				FS		FID			On stream																				
	Hydrogen (first plant)									FS		FID			On stream															
Coal	Barapukuria U/G Extension North	FID	*Construction*		On stream																									
	Barapukuria U/G Extension South								FID				On stream																	
	Barapukuria Open cut			FS			FID								On stream															
	Digipara Underground			FID					On stream																					
	Karaspir Underground			FS			FID					On stream																		
Oil	ERL expansion			FID		On stream																								
	Refinery																	FS			FID				On stream					
	SPM #1~#3 & Tank yard	FID #1	On stream?							FS		FID#2			On stream	FS		FID#2		On stream										
	Dhaka-Chittagon pipeline		On stream																											
	Import pipeline from India					FID			On stream																					
	LPG terminal				FS	FID#Moheshkali			On stream					FS		FID#2		On stream			FS		FID#3		On stream					
Natural gas/LNG	FSRU #3~#8		FS		FID#3	On stream		FS			FID#4	On stream		FS		FID#5	On stream	FS			FID#6	On stream		FS	FID#78&#8		On stream			
	FSRU-Replace																							FS	FID#3 rep		On stream			
	Onshore terminal											FS		FID	*Construction*	On stream						FS		FID		On stream				
	Domestic pipeline*			FS		FID	*Construction*		On stream																					
	Feni~Bakhrabad pipeline														FS		FID	*Construction*	On stream											
	Satelite terminal #1~#3								FS		FID#1~#3		On stream																	

Domestic pipeline*: Moheshkali~Ashugani; Moheshkali~Feni; Bheramara~Khulna; and Bakhrabad~Langajband.

(2) CO_2 Intensity of Energy Outlook

A preliminary study was run to examine these three scenarios in terms of energy efficiency on the total primary energy supply (TPES) and carbon emissions, while CO_2 intensity of a country can be observed as follows:

CO_2 Intensity: CO_2/GDP=(TPES/GDP) x (CO_2/TPES)

The energy efficiency index (EEI: TPES/GDP) declines along with technology progress and energy conservation efforts (Figure 2.1-1). It falls 64% between 2019 and 2050 in REF (3.2% annual decline), 69% in ATS (3.7%), and 78% in NZS (4.7%). As a reference, India's EEI reduced 2.4% annually between 2010 and 2019, and China's EEI reduced 3.5% annually between 1996 and 2019 after achieving the US$1,300 (2010 price) of real GDP per capita, respectively, which is close to the present status in Bangladesh. The estimated EEI improvement in ATS is almost the same as China's experience, and the estimated EEI improvement in NZS is considerably greater than China's experience.

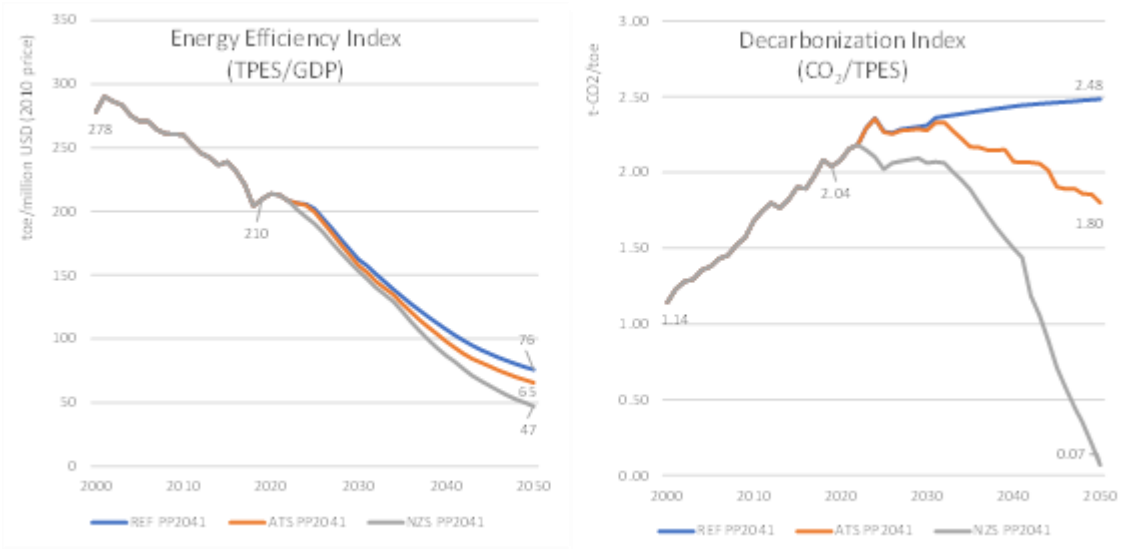


Figure 2.1-1 Comparison of Three Scenarios on Technology Development

CO_2 emissions from energy will be the largest in REF, followed by ATS and NZS. It will grow significantly in REF PP2041 to 485 million tons-CO_2 in 2050, which is about half of Japan's emissions in 2019. In ATS PP2041, it will grow moderately to 304 million tons- CO2, almost two thirds of that in REF. The emissions of NZS PP2041 are, by definition, almost zero in 2050.

Decarbonization Index (DCI: CO2/TPES) follows very different paths among three scenarios (Figure 2.1-1). It will continue to grow in REF, while it will gradually decline in ATS, reflecting the accelerated efforts to manage carbon emissions and adoption of advanced decarbonization technologies in the 2030s and 2040s. In NZS, applying a back-casting approach, it needs to drop sharply to achieve net zero in 2050. However, in Asia, no country, such as Thailand, Indonesia,

China, India, and Vietnam, has experienced reduction of DCI at the level that achieves US$1,300 (2010 price) of real GDP per capita.

Considering the required reduction of CO_2, the NZS is almost impractical to achieve by 2050 while the ATS has the potential to work around the reduction target. Based on the discussion above, the energy demand/supply forecast is run on the Advanced Technology Scenario (ATS) with two GDP projections of the PP2041 case and In-Between Case.

(3) Total Primary Energy Supply

Total primary energy supply (TPES) is a sum of the final energy consumption except for electricity and the fuel input in power sector (Figure 2.1-2). In the ATS PP2041 case, TPES will expand by about four-fold to 169 million tons oil equivalent (Mtoe) in 2050 from 44 Mtoe in 2019. The size of TPES in 2050 is close to that of the United Kingdom in 2019. To be comparable, in the ATS 'In-between' is also considered to make a reasonable adjustment of the current GDP growth ratio that reflect the trajectory of the development path like other Asian countries. TPES for the ATS in between case will expand by about three-fold to 141 Mtoe in 2050, which is close to that of Thailand in 2019.

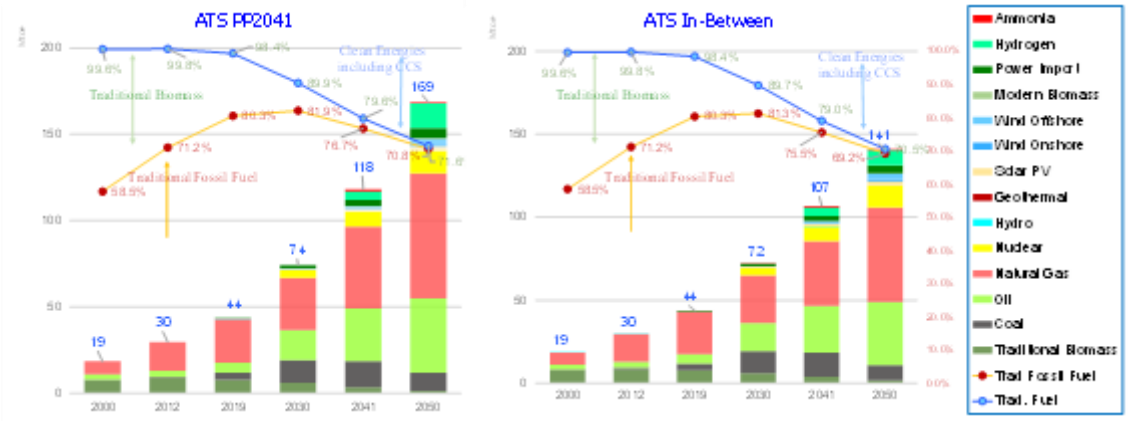


Figure 2.1-2 Total Primary Energy Supply

(4) Evaluation of Energy Outlook Scenarios (Alternative Analysis)

At present, 91.3% of the power supply comes from thermal power plants burning conventional fossil fuels such as coal, oil and natural gas while 1.3% is supplied by clean energy, mainly PVs and 7.5% comes from import.

Reference Scenario (REF) continues to depend on natural gas although the new technological advancement is somehow limited. On the other hand, Advanced Technology Scenario (ATS), consisting of a variety of power and energy sources such as solar, onshore and offshore wind and

hydrogen, and other emerging technologies such as ammonia and CCS, diversifies the national power and energy portfolio. Adaption ratio of renewable technologies under ATS are similar to that of the countries like Thailand and China as described above. In contrast, Net-Zero Scenario (NZS) takes the strict decarbonization measures to achieve net zero by 2050, revealing that this development path is not achievable as it requires substantial technology transfer in a limited timeframe, which may severely impact the economic activity of the country.

Among three energy outlook scenarios, ATS and ATS in-between cases are a well-balanced scenario in view of economic affordability, environmental sustainability, and energy security, compared with REF and NZS. ATS will achieve the NDC conditional target by 2030 and this development path will meet adaption of 21% of clean energy by 2041, which is the target declared by the Prime Minister at COP26 in 2021.

Under these two ATSs, the power supply will expand 7.38-fold in the PP 2041 case between 2019 and 2050, while 5.91-fold in the In-Between case. In contrast, the conventional fossil fuel ratio including natural gas used at captive and co-generation users needs to be decreased from 97.1% in 2019 to about 40% in 2050. Coal-fired power remains more than 10% in 2041, but will almost disappear towards 2050.

The ratio of clean energy surpasses 40% in 2041 though natural gas will continue to be the largest power generation source in 2050. Hydrogen-fired power and gas-fired power with CCS will occupy remarkable shares in 2050. Power import from the neighboring countries and nuclear power also have considerable shares. In contrast, the share of renewable energies will be relatively small mainly due to limited availability of suitable land areas.

Table 2.1-4 Comparison of Energy Outlook Scenarios by 2050 (Alternative Analysis)

Criteria		REF-PP2041	ATZ-PP2041	ATZ-In between	NZS-PP2041	Narrative Evaluation Among Three Scenario
Economic Affordability	Average LCOE (2050)	1	1.1	1.1	1.3	- REF: Excellent - ATZ PP2041: Good - ATZ In between: Good - NZS: Fair
Environmental Sustainability	EEI	76 tons/$ million (-3.2%/yr. Average)	66 tons/$ million (-3.7%/yr. Average)	65 tons/$ million (-3.7%/yr. average)	47 tons/$ million (-4.7%/yr. Average)	- REF: Fair (Relatively high CO2 emissions in terms of climate change. (Relatively high impact on environmental aspects such as air pollution associated with the use of fossil fuels) - ATZ PP2041: Good (Positioned between REF and NZS) - ATZ In-between: Good (Positioned between REF and NZS) - NZS: Excellent (Relatively low CO2 emissions in terms of climate change. Relatively low impact on environmental aspects such as air pollution. On the other hand, land acquisition associated with solar power generation and ecological impacts associated with wind power generation are expected to be relatively larger than those of the REF. (Since the proportion of hydrogen, ammonia, and nuclear power generation is relatively large, attention must be paid to social aspects such as accidents associated with their operation.)
	DCI	2.48 ton-CO2/toe	1.80 ton-CO2/toe	1.93 ton-CO2/toe	0.07 ton-CO2/toe	
	Power mix of renewable energies, etc.	REF: Fair (6% Clean Energy and renewables of the total primary energy supply except import)	ATZ PP2041: 21% Clean Energy and renewables of the total primary energy supply except import	ATZ In-between: (25% Clean Energy and renewables of the total primary energy supply	NZS : 40% Clean Energy and renewables of the total primary energy supply except import	
	Solar	760 MW	6 GW 12 GW (Rooftop)	6 GW 12 GW (Rooftop)	16 GW 12 GW (Rooftop)	
	Wind		5GW (onshore) 15GW (offshore)	5GW (onshore) 15GW (offshore)	5 GW (onshore) 50 GW (offshore)	
	Hydrogen and Ammonia		20% Ammonia co-firing from 2030. 20% hydrogen co-firing from 2035	20% Ammonia co-firing from 2035. 20% hydrogen co-firing from 2037	50% Ammonia co-firing from 2030. 100% hydrogen from 2035	
	CCS		Gas-fired with CCS from 2040	Gas-fired with CCS from 2040	Gas-fired with CCS	
	Nuclear	2.4 GW	7.2 GW	4.8 GW	9.6 GW	
Energy Supply Security	HHI of PES mix (2050)	1	0.7	0.7	0.6	- REF: Fair - ATZ PP2041: Good - ATZ In-between: Excellent - NZS: Excellent
	HHI of power mix (2050)	1	0.5	0.3	0.3	

Note: EEI: Energy efficiency index, DCI: Decarbonization Index, PES: Primary Energy Supply, PP2041: Perspective Plan of Bangladesh 2021-41
Source: JICA Study Team

3. Current States of the Environment

The IEPMP has proposed the integrated trajectory of energy and power infrastructure development plan that includes construction of the power and energy facilities and the selection of the physical locations needs to take into account the sub infrastructure like roads, power line, water supply and sewerage among others which may be socially, economically and environmentally impacted.

The SEA study has examined the baseline of the environment at the national level because the IEPMP does not specify the location of sub projects as it is a planning process of the project intervention for the future. The baseline information is summarized below while the detailed information and data are provided in Annex C.

1) Baseline of the Environment

Table 3.1-1 Baseline of the Environment

Topics	Summary of the Environmental Baseline
Topography of Bangladesh (Annex C.1.2)	● Bangladesh is a small country, but it has considerable topographic diversity. It has three distinctive features: (i) a broad alluvial plain subject to frequent flooding, (ii) a slightly elevated relatively older plain, and (iii) a small hill region drained by flashy rivers.
Water Resources (Annex C.1.6)	● Bangladesh consists of seven major surface geologic units mapped in the Holocene plain lands which are (1) alluvial fan deposits, (2) alluvial deposits, (3) deltaic deposits, (4) Pleistocene terraces and (5) coastal deposits, (6) Holocene depression deposit and (7) tertiary deposit. Brahmaputra is the 22nd longest (2,850 km) and the Ganges is the 30th longest (2,510 km) river in the world.
Air quality (Annex C.1.7)	● Air pollution-related deaths and diseases have been on the rise in recent years, exacerbating people‘s health condition, particularly children, women, and the elderly. Industries are mainly concentrated in major urban metropolitan areas such as Dhaka, Rajshahi, the seaport cities such as Chittagong and Khulna, the inland port cities like Narayanganj, and other divisional towns.
Noise pollution (Annex C.1.7)	● In Bangladesh noise pollution is a major health hazard. In fact, millions of people in Bangladesh are exposed to a number of health risks – from deafness to heart attacks. On city streets noise pollution can be caused by hydraulic horns used by buses, trucks, and scooters in the crowded city streets.
Biodiversity, ecosystem (Annex C.1.10)	● Bangladesh is a biodiversity-rich country, provided with its location in the subtropical belt at the confluence of two major biotic sub-regions of the oriental region: Indo-Himalayas and Indo-China. The Encyclopedia of Flora and Fauna of Bangladesh has recorded 3,723 species. Forest genetic resources are also rich (e.g., 2,260 plant species

	are reported from the Chittagong region and 1,048 tree species including the gymnosperm, dicot and monocots reported from the country)
Social environment (Annex C.1.3)	● Bangladesh is ranked in the 1st position for having 1,252 people per square km, which is three times as dense as India. Bangladesh is a country of about total of 146.10 million of people, of which 5.3 million are slum dwellers. The total population of indigenous ethnic minorities was estimated to be over 2 million in 2010, spread across the division of the country. Main fuel used for cooking is wood/firewood (41.3%) and followed by dung / leaves / straw (38.7%) and natural gas/LP gas (19.6%). There still exists a wide variation in the use of fuel between the urban and rural areas. In the urban area, 53.9% used natural gas for cooking compared to only 5.4% in the rural areas.
Education (Annex C.1.12)	● The government is providing free education up to HSC (Class- 12) for the female along with stipend. It is expected that this will contribute to enhancing the enrollment rate of the female students, decreasing the rate of dropouts and enriching the country with an educated mass. Literacy rate at the national level is that both sex accounts for 73.2% while Male is 73.2% and female is 71.2%.
Public Health (Annex C.1.13)	● The Government of Bangladesh has given the highest priority to reduce infant and maternal mortality below 5, ensuring safe delivery. It is found that the highest percent (35. 71%) of the population is having morbidity in Dhaka division while the lowest percent (4.47%) of the population having morbidity in Barisal division.
Cultural Heritages (Annex C.1.14)	● Until 2010, there are 397 protected sites, 14 museums and 4 libraries. Of them, Panam City of Sonargaon itself possesses 49 individual heritage buildings which has been treated as single site as per gazette notification.
Natural Hazards (Annex C.1.5)	● Earthquake: Bangladesh has been divided into four generalized seismic zones. The northeastern folded regions of Bangladesh are the most active zones and belong to the zone-IV. ● Tsunamis: Tsunami zones are divided into three Tsunami Vulnerability Belts. It has been estimated that at least 4.7 million people live in the most tsunami-vulnerable area of Coastal Belt I and 12.9 million people in Coastal Belt II. ● Climate Risk: Bangladesh ranks between 11 and 20 climate risk index. Bangladesh is ranked 7th in the 10 most affected countries considering the Long-Term Climate Risk Index (CRI) from 2000 to 2019. ● Flooding: Bangladesh is divided into flood prone zones. In the coastal zone, severe tidal surge zone is identified. It is classified mostly in the riverbank of the major rivers such as Meghna, Padma and Brahmaputra. Severe flash flooding can be observed in the eastern part of Bangladesh. ● Cyclone: Devastating cyclones hit the coastal areas of Bangladesh almost every year. Most of the damage occur in the coastal regions of Khulna, Patuakhali, Barisal, Noakhali and Chittagong and the offshore islands of Bhola, Hatiya,

	Sandwip, Manpura, Kutubdia, Maheshkhali, Nijhum Dwip, Urir Char and other newly formed islands.

2) Bangladesh's Legal Framework Relevant to Environmental and Social Safeguards

The SEA study has also examined the relevant laws and regulations applicable for the infrastructure development. The summary of the relevant legal framework is described below while the detailed information and data are provided in Annex D.

Table 3.1- 2 Summary of Bangladesh's Laws and Regulations

Topics	Name of Laws and Regulations	Summary of the Description
Biodiversity (Annex D.1.6)	Biodiversity Act	● The Act is to ensure conservation of biodiversity, the sustainable use of its components and fair and equitable sharing of benefits arising out of the utilization of genetic resources. The government is empowered to declare any place or area significant for its biological heritage as "Biodiversity Heritage Sites", prohibiting the taking of activities that may have an adverse effect on endangered animals or organisms, etc.
	Wildlife Act	● This Act is to provide for the conservation and safety of biodiversity, forest, and wildlife of the country. One of the important chapters in this act deals with the protection of wild animals and plants: 1) No person shall hunt any wild animal without a license or pick, uproot, destroy, or collect any plant (mentioned in Schedule IV), and 2) The Government may prohibit hunting of any specified or all wild animals in a specific forest area or throughout Bangladesh for a specific period
	Protection and Conservation of Fish Rules	● Section 5 of the Rules requires that "No person shall destroy or make any attempt to destroy any fish by explosives, gun, bow and arrow in inland waters or within coastal waters".
Climate Change	Bangladesh NDC (Power Sector)	Unconditional Contribution: ● Implementation of renewable energy projects of **911.8 MW** ● Installation of new Combined Cycle Gas based power plant (**3208 MW**) ● Efficiency improvement of Existing Gas Turbine power plant (570 MW) ● Installation of prepaid meter Conditional Contribution: ● Implementation of renewable energy projects of 4114.3 MW

		● Coal power plant with Ultra super critical technology-12147 MW ● Installation of new Combined Cycle Gas based power plant (5613 MW) ● Efficiency improvement of Existing Gas Turbine power plant (570 MW) ● Installation of prepaid meter ● Bring down total T&D loss to a single digit by 2030
Air/Noise (Annex D.1.3)	Environmental Conservation Act	● The Act conserves and enhances the quality of the environment and to control, prevent and mitigate pollution. Highlights of the Act include (1) regulation with respect to vehicles emitting smoke harmful for the environment, (2) regulation of development activities from environmental perspective, (3) promulgation of standards for quality of air, water, noise, and soils for different areas and for different purposes.
Water (Annex D.1.9)	Water Act	● The Water Act establishes a new, integrated approach to the protection, improvement and sustainable use of the rivers, lakes, estuaries, coastal waters and groundwater of the country. Key highlights of the Act are (1) right to water, (2) adoption of National Water Policy and National Water Resources Plan, (3) clearance Certificates, (4) water stressed areas and safe yield, (4) restricting abstraction, protection orders and compliance order, (5) right to information and false information, (6) water resource protection / pollution control and water quality standards.
Human Health and Safety (Annex D.1.8)	Labor Rules	● In Bangladesh 47 labor related laws are now in operation. These relate to (a) wages and employment, (b) trade union & industrial disputes, (c) working environment and (d) labor administration and related matters.
Land Use (Annex D.1.4)	Land acquisition	● The Ordinance governs acquisition and requisition by the government of immovable property for any public purpose or in the public interest.

3) International Conventions and Treaties

The SEA study has also reviewed the relevant international conventions and treaties ratified by the Government as shown in Table 3.1-3.

Table 3.1- 3 Bangladesh's International Conventions and Treaties

Environment-related international conventions and Treaties	Status
International Plant Protection Convention (Rome, 1951.)	01.09.78 (ratified)

Environment-related international conventions and Treaties	**Status**
International Convention for the Prevention of Pollution of the Sea by Oil (London, 1954 (as amended on 11 April 1962 and 21 October 1969.)	28.12.81 (entry into force)
Plant Protection Agreement for the Southeast Asia and Pacific Region (as amended) (Rome, 1956.)	04.12.74 (accessed) (entry into force)
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (Brussels, 1969.)	04.02.82 (entry into force)
Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, 1971) ("Ramsar Convention").	20.04.92 (ratified)
Convention Concerning the Protection of the World Cultural and natural Heritage (Paris, 1972.)	03.08.83 (accepted) 03.11.83 (ratified)
Convention on International Trade in Endangered Species of Wild Fauna and flora (Washington, 1973.) ("CITES convention")	20.11.1981 (signed), 18.02.82 (ratified)
United Nations Convention on the Law of the Sea (Montego Bay, 1982.)	10.12.82 (ratified)
Vienna Convention for the Protection of the Ozone Layer (Vienna, 1985.)	02.08.90 (accessed) 1.10.90 (entry into force)
Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal 1987.)	02.08.90 31.10.90 (accessed) (entry into force)
CBD (Convention on Biological Diversity)	05.06.1992 (signed), 20.03.1994 (ratified)
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (Basel, 1989.)	01.04.93 (accessed)
London Amendment to the Montreal Protocol on substances that Deplete the Ozone Layer (London, 1990)	8.03.94 (accessed) 6.06.94 (entry into force)
UNCCD (United Nations Conventions to Combat Desertification)	14.10.1994 (signed), 26.01.1996 (ratified)
Copenhagen Amendment to the Montreal protocol on Substances that Deplete the Ozone Layer, Copenhagen, 1992	27.11.2000 (accepted) 26.2.2001 (entry into force)
Montreal Amendment of the Montreal Protocol on Substances that Deplete the Ozone Layer, Montreal, 1997	27.7.2001 (Accepted) 26.10.2001 (Entry into force)

Environment-related international conventions and Treaties	Status
Kyoto Protocol	22.10.2001 (ratified)
Paris Agreement on climate change	21.09.2016 (ratified)

4) Gap Analysis Between National Laws and JICA Guidelines

During the SEA process, gap analysis between National Laws and JICA Guidelines was conducted. The following is a description of the differences between the legal systems of the target country and the JICA guidelines, and identifies the gaps to be bridged to meet the requirements of the SEA and international good practices.

Table 3.1- 4 Gap Analysis Between National Laws and JICA Guidelines

Items	JICA Guidelines	Relevant laws/ regulations in Bangladesh	Are there any gaps?	Policies to be taken by this project
Underlying Principles	・ Environmental impacts that may be caused by projects must be assessed and examined in the earliest possible planning stage. Alternatives or mitigation measures to avoid or minimize adverse impacts must be examined and incorporated into the project plan. (JICA guidelines, Appendix 1, Underlying principles. 1)	For EIA process, Environment Conservation Act (1995), Environment Conservation Rules (1997) and EIA guidelines for Industries 2021	Yes: Experience of preparing the Strategic Environmental Assessment (SEA) is still limited for bilateral and multilateral financed projects in Bangladesh while the legal modality is not yet in place for handling the requirements of the SEA. However, an idea of the SEA is introduced in Environmental Policy 2018 to carry out the SEA on policy, plan, and program	・ SEA will be implemented during the preparation of the integrated Energy and Power MP, carrying out alternatives and mitigation measures ・ In consultation with the DoE, this project will work with the DOE from the scoping stage to ensure the government involvement in SEA process
Information disclosure	・ EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local	There is no provision for information disclosure in the EIA Guidelines for Industries 2021.	Yes: There is no stipulation on the language to be used in SEA and EIA reports nor the methods of SEA/EIA report disclosure as well as copying	・ SEA report will be prepared in English. ・ SEA report will be disclosed on the website of JICA.

Items	JICA Guidelines	Relevant laws/ regulations in Bangladesh	Are there any gaps?	Policies to be taken by this project
	residents, written materials must be provided in a language and form understandable to them. (JICA guidelines, Appendix 2) ・ It is necessary to make EIA reports available to the local residents of the country, in which the project is to be implemented. The EIA reports must be available at all times for perusal by project stakeholders such as local residents, and copying must be permitted. (JICA guidelines, Appendix 2)		of EIA report.)	
Public consultations	・ For projects with a potentially large environmental impact, sufficient consultations with local stakeholders, such as local residents, must be conducted via disclosure of information at an early stage, at which time alternatives for project plans may be examined. The outcome of such consultations must be incorporated into the contents of project plans. (JICA Guidelines, Appendix 1, 5. Social acceptability. 1) ・ Appropriate consideration must be given to vulnerable social groups, such as women, children, the elderly, the poor, and ethnic minorities, all members who are susceptible to environmental and social impacts and may have little access to decision-making processes within society. (JICA Guidelines, Appendix 1, 5. Social acceptability. 2)	There is a detailed provision for public consultation in the EIA Guidelines for Industries 2021	Yes: No provision is provided for public consultation for SEA process. Yes: There are no laws/ regulations which stipulate specific requirements of measures for vulnerable groups.	・ At the inception, the scoping stage and the preparation stage of the draft SEA report, public consultations and comments from the concerned stakeholders, including government officials, academia and CSOs will be collected and reflected in the report. ・ Appropriate measure for identified vulnerable groups from this study will be proposed in this SEA
Items to be assessed	・ The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted through	EIA Guidelines for Industries 2021 has clear provision for the assessment of Direct, Indirect and Cumulative Impact.	Yes: There is no guidance on what impacts are to be assessed in the SEA. ・ In the process	・ At SEA stage, overall environmental and social mitigation measures specific to the

Items	JICA Guidelines	Relevant laws/ regulations in Bangladesh	Are there any gaps?	Policies to be taken by this project
	air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. These also include social impacts, including migration of population and involuntary resettlement, local economy such as employment and livelihood, utilization of land and local resources, social institutions such as social capital and local decision-making institutions, existing social infrastructures and services, vulnerable social groups such as poor and indigenous peoples, equality of benefits and losses and equality in the development process, gender, children's rights, cultural heritage, local conflicts of interest, infectious diseases such as HIV/AIDS, and working conditions including occupational safety. (JICA Guidelines, Appendix 1, Scope of impacts to be assessed. 1) ・ In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the project are also to be examined and assessed to a reasonable extent. It is also desirable that the impacts that can occur at any time throughout the project cycle should be considered throughout the life cycle of the project. (JICA Guidelines, Appendix 1, Scope of impacts to be assessed. 2)		of SEA, high level assessment of potential direct and indirect impacts associated with the implementation of the integrated MP on future energy and power applications shall be examined. ・ In the process of SEA, high level assessment of environmental, social, and ecological, cultural aspects related to implementation of the integrated MP shall be examined. ・ In the process of SEA, legal aspects related to implementation of the integrated MP shall be assessed. ・ In the process of SEA, environmental, safety and health aspects related to implementation of the integrated MP shall be assessed.	proposed energy and power mix/applications proposed in the MP will be outlined as a reference to project level implementation when financial arrangement is realized for a particular project.
Monitoring/ Grievance mechanism	・ Project proponents, etc. should make efforts to make the results of the monitoring process available to local	There is no clear indication in EIA Guidelines for Industries 2021	Yes: There are no laws/ regulations which stipulate grievance	・ SEA will propose the reporting of monitoring

Items	JICA Guidelines	Relevant laws/ regulations in Bangladesh	Are there any gaps?	Policies to be taken by this project
	project stakeholders. (JICA Guidelines, Appendix 1, Monitoring. 3) ・When third parties point out, in concrete terms, that environmental and social considerations are not being fully undertaken, forums for discussion and examination of countermeasures are established based on sufficient information disclosure, including stakeholders ‘ participation in relevant projects. Project proponents, etc. should make efforts to reach an agreement on procedures to be adopted with a view to resolving problems. (JICA Guidelines, Appendix 1, Monitoring. 4)	regarding the disclosure of monitoring results. No clear provision is stipulated in the EIA Guidelines for Industries regarding Grievance Redress Mechanism.	mechanism and disclosure of monitoring results.	results to be submitted to the Ministry of Environment. ・SEA will propose grievance mechanism to be established at the project level, based on which any person can submit grievance.
Ecosystem and Biota	・Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests. (JICA Guidelines, Appendix 1, Ecosystem and Biota. 1)	Environmental Conservation Act (ECA) has a provision regarding the declaration of Ecologically Critical Area (ECA). As per the ECA Management Rules 2016, alteration or any significant degradation of critical natural habitat and forests are strictly prohibited.	No	・SEA will propose that Project shall comply with the Ecologically Critical Area Management Rules 2016.
Indigenous Peoples	・Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. When, after such an examination, avoidance is proved unfeasible, effective measures must be taken to minimize impacts and to compensate indigenous peoples for their losses. (JICA Guidelines, Appendix 1, Indigenous Peoples. 1)	There is no stipulated provision in EIA Guidelines for Industries 2021 regarding the indigenous peoples.	Yes: There are no laws/ regulations which stipulate the avoidance or minimization of impacts and compensation of loss, etc.	・If indigenous peoples are identified, in line with JICA Guidelines, SEA will propose minimization of impacts and compensation of loss, based on international good practices.

4. Strategic Environmental Objectives

Bangladesh is recognized worldwide as one of the most vulnerable countries to the impacts of global warming and climate change due to its unique geographic location, dominance of floodplains, low elevation from the sea, high population density, and high levels of poverty. Over the last decades, environmental issues in Bangladesh have been seen as much more linked to broader development issues. In response to ever deteriorating conditions, there have been several key laws enacted, ensuring environmental and social safeguards for development.

For implementation of IEPMP, it is expected that Bangladesh should consider a wide range of environmental and social impacts associated with the development of the projected energy and power systems. In this SEA, Strategic Environmental Objectives (SEO) are introduced and referenced as indicative instrument/tool against which provisions (e.g., type of energy application, geographic location, climatic and habitat conditions, and human health, etc.) of the IEPMP require assessment of environmental and social impacts, which are potentially result in significant environmental effects, where such effects would be likely to occur and how they are mitigated and managed.

The SEOs are linked to indicators, which can be utilized as monitoring the environmental effects of the subproject as well as the targets that the subproject must consider environmental and social considerations.

In case SEOs are not supported by the national legal framework, they are reinforced and/or supplemented with international best practices such as IFC's Performance Standards and JICA Environmental and Social Considerations.

Table 4.1-1 Strategic Environmental Objective

Environmental Parameter	No.	Bangladesh's Laws, Acts, and Regulations	Strategic Environmental Objective (SEO)	Indicator	Targets
Biodiversity, Fauna and Flora	B1	Environmental Conservation Act	To ensure compliance with Ecologically Critical Areas (CSAs)	The subproject impacts on conservation areas of habitats and species	Maintain conservation status of the habitats and protect not to be affected by the sub projects of IEPMP
	B2	Biodiversity Act	To ensure compliance with biodiversity heritage sites and Ramsar Convention	The subproject impacts on biodiversity related important areas.	Maintain conservation status of endangered species and registered wetlands not to be affected by the sub projects of IEPMP
	B3	Wildlife (Conservation and Security) Act	To comply with the Act, prohibiting any capture, and entry to sanctuary, park, conservation area, etc.) without licenses	The subproject is located in the protected areas.	Maintain conservation status of the protected areas and protection of the listed species not to be affected by the sub projects of IEPMP
	B4	The Protection and Conservation of Fish Rules	To ensure compliance with the Rules, not fished by explosives in inland waters, and within coastal waters.	The subproject is located in the inland or coastal waters.	Maintain all new development not to cause deterioration of the fishery resources
Soil	S1	Rules/regulations preventing soil contamination under Environmental Conservation Rules (1997)	To avoid damage to the hydrogeological and ecological function of the soil resource	The subproject requires substantial alternation of topology and geologic condition in the area	Develop the prevention of soil contamination guideline and procedure to minimize deterioration of soil and implement mitigation measure not to contaminate soil.
Water	W1	Water Act	To comply with water quality standards, water rights, and clearance certificates of the Act	The subproject activity requires wastewater discharge into rivers, estuaries, and coastal waters.	Protect utilization of water resources in water stressed areas and control pollution
	W2	Environmental Conservation Rules	To comply with Environmental Quality Standards (EQS) for surface water, groundwater, industrial effluents	The subproject is subject to categorization of four classes required for environmental clearance	Undertake impact assessment and formulate environmental management plan to monitor the status of the environment

Air and Climatic Factors	AC1	Environmental Conservation Rules	To comply with Environmental Quality Standards (EQS) for ambient air, emissions, and noise	The subproject is subject to categorization of four classes required for environmental clearance	Introduce technologies reducing the emission of air pollutants and undertake impact assessment and formulate environmental management plan to monitor the status of the environment
Labor and Land Acquisition	LL1	Labor Rules	To protect populations and human health from exposure health and safety risks by development	The project owner/developer develops the employment and service documentations which ensure labor safety, including wages, health and safety	Record occurrence of incidents, monitor and improve human health and safety conditions.
	LL2	The Acquisition and Requisition of Immovable Property Ordinance	To properly acquire land and compensate the values based on locality, soil fertility and market price	The project location requires land acquisition of government's property	Follow the national legal procedure and develop the project specific land acquisition, resettlement framework and redress mechanism
Natural Hazards (e.g., response to flooding, earthquake, cyclone)	NH1	No laws/regulations on climate risk assessment and prevention procedure	To reduce natural hazard risks, provided with emergency response plan, including preparedness, response, and recovery	Selection of the project location requires climate hazard risk assessment and foundation of the energy and power facility meet the construction and operational standards	Develop the hazard risk assessment guidance and procedures for the selection of the energy and power facility
Waste Management	WM1	Laws/regulations on waste management (Solid Waste Management Rules, Environmental Conservation Rules)	To properly manage wastes from construction and operation phases, including hazardous wastes such as wastes from power plant, including wastes from nuclear plants	The waste management plan is developed specific to the project location.	Develop the construction and operation procedural manuals for waste management.

5. Alternative Considerations and Evaluation

Considering the nature of the Project, the IEPMP predicts the next two decades of the power and energy plan, and variety of energy and power development is proposed. The proposed energy and power types are constructions of oil and gas-fired, coal fired, thermal, nuclear, solar, wind and biomass as well as newly emerging technologies such as hydrogen, ammonia, and CCS while environmental and social impacts vary among the technology applications and geographic locations. As Bangladesh has its abundant natural resources with densely populated in a country, infrastructure development needs to take in account careful considerations on environmental and social impacts.

This section introduces a comparative evaluation approach for alternative consideration, which may improve overall environmental components of subproject, conflict with negative impacts or trade off with appropriate mitigation measures.

The alternatives are evaluated by using the multi-criteria to determine how they would be likely affected by the subproject interventions. The multi-criteria is based on the indicators of the SEOs and the alternatives are referenced if they are against the criteria and identify which interactions would cause negative or positive effects on specific environmental and social components of the environment. When appraisal of a subproject does meet in part or some of the SEO, the relevant SEO code is marked as illustrated in Table 5.1-1.

The degree to which environmental and social effects can be determined is based on the nature of the subproject but the lower tier of environmental assessments is considered a preferred alternative. Criteria for determining the environmental and social effects is classified as (1) Likely to improve the status of SEOs[1], (2) Potential conflict with the status of SEOs likely to be mitigated[2], (3) Probable conflict with the status of SEOs, not to be mitigated[3], and (4) No significant interaction with the status of SEOs.

Table 5.1-1 Criteria for Determining the Alternatives for Subproject Selection

SEO Code	Criteria/SEO
B1	To ensure compliance with Ecologically Critical Areas (CSAs)
B2	To ensure compliance with Biodiversity Heritage Sites and Ramsar Convention
B3	To comply with the Act, prohibiting any capture, and entry to sanctuary, park, conservation area, etc. without licenses
B4	To ensure compliance with the Rules, not fished by explosives in inland waters, and within coastal waters.
S1	To avoid damage to the hydrogeological and ecological function of the soil

[1] Interactions would be likely to improve the status of a particular SEO and likely to result in a positive effect on the environmental component.
[2] Interactions would potentially conflict with the status of an SEO and would be likely to be mitigated.
[3] Interactions that would probably conflict with the status of an SEO and would be unlikely to be mitigated.

	resource
W1	To comply with water quality standards, water rights, and clearance certificates of the Act
W2	To comply with Environmental Quality Standards (EQS) for surface water, groundwater, industrial effluents
AC1	To comply with Environmental Quality Standards (EQS) for ambient air, emissions, and noise
LL1	To protect populations and human health from exposure health and safety risks by development
LL2	To properly acquire land and compensate the values based on locality, soil fertility and market price
NH1	To reduce natural hazard risks, provided with emergency response plan, including preparedness, response, and recovery
WM1	To properly manage wastes from construction and operation phases, including hazardous wastes such as wastes from power plant, including wastes from nuclear plants

6. Cumulative Effects

Cumulative effects are types of effects that the successive, incremental, and/ or combined effects of an action, project, or activity when added to other existing, planned, and/ or reasonably anticipated future projects, may create one larger, more significant impact.

Since IEPMP proposes a variety of energy and power development, the extent and type of cumulative effects may vary, depending on environmental and social components (VECs), therefore its scope must be properly defined.

VECs are environmental and social attributes which are physical features, habitats, wildlife populations, ecosystem services, natural processes (e.g., water, soil and nutrient cycles), social conditions (e.g., health, economics), and cultural aspects (e.g., traditional spiritual ceremonies).

IFC introduces cumulative impact assessment of VECs in emerging market, outlining the steps to identify conditions of VECs, assess the impacts of VECs and manage cumulative impacts. The process of cumulative effect assessment (CEA) is outlined as follows:

- Scoping: identification of regional issues of concern, VEC's, spatial and temporal boundaries, other unrelated projects, and potential effects of unrelated projects;
- Analysis of Effects: analysis of effects of VEC' s identified during scoping;
- Mitigation: recommend mitigation for effects identified;
- Evaluation of significance: determine residual effects and their significance with consideration of land use thresholds and land use objectives and trends; and
- Follow-up: identify appropriate monitoring.

Under the IEPMP, there are no site-specific locations identified as it is a Master Plan, the assessment of in-combination effects with other plans or projects could be done when subproject is proposed. In principle, there are many other plans/ projects that interact with or have the

potential to combine pressures and threats to the sites; however, the in-combination assessment is a matter of applying a practical and realistic approach.

The following is potential environmental interaction, which may be a cause of cumulative effects associated with the type of energy and power systems as they may be potentially long term, may create a larger, more significant impact in the future. Cumulative effects at the subproject level must be considered and specific cumulative effects by type of power and energy systems are illustrated in Table 6.1-1.

Table 6.1-1 Cumulative Effects by the Type of Energy and Power Development

Type of Energy and Power Generation	Environnemental Interaction on Cumulative Effects
Gas Fired Plant	● Operational storm and process water discharges in combination with other projects with similar discharges to the same marine area affecting habitat quality ● Operational air emissions in combination with other projects with similar emissions to the same airshed ● Construction habitat loss / disturbance within the local area from oil and gas development and easements ● Project effects on local wells or surface water/wetlands.
Coal Fired Plants	● Operational storm and process water discharges in combination with other projects with similar discharges to the same marine area affecting habitat quality ● Operational air emissions in combination with other projects with similar emissions to the same airshed ● Construction habitat loss / disturbance within the local area from oil and gas development and easements ● Project effects on local wells or surface water/wetlands.
Oil	● Operational air emissions of GHG in combination with other Project components and other future projects with similar emissions regionally and nationally ● Operational storm and process water discharges in combination with other projects with similar discharges to the same marine area affecting habitat quality ● Construction habitat loss / disturbance within the local area from oil and gas development and easements
Nuclear	Aside from the source of heat, nuclear power plants are like coal-fired power plants but require different safety measures. ● Operational storm and process water discharges in combination with other projects with similar discharges to the same marine area affecting habitat quality ● Radiological or other health effects may occur in populations affected by cumulative or multiple exposures to environmental hazards.
Hydro	● Changes in hydro morphology in combination with other projects with similar scale of development to the same basin area affecting habitat quality

Geothermal	● Operational storm and process water discharges in combination with other projects with similar discharges to the same marine area affecting habitat quality ● Operational air emissions in combination with other projects with similar emissions to same airshed ● Construction habitat loss / disturbance within the local area
Solar PV	● Reflections from Solar Photovoltaic Systems (SPV) could potentially affect the interests of aviation personnel, nearby home owners, road users and railways.
Onshore Wind	● Noise impacts may be associated with construction of the wind tower which may result in disturbance in the environment. ●
Offshore Wind	● Collision mortality (existing and proposed) in the area ● Noise interference with feeding areas of marine infrastructure (existing and proposed) in the area ● Fish access to Bay or Harbor and other migratory patterns could be disrupted by construction of wharf and proposed marine facilities in the area.
Biomass	● Operational storm and process water discharges in combination with other projects with similar discharges to the same marine area affecting habitat quality ● Operational air emissions in combination with other projects with similar emissions to the same airshed ● Construction habitat loss / disturbance within the local area from oil and gas development and easements

7. Strategic Environmental Management Plan/Mitigation Measures

A Strategic Environmental and Social Management Plan (SESMP) is prepared to address how site-specific mitigation measures are implemented during construction and operation phases of a sub project. It aims to create a linkage between the impacts of project activities and the mitigation measures to minimize negative impacts and enhance the positive impacts.

In this SEA report, the proposed plan interventions are at national level as the locations are determined at later stage of implementation of IEPMP, therefore, this SEA is only envisaged to provide strategic guidelines for the subsequent project specific to the location and nature of work which will be based on detailed component designs, construction, and operation plans.

The environmental management plan (EMP) of subproject will be formulated when project and site specific environmental and social impact assessments are undertaken before implementation of the various specific project commences. This SESMP prescribes and directs the management of environmental aspects of the proposed infrastructure development identified in the IEPMP, including the physical, natural and social impacts, associated with construction, and operation of the proposed components of the Master plan.

The specific objectives of this Strategic Environmental and Social Management Plan are to:

- Provide appropriate management of environmental issues resulting from all activities associated with implementation of all subproject identified in the IEPMP;
- Provide guidelines to project implementers responsible for protecting the environment and minimizing negative environmental effects, thereby contributing to the objective of the Master Plan.

The various conditions of implementing the Strategic Environmental and Social Management Plan include among others:

- All investors will adhere to the recommendations of this SESMP;
- All investors will ensure sound environmental management by minimizing negative environmental impacts in all the activities they undertake;
- SESMP shall be expanded, modified and corrected where there is need to customize to specific project/development conditions; and
- SESMP recognizes the laws and regulations attached to environmental aspects and it will be implemented accordingly and supplemented by international good practices if not specified in existing laws and regulations.

Table 7.1-1 Impacts, Sources and Mitigation Measures by Type of Energy and Power System Development

Type of Energy and Power Generation	Environmental Impact	Impact source/activity	Mitigation Measures
Gas, and Oil Fired Plant	● Air emissions	● Exhaust gases ● Venting and Flaring ● Fugitive emissions	● Specify air emission specifications for all equipment selection and procurement ● Implement source gas reduction measures ● Develop leak detection and repair programs
	● Wastewater/effluent discharges	● Produced water ● Cooling and heating systems	● Adequate well management during well completion activities to minimize water production ● Discharge cooling water to surface waters in a location that will allow maximum mixing and cooling of the thermal plume to ensure that the temperature is within 3 degrees Celsius of ambient temperature at the edge of the defined mixing zone or within 100 meters of the discharge point.
	● Solid and liquid waste	● Drilling fluids and drilling cuttings ● Completion and well work over fluids ● Naturally occurring radioactive materials	● Manage Water-Based Drilling Fluids (WBDF): The continuous phase and suspending medium for solids (or liquid) is water or a water miscible fluid. Non-Aqueous Drilling Fluids (NADF): The continuous phase and suspending medium for solids (or liquid) is a water immiscible fluid that is oil-based, enhanced mineral oil-based, or synthetic-based. ● Collection of the fluids if handled in closed systems and shipping to the original vendors for recycling; Spent acids should be neutralized before treatment and disposal.; On-site or off-site biological or physical treatment at an approved facility in accordance with the waste management plan. ● Where naturally occurring radioactive material (NORM) is present, a NORM management program should be developed.
	● Noise and vibration generation	● Seismic surveys ● Construction activities, ● Drilling and production, aerial surveys	● Minimize seismic activities in the vicinity of local populations wherever possible. ● Minimize simultaneous operations on closely spaced survey lines.

		● Air or road transportation	● Use the lowest practicable vibrator power levels.; Proper back-fill or plugging of holes will also help to reduce noise dispersion; ● Identify areas and time periods sensitive to wildlife such as feeding and breeding locations and seasons and avoid them when possible.
	● Terrestrial impacts	● Exploration and construction activities ● Power generation and transmission lines	● Site all facilities in locations that avoid critical terrestrial and aquatic habitat and plan construction activities to avoid sensitive times of the year; Safety fences and other safeguards to prevent people or animals from falling into open trenches should be constructed in sensitive locations and within 500 m of human populations. ● Clean-up and install temporary and permanent erosion and sediment control measures, slope stabilization measures, and subsidence control and minimization measures at all facilities, as necessary
	● Spills	● Leaks ● Equipment failure (accidents) ● Results of third-party interference	● Conduct a spill risk assessment for the facilities and design, drilling, process, and utility systems to reduce the risk of major uncontained spills.; Install secondary containment around vessels and tanks to contain accidental releases; ● Install shutdown valves to allow early shutdown or isolation in the event of a spill.; Ensure spill response and containment equipment is deployed or available for a response. ● Develop corrosion maintenance and monitoring programs to ensure the integrity of all field equipment.
	● Occupational health and safety	● Occupational exposure to gas leaks and explosions ● Confined Spaces ● Electrocution	● Training of employees and contractor personnel in safety procedures, together with provision of appropriate tools and equipment; ● Requiring work permits for all confined space entries; Installation of appropriate access controls for unauthorized personnel including signage to alert workers to the hazards of confined spaces; ● Use of ventilation and oxygen / explosive level detection and alarm equipment prior to access

	● Community health and safety	● Physical hazard (exposure to spills, fires, explosions) ● Security (e.g., trespassing)	● Gas distribution system operators should establish an emergency preparedness and response plan and share this plan with the public as necessary. ● Proper location, installation, and maintenance of appliances and equipment such as natural gas fired heating units; Recognition of potential hazards or operating problems
Liquefied Natural Gas	● Hazardous material management	● Storage, transfer and transport of LNG ● Spills	● LNG storage tanks and components (e.g., pipes, valves, and pumps) should meet internationally recognized standards for structural design integrity and operational performance to avoid catastrophic failures and to prevent fires and explosions during normal operations and during exposure to natural hazards. ● Conduct a spill risk assessment for the facilities and related transport/shipping activities; Develop a spill prevention and control plan that addresses significant scenarios and magnitude of releases.
	● Wastewater discharges	● Cooling water and cold water streams ● Drainage and storm water (from non-process area)	● Water conservation should be considered for LNG facility cooling systems. ● Cooling or cold water should be discharged to surface waters in a location that will allow maximum mixing of the thermal plume to ensure that the temperature is within 3 degrees Celsius of ambient temperature at the edge of the mixing zone.
	● Air emissions	● Combustion, power and heat generation ● Venting and flaring ● Boil-off gas ● Fugitive emissions (e.g., cold vents, leaking pipe, flanges, open-ended lines, etc.)	● Air quality impacts should be estimated by the use of baseline air quality assessments and atmospheric dispersion models.; Technically feasible and cost-effective attempts should be made to optimize energy efficiency and design facilities to reduce energy use with an overall objective of reducing air emissions.; Aggregate greenhouse gas emissions from all facilities should be quantified annually in accordance with internationally recognized methodologies. ● Flaring or venting should be used only in emergency or plant upset conditions.; Continuous venting or flaring of boiloff gas under normal operations is not considered good industry practices and should be avoided.

			● BOG should be collected using an appropriate vapor recovery system (e.g., compressor systems).; For LNG plants (excluding LNG carrier loading operations) the vapor should be returned to the process for liquefaction or used on-site as a fuel.; on board LNG carriers, BOG should be re-liquefied and returned to the storage tanks or used as a fuel. ● Methods for controlling and reducing fugitive emissions should be considered and implemented in the design, operation, and maintenance of facilities, including appropriate valves, flanges, fittings, seals, and packings, etc.
	● Waste management	● Packaging wastes, waste oil and hydraulic fluids, chemical containers, etc.	● Waste materials should be segregated into non-hazardous and hazardous wastes and considered for re-use/recycling prior to disposal.; A waste management plan should be developed that contains a waste tracking mechanism.
	● Noise generation	● Regasification process (e.g., compressor, dryers, heaters, air coolers, etc.)	● No employee should be exposed to a noise level greater than 85 dB(A) for a duration of more than 8 hours per day without hearing protection.; The use of hearing protection should be enforced actively when the equivalent sound level over 8 hours reaches 85 dB(A).; The peak sound levels reach 140 dB(C), or the average maximum sound level reaches 110dB(A); Hearing protective devices provided should be capable of reducing sound levels at the ear to at least 85 dB(A).
	● LNG transport related issues	● Vessels and shipping (e.g., hazardous waste transport, effluents, solid waste generation, etc.)	● The pressure rating of the actual LNG cargo tanks should be maximized.; The LNG cargo tanks' pressure relief systems should actuate quickly to relieve large volumes of vapor that can be generated by a Rapid Phase Transition (RPT) event.
	● LNG fueling	● Spill containment, operation of container, vessels, pumps, vaporization equipment, building, etc.	● The design, siting, construction, installation, spill containment, and LNG operation should follow internationally recognized standards.

	● Occupational health and safety	● Fires and explosions ● Roll-over ● Contact with cold surfaces ● Chemical hazards ● Confined spaces	● Design, construct, and operate LNG facilities according to internationally recognized standards and practices for the prevention and control of fire and explosion hazards. ● Measure stratification by monitoring LNG storage tanks for pressure, density, and temperature all along the liquid column. ● Develop a contingency plan for H2S release events, including appropriate aspects from evacuation to resumption of normal operations.; Provision of personal H2S detectors to workers in locations of high risk of exposure along with self-contained breathing apparatus and emergency oxygen supplies ● Requiring work permits for all confined space entries; Installation of appropriate access controls for unauthorized personnel including signage to alert workers to the hazards of confined spaces; Use of ventilation and oxygen / explosive level detection and alarm equipment prior to access;
	● Community health and safety	● Natural gas leaks during operation and transport of LNG ● Security	● LNG facilities should prepare an emergency preparedness and response plan that considers the role of communities and community infrastructure in the event of an LNG leak or explosion. ● Adequate signs and closed areas should establish the areas where security controls begin at the property boundaries.
Nuclear	Waste	Disposal of spent nuclear fuel	Design regulations governing the handling, transportation, storage, and disposal of nuclear materials (through Nuclear Regulatory Commissions)
	Occupational health and safety	Operation or system failure	Monitor reactor's environmental radiation, plan for emergency response plan, and evacuation plan[4]
Hydroelectric	Habitat	Reservoir filing terrestrial wildlife	Rescue species threatened with extinction and create the new habitat ecologically suitable and protect.
	Involuntary Displacement	Loss of land due to construction of reservoir	Support resettlement, provide new housing, land and other material assistance in accordance with the laws[5].

[4] IAEA Commissioning Guidelines for Nuclear Power Plants is proposed.
[5] IFC Hydroelectric Power A Guide for Developers and Investors is proposed.

Geothermal	● Effluents	● Drilling fluids and cuttings ● Spent geothermal fluids	● Recovery and storage of oil-based drilling fluids and cuttings in dedicated storage tanks or sumps, lined with an impervious membrane, prior to treatment (e.g., washing), recycling, and / or final treatment and disposal; During acid treatment of wells, use of leak-proof well casings to a depth appropriate to the geological formation to avoid leakage of acidic fluids to groundwater. ● Carefully evaluating potential environmental impacts of geothermal fluid discharges depending on the selected cooling system; Opportunities for reuse of reject geothermal fluids should be considered.
	● Air emission	● Hydrogen sulfide and mercury	● If necessary, use of abatement systems to remove hydrogen sulfide and mercury emissions from non-condensable gases.
	● Solid waste	● Cooling tower, air scrubber system, turbines, and stream separators (sulfur, silica, and carbonate precipitates)	● Proper on-site storage and containment before final treatment and disposal at an appropriate waste facility; Recoverable solids such as sulfur cake should be recycled by third parties to the extent feasible.
	● Well blowouts and pipeline failure	● Well drilling or facility operations	● Regular maintenance of wellheads and geothermal fluid pipelines, including corrosion control and inspection; Design of emergency response for well blowout and pipeline rupture, including measures for containment of geothermal fluid spills.
	● Water consumption and extraction	● Well drilling, injectivity testing, cooling systems	● Assess hydrological records for short and long-term variability of streams serving as source water, and ensuring critical flows are maintained during low flow periods so as to not obstruct passage of fish or negatively impact aquatic biota.
	● Occupational health and safety	● Geothermal gases ● Confined spaces ● Heat ● Noise	● Installation of hydrogen sulfide monitoring and warning systems; Development of a contingency plan for hydrogen sulfide release events, provided with personal hydrogen sulfide monitors, self-contained breathing apparatus and emergency oxygen supplies, and training in their safe and effective use; ● Development and implementation of a confined space entry program for areas designated as ‘Confined Spaces’ (see below); Providing workers with a fact sheet or other readily

			available information about the chemical composition of liquid and gaseous phases with an explanation of potential implications for human health and safety; ● Reducing the time required for work in elevated temperature environments and ensuring access to drinking water; Shielding surfaces where workers come in close contact with hot equipment, including generating equipment, pipes, etc.; ● Noise abatement technology includes the use of rock mufflers, sound insulation, and barriers during drilling, in addition to silencers on equipment in the steam processing facility.
	● Community health and safety	● Exposure to hydrogen sulfide gas ● Infrastructure safety ● Impacts on water resources	● Installation of hydrogen sulfide gas monitoring network, considering the location of emissions sources and areas of community use and habitation; ● Placement of access deterrents, such as fences and warning signs, to prevent access and warn of existing hazards; Minimizing the length of necessary pipeline systems; ● Elaboration of a comprehensive geological and hydrogeological model including overall geological, structural and tectonic architecture, reservoir size, boundaries, geotechnical and hydraulic host rock properties;
Solar PV	● Habitat loss	● Land clearance	● Rescue species threatened with extinction and create the new habitat ecologically suitable and protect.
	● Involuntary Displacement	● Land clearance	● Support resettlement, provide new housing, land and other material assistance in accordance with the laws.
	● Waste management	● Used storage battery and solar panels	● Develop a management protocol/procedure to handle hazardous waste materials derived from battery and solar panels
Wind (Onshore and Offshore)	● Landscape, sea space, and visual impacts	● Viewscape of wind energy facility (e.g., turbines, facility)	● Maintain a uniform size and design of turbines (e.g., type of turbine and tower, as well as height).; Minimize presence of ancillary structures on the site by minimizing site infrastructure.; Erosion measures should be implemented and cleared land should be promptly re-vegetated with local seed stock of native species.

	● Noise	● Construction noise including underwear noise (e.g., blasting, pilling, road construction turbine foundation, erection) ● Operational noise (e.g., interaction of air and the turbine blades, motors, generator, etc.)	● Noise assessments should be conducted to identify where and/or when underwater noise has the potential to impact marine life significantly and to identify appropriate mitigation measures. ● Operating turbines in reduced noise mode; Building walls/appropriate noise barriers around potentially affected buildings (only an option in hilly terrain, due to the height of turbines);
	● Biodiversity	● Collision related fatality, displacement of wildlife	● Early screening can improve macro-level project site selection and the scoping of priorities for further assessment, reducing unnecessary biodiversity impacts and costs in the future. ● Onshore: Modify the number and size of turbines and their layout in accordance with site-, species-, and season-specific risks and impacts; Avoid attracting birds to predictable food sources, such as on-site or off-site waste disposal areas, or landfills. ● Offshore: If species of high biodiversity value are associated with the site, plan construction activities to avoid sensitive times of the year (e.g., migration and breeding seasons) and to coincide with less productive times of year for fish; If species of high biodiversity value, such as marine mammals or sea turtles, are anticipated in the area, appoint observers prior to the commencement of construction.
	● Shadow flicker	● Wind turbine casting a shadow (e.g., residential properties, facilities)	● Site wind turbines appropriately to avoid shadow flicker being experienced or to meet limits placed on the duration of shadow flicker occurrence.; Wind turbines can be programmed to shut down at times when shadow flicker limits are exceeded.
	● Water quality	● Onshore construction activities (e.g., turbine foundation, underground cable, access road, etc.) ● Offshore construction activities (e.g., turbine	● Conduct a site selection process that considers the potential for interference of the project's structural components with commercial or recreational fisheries and marine species habitats. ● Plan the construction, installation, and removal of structural components, considering sensitive lifecycle periods.; Control the use of jetting, bubble curtains, and sediment traps.

		foundation, subsurface cable)	
	● Occupational health and safety	● Working at height ● Working over water ● Working in remote locations ● Lifting operations	● Eliminate or reduce the requirement to work at height.; If working at height cannot be eliminated, use work equipment or other methods to prevent a fall from occurring. ● Complete a risk assessment to develop a safe system of work for all working-over-water tasks and allocate appropriate resources to mitigate the hazards, including Personal Protective Equipment (PPE). ● Suitability of communication equipment available for the work crew; Means for managers to track the exact location of the working crew; Local emergency plan in place; ● Ensure all lifting equipment (including load attachment points) is suitable, capable of supporting the load, in good condition, and in receipt of any statutory inspections required.
	● Community health and safety	● Blade and ice throw ● Aviation ● Marine navigation and safety ● Public access ● Abnormal load transportation	● The minimum setback distance is 1.5 x turbine height (tower + rotor radius), although modeling suggests that the theoretical blade throw distance can vary with the size, shape, weight, and speed of the blades, and the height of the turbine; Ensure that lightning protection systems are properly installed and maintained.; Carry out periodic blade inspections and repair any defects that could affect blade integrity. ● Consult with the relevant aviation authorities before installation, in accordance with air traffic safety regulations. When feasible, avoid siting wind energy facilities close to airports and within known low-flying areas or flight paths. Cumulative impacts associated with the number of existing wind energy facilities within, or in close proximity to, low-flying areas or flight paths should be a consideration in siting turbines. ● Consult with marine regulatory traffic authorities before installation.; Use anti-collision lighting and marking systems on turbines and all other hazards.; Safety zones can be established

			around each turbine and construction vessel during the construction phase to minimize disruption to other sea users. ● Modify placement of wind turbines to avoid direct physical interference of point-to-point communication systems. ● Use gates on access roads.; Provide fencing of an appropriate standard around the substation with anti-climb paint and warning signs.; Post information boards about public safety hazards and emergency contact information. ● Use only approved access routes, provide traffic management to stop other traffic where needed.

Ports, Harbors and Terminals	● Terrestrial and aquatic habitat alternation and biodiversity	● Construction and operation of new port and terminal facilities (e.g., reclamation, clearing and paving, dockyard, wharves, piers and vessel berths) ● Coastal processes and seabed coastal geomorphology (e.g., coastal land erosion, sediment transport, change in physical shape of coastal zone)	● The port design should take into account assessment of hydrological, sedimentological coastal geomorphological conditions and the amount and type of dredging, blasting and reclamation required and their potential interference with natural or critical habitats. ● Design, siting considerations and coastal protection measures (e.g., beach nourishment, sand bypassing, groynes, seawalls, coastal revegetation, etc.) should be considered to minimize adverse impacts from these structures.
	● Climate change resilience	● Potential changes in water levels and inundation risks	● Design port-related infrastructure to increase climate resiliency in the context of changing sea levels, and more extreme weather events.; Review and select cargo transport routes (e.g., avoiding flood prone areas, improving on-site drainage systems and maintenance) to increase climate resiliency.
	● Water quality	● Construction activities (e.g., clearing of vegetation, capital dredging, reclamation, building construction, effluent disposal, etc.)	● The Dredging Management Plan should be tailored to the project and should define the dredging methodology, the area of influence, assessment and modeling of sensitive ecological receptors, mitigation measures to address adverse impacts and relevant environmental monitoring parameters and indicators.

			● Avoid installing storm drainage catch basins that discharge directly into surface waters.; Install filter mechanisms (e.g., draining swabs, filter berms, drainage inlet protection, oil separator, sediment traps and sediment basins) to prevent sediment and particulates from reaching the surface water.
	● Air emissions	● Construction activities (e.g., trucks, excavators, paving, material transport, etc.) ● Combustion exhaust emission during operation	● Validate ship engine performance documentation and certification to ensure compliance with combustion emissions specifications (including NOx, SOx, and PM), within the limits established by international regulations. ● Where practicable, design port layouts and facilities to minimize travel distances and transfer points to avoid/minimize re-storage and re-shuffling of cargo; Maintain cargo transfer equipment (e.g., cranes, forklifts, and trucks) in good working condition to reduce air emissions.
	● Wastes	● Solid wastes from cargo, administrative offices, and vehicle maintenance operations	● A collection and disposal system should be developed for ship-generated garbage for ships alongside and at anchor, consistent with the International Maritime Organization (IMO) Comprehensive Manual on Port Reception Facilities.
	● Hazardous materials	● Hazardous material storage (oils, fuels, solvents, lubricants, etc.) and handling facilities	● Oil and chemical-handling facilities in ports should be located with consideration of natural drainage systems and the presence of environmentally-sensitive areas/receptors (e.g., mangroves, corals, aquaculture projects, and beaches, etc.). ● Hazardous materials storage and handling facilities should be constructed away from traffic zones and should include protective

			mechanisms (e.g., reinforced posts, concrete barriers, etc.) to protect storage areas from vehicle accidents; Port operators should prepare a spill prevention, control, and countermeasure plan consistent with the IMO Manual on Oil Pollution Section II—Contingency Planning.
	● Noise and vibration (including underwater)	● Construction activities (e.g., blasting, piling (including offshore piling), dredging, reclamation, construction of breakwaters and access roads, etc.)	● Onshore: Establishing noise deflection walls; Paving and leveling the terminal area; Substituting diesel engines with electric power; ● Offshore (underground): Coordinating and scheduling offshore piling and dredging activities to avoid or minimize the presence of sensitive aquatic species; Implementing noise mitigation techniques for offshore pile driving, including bubble curtains, pile caps, and cofferdams (where practicable) to absorb/scatter pile driving energy;
	● Occupational health and safety	● Physical hazards (e.g., cargo handling, use of equipment) ● Chemical hazards (e.g., VOC, fuels, flammable liquid cargo) ● Confined spaces (e.g., ship cargo holds, silos, sewage tanks, etc.) ● Exposure to noise	● Separate people from areas of vehicle traffic and make vehicle passageways one-way.; Minimize the risk of free fall of materials by installing telescoping arm loaders and conveyors.; Equip lifting appliances with means of emergency escape from the driver's cabin and a safe means for the removal of an injured or ill driver.; ● Replacement of the hazardous substance with a less hazardous substitute; Communicating chemical hazards to workers through labeling and marking according to national and internationally recognized requirements and standards, including the International Chemical Safety Cards (ICSC), Materials Safety Data Sheets (MSDS), or equivalent; ● Port operators should implement confined space entry procedures.

			● No employee should be exposed to a noise level greater than 85 dB(A) for a duration of more than 8 hours per day without hearing protection.; Hearing protective devices provided should be capable of reducing sound levels at the ear to at least 85 dB(A).; Periodic medical hearing checks should be performed on workers exposed to high noise levels.
	● Community health and safety	● Port marine safety (e.g., safety movement of vessels with the harbor) ● Port security (e.g., crew security in port) ● Visual impacts (e.g., nighttime illumination of bulk storage facilities to sensitive land,)	● Implement a Safety Management System (SMS) able to effectively identify and correct unsafe conditions. ● Port security arrangements (e.g., access control) may be established through a Port Facility Security Assessment of port operations. ● Visual impacts, including excessive background illumination, should be prevented during the port planning process or managed during operations through the installation of natural visual barriers such as vegetation or light shades.
Gas Distribution System	● Habitat alternation	● Construction of gas distribution pipeline systems	● Distribution pipeline rights-of-way and regulating stations should be sited to avoid critical habitat through use of existing utility and transport corridors, including aquatic habitat such as watercourses, wetlands, and riparian areas, as well as fish spawning habitat, and critical fish over-wintering habitat.
	● Air emissions	● Equipment venting, pipeline components (e.g., gas leaks such as	● Gas pipelines and pipeline components should meet international standards for the structural integrity and operational performance.; Leak and corrosion detection programs should be undertaken,

		methane greenhouse gas)	including use of appropriate leak detection assessment techniques and equipment.; Pipelines, valves, and other component infrastructure should be regularly maintained.
	● Occupational health and safety	● Occupational exposure to gas leaks and explosions ● Confined Spaces ● Electrocution	● Training of employees and contractor personnel in safety procedures, together with provision of appropriate tools and equipment; ● Requiring work permits for all confined space entries; Installation of appropriate access controls for unauthorized personnel including signage to alert workers to the hazards of confined spaces; Use of ventilation and oxygen / explosive level detection and alarm equipment prior to access; ● Identification and location of all relevant existing underground utilities should be undertaken prior to any construction and excavation activities.
	● Community health and safety	● Physical hazard (exposure to spills, fires, explosions) ● Security (e.g., trespassing)	● Gas distribution system operators should establish an emergency preparedness and response plan and share this plan with the public as necessary. ● Identify proper location, installation, and maintenance of appliances and equipment such as natural gas fired heating units; Recognition of potential hazards or operating problems.
Electric Power Transmission and Distribution	● Terrestrial habitat alternation	● Construction and maintenance of transmission line rights of way (especially in forested area) ● Forest fires	● Site transmission and distribution rights-of-way, access roads, lines, towers, and substations to avoid critical habitat; whenever possible; Installation of transmission lines above existing vegetation to avoid land clearing;

		● Avian collisions and electrocutions	● Monitoring right-of-way vegetation according to fire risk; Time thinning, slashing, and other maintenance activities to avoid forest fire seasons; ● Site power transmission towers and substations to avoid critical aquatic habitat as well as fish spawning habitat, and critical fish over-wintering habitat; Maintaining fish access when road crossings of watercourses are unavoidable by utilizing clear span bridges, open-bottom culverts, or other approved methods; Minimizing clearing and disruption to riparian vegetation;
	● Aquatic habitat alternation	● Construction of corridors and crossing water courses and wetlands	● Locating and siting cable routes, and shore access, to avoid critical marine habitats (e.g., breeding grounds and eelgrass) and coral reefs; Burying submarine cables when traversing sensitive intertidal habitat; Avoiding laying submarine cable during fish and marine mammals breeding periods, calving periods, and spawning seasons;
	● Electric and magnetic fields	● Power lines and electric equipment	● Evaluating potential exposure to the public against the reference levels developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP); If EMF levels are confirmed or expected to be above the recommended exposure limits, application of engineering techniques should be considered to reduce the EMF produced by power lines, substations, or transformers.
	● Hazardous materials	● Insulating oils and gas (e.g., Polychlorinated Biphenyls (PCB), sulfur hexafluoride (SF6)	● Replacing existing transformers and other electrical equipment containing PCB, and ensuring appropriate storage, decontamination, and disposal of contaminated units; Surrounding soil exposed to PCB leakage from equipment should be assessed, and appropriate removal and/ or remediation measures should be implemented.

	● Occupational health and safety	● Love power lines ● Working at height ● Electric and magnetic fields ● Exposure to chemicals	● Only allowing trained and certified workers to install, maintain, or repair electrical equipment; Ensure proper use of special safety equipment and procedures when working near or on exposed energized parts of an electrical system. ● Implementation of a fall protection program that includes training in climbing techniques and use of fall protection measures; Establishment of criteria for use of 100 percent fall protection (typically when working over 2 meters above the working surface, but sometimes extended to 7 meters, depending on the activity); ● Identification of potential EMF exposure levels in the workplace; Training of workers in the identification of occupational EMF levels and hazards; Establishment and identification of safety zones; Personal exposure monitoring equipment should be set to warn of exposure levels that are below occupational exposure reference levels (e.g., 50 percent). ● Train personnel to apply pesticides and ensure that personnel have received the necessary certifications; Respect post-treatment intervals to avoid operator exposure during reentry to crops with residues of pesticides.
	● Community health and safety	● Electrocution ● Visual amenity ● Aircraft navigation safety	● Use of signs, barriers (e.g., locks on doors, use of gates, use of steel posts surrounding transmission towers, particularly in urban areas), and education / public outreach to prevent public contact with potentially dangerous equipment; ● Extensive public consultation during the planning of power line and power line right-of-way locations; Locating high-voltage

			transmission and distribution lines in less populated areas, where possible; ● Avoiding the siting of transmission lines and towers close to airports and outside of known flight path envelopes; Adherence to regional or national air traffic safety regulations; Use of buried lines when installation is required in flight sensitive areas;

Source: IFC EHS Guidelines and customized by the JICA Study Team

Table 7.1-2 Emerging Technologies

Topics			
CCS	Air emission	Leakage of CO2 from storage and transport	● Monitor gas leaks, regulate the well construction specifications and transport modality
Ammonia-co generation	Occupational health and safety	Handling, storage, and transport	● Manage highly volatile and flammable element to prevent leakage and explosions as ammonia is explosive in liquid form. ● Monitoring equipment should be in place to detect signs of gas leaks and prompt appropriate action as ammonia forms a toxic gas in ambient condition.
Hydrogen	Occupational health and safety	Handling, storage, and transport	● Manage highly volatile and flammable element to prevent leakage and explosions.

8. Monitoring Measures

The intents of the SEA aim to outline the identification of potential environmental and social impacts associated with energy and power infrastructure development at the subproject level and enables to monitor the impact mitigation measures to see if the subproject meets the requirements by the national laws and regulations or international good practices.

Monitoring can identify unforeseen adverse effects (if the proposed measures are not properly implemented) and undertake appropriate remedial actions to minimize or avoid the risks. The establishment of site-specific monitoring strategy is critical to systematically monitor the environmental conditions, based on the nature and extent of the proposed interventions at the locations.

Central to the monitoring of the implementation of subprojects is facilitated by a monitoring group represented by the environmental authorities, aiming to ensure that robust system is in place, and all key mitigation measures are committed by the project owners, investors, and developers.

(1) Updating monitoring measures

Monitoring is an ongoing process. The measures identified during the monitoring may find the unforeseen risks, which are not assumed at the time when environmental management plan is developed. Environmental authorities shall request additional monitoring sources when the project activities may pose significant risks to the environment, including negative, cumulative, and indirect impacts, which may have the potential to occur at the result of individual projects or multiple projects.

(2) Thresholds and corrective action

The occurrence of persistent adverse environmental effects at the subproject level not meeting the SEOs would necessitate consultation with environmental authorities and the possible coordination of corrective actions may be required:

- Complaints received from the neighboring communities, impacted by the development, approved by the government authorities:
- Court cases taken by the entities (e.g., the government authorities, private and public sectors, and civil societies, etc.)
- Failure to meet the respective laws and regulations (e.g., loss of the assets, ecological values, human health, and safety).

(3) Reporting

Implementation of the environmental and social management plan (EMP) at the subproject level is expected to be monitored by the owners and government authorities as it is determined at project approval stage. The findings of the monitoring results may reveal the environmental values exceeding the requirements by the laws and regulations and then environmental authorities

coordinate the ongoing review of indicators and targets, collating existing relevant monitored data, the preparation of monitoring evaluation, the publication of these reports and, if necessary, the carrying out of corrective action.

Table 8.1-1 Environmental and Social Monitoring Measures, Source of Information, Frequency and Responsible Institutions

SEO Code	Criteria/SEO	Monitoring Measures	Source of Information	Frequency of Monitoring		Responsible Institution
				Construction Phase	Operation Phase	
B1	To ensure compliance with Ecologically Critical Areas (CSAs) under Environmental Conservation Act	Fauna and flora species	Local studies Department of Environment	Annually	-	Project developer Department of Environment
B2	To ensure compliance with Biodiversity Heritage Sites and Ramsar Convention under Biodiversity Act	Fauna and flora species	Local studies Department of Environment	Annually	-	Project developer Department of Environment
B3	To comply with the Wildlife Act, prohibiting any capture, and entry to sanctuary, park, conservation area, etc.) without licenses	Fauna and flora species	Local studies Department of Environment	Annually	-	Project developer Department of Environment

B4	To ensure compliance with the Rules, not fished by explosives in inland waters, and within coastal waters under Protection and Conservation of Fish Rules.	Fishery species	Local studies Department of Environment	Annually	-	Project developer Department of Environment
S1	To avoid damage to the hydrogeological and ecological function of the soil resource	Soil erosion	Local studies Department of Environment	Quarterly	Quarterly	Project developer Department of Environment
W1	To comply with water quality standards, water rights, and clearance certificates of the Water Act	Water quality under environmental quality standards (EQS)	Local studies Department of Environment	Quarterly	Quarterly	Project developer Department of Environment
W2	To comply with Environmental Quality Standards (EQS) for surface water, groundwater, industrial effluents under	Water quality under environmental quality standards (EQS)	Local studies Department of Environment	Quarterly	Quarterly	Project developer Department of Environment

	Environmental Conservation Rules					
AC1	To comply with Environmental Quality Standards (EQS) for ambient air, emissions, and noise under Environmental Conservation Rules	Air, and noise quality levels	Local studies Department of Environment	Quarterly	Quarterly	Project developer Department of Environment
LL1	To protect populations and human health from exposure health and safety risks by development under Labor Rules	Illness, incident measures, labor working condition	Record of employee health, incident, and safety protocol	Quarterly	Quarterly	Project developer Department of Environment
LL2	To properly acquire land and compensate the values based on locality, soil fertility and market price under The Acquisition and Requisition of Immovable Property Ordinance	Individual compensation, the property information, and market price	Record of compensation, the property, and market price	Annually	Annually	Project developer Department of Environment

NH1	To reduce natural hazard risks, provided with emergency response plan, including preparedness, response, and recovery)	Weather condition, early warning system	Annual committee meeting report on emergency response plan and its exercise record	Annually	Annually	Project developer Department of Environment
WM1	To properly manage wastes from construction and operation phases, including hazardous wastes such as wastes from power plant, including wastes from nuclear plants	Quantities, types of waste (hazardous, chemical, nuclear wastes)	Record of waste management	Quarterly	Quarterly	Project developer Department of Environment

9. SEA Stakeholder Meeting

The Ministry of Power, Energy and Mineral Resources and JICA Study Team organized the 3rd Stakeholder meeting on December 13, 2022 to disseminate the draft final report of the Integrated Energy and Power Master Plan (IEPMP). Total of over 290 individuals (40 participants via online platform) took part in the final consultation meeting, representing from the government officials, academic professionals, civil society, and development partners.

The meeting concluded that the Government of Bangladesh and JICA Study Teams delivered successful development of the Integrated Energy and Power Master Plan, outlining the next three decades of the primary energy supply, along with the requirements of transmission and distribution systems that introduce the application of energy efficiency, operational reliability and necessary legal framework enabling to import LNG in a sustainable manner.

IEPMP diversifies Bangladesh's energy mix by introducing renewable energy sources such as solar PV, onshore and onshore wind power, modern biomass, hydrogen, and CCS, of which some technologies are not fully approved at this present time but it is an investment for Bangladesh to vision a long-term perspective of energy and power supply.

Strategic environmental objectives associated with the proposed energy and power infrastructure development were presented in the meeting, ensuring that IEPMP will be implemented along with environmental and social safeguarding measures, which comply with internationally best practiced approaches as introduced in the Strategic Environmental Assessment report.

Upon completion of the session on technical presentation, Q&A session was provided to receive comments from public and the session are mostly likely in view of implementation of the IEPMP in the future. Some comments are summarized as follows:

Table 9.1-1 Comments Received and Resposens During the Final Stakeholder Meeting

Comment#	Comment	Response
1	Roadmap of the IEPMP outlines the trajectory of energy and power development plan, especially introducing renewable energy by 10% in 2030. Current renewable application only accounts for 1% by 2022, 9% increase by 2030 seems a challenging in Bangladesh.	The target is indicative status to achieve the supply increase by the targeted date and it is also a matter of implementation which will be facilitated along with investment support by the development partners.
2	Demand in the northern Bangladesh substantially falls in winter season and instead, the surplus of energy can be exported to India.	The Master Plan was developed by assessing the need of energy and power supply for the future. The plan is not the end of product but any

3	Cost of utilization of renewables in Bangladesh is higher than that of India and thermal energy cost is lower in India. Considering the price fluctuation, Bangladesh may import it from India.	future potential development can be incorporated and adopted accordingly.
4	Construction of solar power station requires a lot of land and may potentially impact on agriculture land.	The Master Plan is not intended to replace the existing agriculture land for solar energy station nor intend to hamper the food security in Bangladesh. In next phase of the development such as feasibility study, the requirements of the land clearance shall sort out the land is not fertile nor used as farming lands.

Mr. Nasrul Hamid MP, State Minister of the Ministry of Power, Energy and Mineral Resources made the final concluding remarks, expressing his gratitude to JICA study team and concerned institutions and state companies which supported this Project over the last two years.

Diversification of the energy mix is of important considerations in Bangladesh as the country is one of the most climate vulnerable countries, needing the adaptation to clean energies by utilization of carbon emission reduction technologies. Is it also critical that these energy applications are affordable by the customers. In concluding remarks, he emphasized that the IEPMP is not a static document but needs to revise as new technologies are constantly evolving over time.

10. Conclusions and Recommendations

1) Conclusions

The broad objective of the SEA was introduced to various stakeholders through the course of the Project implementation and the principles of the sustainability of the project implementation are integrated into the Master Plan to support sound decision making processes.

The specific objectives of this Project were to (i) develop the strategic environmental objectives ensuring environmental sustainability measures in the design phase of the master plan, (ii) provide a strategic guidance on what to be considered for implementation of the energy and power development at the subproject level, considering impact identification, cumulative effects and environmental management plan specific to nature of the sub-project, and (ii) provide monitoring future environmental quality.

Environmental issues tend to be undermined in many development projects even when planned for and targets are set. To ensure that the proposed SEA is implemented, the study proposes creation of an environmental unit by the Power Division and Energy and Mineral Resources Division of the Ministry of Power, Energy and Mineral Resources. It should be hosted by representatives of both divisions within the Ministry and the Unit which will work very closely with the Department of Environment. Their work will include ensuring that all investors comply with the SEA's objectives, indicators and targets for their individual subprojects and ensure implementation of all the recommended mitigation measures in collaboration with all the relevant line agencies/sectors.

2) Recommendations

For the IEPMP to achieve its intended strategic objectives, the following policy, governance and EHS management measures are recommended to develop and adopt by the government which ensures these measures to be complied by the project developers and investors.

a. The proposed Strategic Environmental and Social Management Plan (SEMP) should be implemented effectively at the subproject level and ensure that all the recommended mitigation measures are implemented.
b. The MPEMR should establish an Environmental Management, Coordination and Monitoring Unit to oversee all the environmental aspects of the IEPMP.
c. Policy on Renewable Energy should be developed to incentivize the economic instruments and tools to facilitate the investment of renewable applications by 2024.
d. Legal framework on Clean Energy (construction and operational procedures for nuclear, onshore and offshore wind, solar PV, and biomass) should be developed.
e. Rules and regulations on occupational health and safety (e.g., construction safety, labor conditions, and management system) should be developed by 2024.
f. Rules and regulations on safety of nuclear plant operation, waste and wastewater management, operational safety and health guideline should be developed and adopted.
g. EHS guideline for offshore and onshore wind farm development should be developed and adopted by 2028.
h. EHS Guidelines for Solar Park development should be developed and adopted by 2028.
i. EHS Guidelines for CCS and hydrogen mono firing power generation should be developed and adopted by 2028.
j. EHS Guidelines for Electric Power Transmission and Distribution should be developed and adopted by 2024.
k. EHS Guideline for Hydroelectric Power should be developed and adopted.

l. The redress grievance mechanism guidelines for construction and operation of infrastructure development should be developed and exercised by all investors.

Annexes

A. Minutes of Meetings for the Inception Meeting (First Stakeholder Meeting)

(1) Afternoon Session

Minutes of the First Stakeholder Meeting on Integrated Energy and Power Master Plan (IEPMP) for Bangladesh (Afternoon Session)

Date: November 23, 2021

Location: Grand Ballroom (11th F), Sheraton Dhaka Hotel, (44, Kemal Ataturk Avenue, Banani, Dhaka 1213)

Starting Time: 13:00 PM

End Time: 17:00 PM

Participants: See appendix section for participant list

Objective of the Meeting:

The Government of Bangladesh has established long-term plans for each energy sub-sector, such as the Power System Master Plan 2016 (Revisiting PSMP2016), the Energy Efficiency and Conservation Master Plan (EECMP2016), and the Gas Sector Master Plan (GSMP-2017). However, it has become necessary to revise the energy plans in response to the current situation such as changes in demand assumptions and the growing global trend toward low-carbon economy and decarbonization. The Institute of Energy Economics, Japan (IEEJ or "JICA Survey Team") has been conducting the Study for the "Integrated Energy and Power Master Plan Project in Bangladesh" financed by the Japan International Cooperation Agency (JICA). In the Survey, IEEJ will develop several scenarios on power development in Bangladesh. Under this study, a Strategic Environmental Assessment (SEA) will be also carried out and reflect the environmental and social consideration on policy making and planning at an early stage. During the master plan preparation, several stakeholder meetings (SHM) will be held on the master plan and SEA sessions. The objective of the 1st SHM is to introduce the project scope, approach, methodology and way of the engagement with key actors in Bangladesh, including academia/thinkers and development partners.

This was the first stakeholder meeting. It was attended by Tawfiq-e-Elahi (Bir Bikrom), Advisor to the Prime Minister, PMO; as the chief guest for and Dr. Ahmed Kaikaus, Principal

Advisor to the PMO was present as the special guest in the afternoon session. The meeting was chaired by the State Minister of Energy Power and Mineral Resources Mr. Nasrul Hamid. Among the other special guests present at the meeting, representing the honorable Ambassador of Japan Mr. Ito Naoki, Chief representative of the JICA Study team Mr. Hayakawa Yuho. The meeting was held both in person and online through the Zoom platform. Around 148 people attended the meeting out of which 19 female participants were at the in-person meeting. The meeting was accessible through an online platform for wider participation.

Opening of the meeting: The meeting was moderated by Mr. Mohammad Hossain, Director General, Power cell and facilitated by Ms. Morsheda Ferdous, Deputy Secretary EMDR. The meeting was started with the welcoming speech of Mr. A.K.M Fazlul Haq Additional Secretary EMRD on behalf of Mr. Habibur Rahman Senior secretary, EMRD. He highlighted the importance of the integrated energy power master plan for the development of Bangladesh. The main goal of the project is to produce a functional long-term energy plan that will be aligned with the current development and future projection and comply with the international commitments that the country is working toward the fulfillment of Paris Agreement, SDGs, COP26.

Speech by JICA representative

After this welcoming speech there was a speech by the chief representative of JICA Mr. Hayakawa Yuho. He addressed the distinguished guests and the participants and expressed his happiness to be a part of the first stakeholder meeting. He thanked the energy and mineral division and the power division for coming up with such initiative and was pleased that JICA is a partner in this project. He sees the master plan as an ambitious one as this will not only integrate two sectors but also take into account possibilities of incorporating state of the art technologies, innovation in power and energy supplies addressing climate change issues, energy price, and keeping the international promises. The project will consider integration of RE along with maintaining energy security and economic efficiency. The future development of Bangladesh will define the master plan and this master plan will also influence the development. The preparation of this master plan is not an easy task as we need to consider several scenarios and various other plans of the country. The time horizon of this master plan is 2050, considering the huge change and volatile nature since we also have to consider the capacity building of the relevant authorities. While the climate issues will be addressed, the development of the country should be in major focus and next in line. To fulfill this ambitious target, he asked everyone across all stakeholder levels to contribute with their experience, knowledge, and ideas.

Speech by the Ambassador of Japan Ito Naoki

The ambassador of Japan in Bangladesh his excellency Mr. Ito Naoki gave his welcoming speech. The ambassador addressed the guests and thanked the Energy and Power divisions for undertaking such an initiative. He highlighted the long-standing friendship between Bangladesh and Japan by informing everyone about an agreement signed by the two countries. This package contributes to COVID-19 crisis response and the realization of a health system, and the acceleration of economic growth through the development of core infrastructure. This package includes two ongoing projects, MRT line 1 and the Matarbari power plant. He is pleased to increase such cooperation between the two countries on the occasion that 2022 will mark the 50 years anniversary of friendship between the two countries. JICA has supported Bangladesh in formulating development plans many times. This master plan is going to be crucial for the country because it needs to multitask, adopt to a changing reality as the country will face changes in the future. He also mentions that Bangladesh will be one of the fastest growing economies in the coming decade in Asia. Despite the need for development, Mr. Naoki has praised Bangladesh for its measures towards disaster management and climate change issues through NDCs. The energy and power sector master plan needs to be revised, given the current scenario of the growth of Bangladesh and the need to decarbonize the society. He expressed his expectations that the support of the expertise of Japan and the collaboration between the two countries will result in a long-term sustainable integrated energy and power master plan for Bangladesh. He finished his speech on this positive note by again thanking the team and the guests.

Presentation:

After the speeches there was a number of presentations related to the integrated master plan. The first presentation was given by Mr. Ichiro Kutani, senior research fellow at the IEEJ and team leader of the IEPMP. He gave an overview of the project and shared the workflow of how they are going to work towards the formulation of a revised master plan. He mainly highlighted the energy demand related issues. There will be three sections of energy analysis: demand, transmission and distribution. He also mentions that the data analysis will be estimated based on three scenario analyses. The idea is to move forward to net zero emission aligned with the COP26 and NDC of Bangladesh. This will also take into consideration the GDP growth rate of the country. Along with this, the legal framework and bindings were also asked to be taken into consideration.

The second presentation was given by Mr. Seiichi Sasaki, JICA Study Team. He shed light on what a Strategic Environmental Assessment is, why is it necessary and how it can be done with the help of data collected from the local stakeholders to have a better understanding of the country profile and its goal. He described how the energy sector will take into account the social and

environmental issues and incorporate them into the master plan. Mr. Sasaki mentioned that through SEA the sustainability principle will be incorporated into the policy making. According to the plan there will be two more stakeholder meetings in the master plan preparation which will be held in March 2022 and May 2022.

Presentation on Technical papers

The second session was on the presentation of technical papers by the JICA Study Team.

Presentation-1

The first presentation was on the discussion on demand forecast, specifically the methodology, scenario settings and scenario evaluation. This was presented by Mr. Ichiro Kutani instead of Mr. Suehiro who was supposed to join online but couldn't join due to a technological glitch. He presented the demand forecast model, its econometric basis, the components of the model, the relation of GDP with energy demand, energy consumption by different sectors such as the industry sector, transport sector, building sector, agricultural sector, etc.

Presentation-2

The third technical paper on Energy System Planning was presented by Mr. Suganuma. The major focus of the presentation was on generation planning, transmission planning, and distribution planning. He talked about the basic workflow of the technical working group-2 with four different tasks: generation, transmission, distribution and power system development. For the generation planning the consideration was on LOLE (loss of load expectation) and LOLP (Loss of Load Probability). The derated capacity problem is a problem in Bangladesh. This is caused by poor maintenance of generators. With both, technical and institutional measures should be taken. He introduced the fundamental concept of Merit Order operation that dictates the type of generator to be selected.

Mr. Suganuma also highlighted the challenges related to energy efficiency and decarbonization that included:

Coal will be an important base load power in the future as Bangladesh is planning to phase out natural gas reserves and also wants to reduce carbon. Promotion of RE is also an important consideration for Bangladesh. As the RE sources such as wind and solar are not consistent all over the country, it is a challenge.

Presentation-3

Mr. Egawa presented the third presentation on the transmission planning of energy in Bangladesh. This presentation highlighted the possible ways to move forward in the future regarding the power transmission system. He pointed out three key factors to make a sustainable power transmission system. Increase of South to North power flow; Reliability improvement of supply network to Dhaka, and international interconnection with Nepal and Bhutan. The challenge he mentioned here was the national security while planning the interconnection.

Question Answer/ Discussion session

The floor was open for the question and answer session. As this was the first meeting of this kind, not all the questions/queries were answered, and instead the issues were noted for further consideration by the study team. There were questions from the moderator, of which the technical part was answered by Mr. Ichiro Kutani and the strategic part was answered by Seiichi Sasaki.

Sl. No	Name	Designation Organization	Question/Comment
1.	Mr. Mohammad Hossain	Director General, Power cell	Mr. Hossain suggested that instead of setting a target for reducing certain percentage of GHG/CO2 the study team should come up with a possible target that is achievable based on the current situation and future advancement Response: Net zero by 2050 is a tough target but not impossible. It is technically possible with high cost. Here the question will come whether we consider the environment at the forefront or the socio-economic condition. Responded by: Mr. Ichiro Kutani
			His question for SEA was how many sectors this study can cover as it is a complex interconnected system. Response: This depends on what type of energy mix government wants to go for. After getting idea from the data, a guideline can be developed for which sectors to look into. Responded by: Seiichi Sasaki
2.	Dr. Md. Rafiqul Islam	DG, Hydrocarbon, EMRD	Mr. Islam, emphasized on the need to go for a pragmatic master plan while planning for the primary energy balance. He added that we need to consider the LPG, technological breakthrough, etc.

3.	Major General Moin Uddin (Retd)	Chairman REB	After having long discussion with JICA about the distribution system he expressed his happiness to see that for the first time there is a scope for inclusion of distribution in the power system planning. He addressed the fact that the study team mentioned about the effect of weather on distribution lines. REB is also thinking to replace the overhead level to underground. He raised the question of increasing the distribution line from 33 KV to higher? Mr. Moin added that in the forecasting the study considered the historical growth, tariff rate, income, etc., but why it didn't consider the industrial growth that is currently not very high but is projected to grow higher. Also, while taking into consideration the weather issue - why the study isn't including the automation issues while forecasting. He gave the following suggestion to the team- Suggestion: Include the distributors in the study and setup the voltage level for distribution
4.	Belayet Hossain	Chairman, BPDB	For the appropriate fuel mix up to 2041, BPDB had a master plan and according to the master plan 35% generation will be from coal-35% gas and 16% imported. But due to climatic issues we are now rethinking the fuel mix. His said that based on the master plan, they have taken various projects up to 2030. Some projects are at the implementation stage, some in contract signing stage. Now if the plan is revised, what will happen to those projects which are already in the pipeline. He suggested to have a good adjustment between the two plans for integrating the projects for their maximum utilization. He added with this that Bangladesh is divided by three main lands separated by two large rivers; Jamuna and Padma. The river crossing of transmission line is very complicated and costly. Considering the cost, it is not a very good option, the river crossing should be minimized as much as possible. Is the study considering

			anything regarding the river crossing of transmission line to minimize the number?
5.	Mr. Bikash Dewan	Managing Director, DPDC	Mr. Dewan talked about the following two points Demand forecast: in the master plan consideration the country is divided in 9 zones, and one of them is Dhaka. He requested the study team to consider the division companywide such as by the load of DESCO, the load of DPDC, and REB. The companies' trend is different from one another. The growth is different in different areas, for example we are considering energy efficiency master plan, DAP, strategic transport plan etc. so the operation and management of the companies is also different. This needs to be taken into consideration. 2. Transmission planning: the most important plan is to have a security of supply in Dhaka. As Dhaka is the capital, we have to maintain an uninterrupted power supply in Dhaka. Mr. Dewan requested the study team to plan in such a way that there should be lot of 230KV, 130KV substations and their infrastructure that will be integrated in the total grid master plan.
6.	Md. Mijanur Rahman	Managing Director SGFL	Mr. Rahman started with the current trend of natural gas and its probable reserve projection. He said "presently we are producing 2400 MCF per day. The present reserve is 28 TCF and the cumulative production is 19 TCF, the remaining reserve is around 10 TCF. The rate we are producing, after 9-10 years the proved reserve will be reduced. According to the gas sector master plan of 2017 the consultant has given the importance to the geological exploration of reserves that could save the LNG import expenses. He suggested that there is a rigorous exploration needed in resource exploration. His question was "Are we following this kind of suggestions in the master plan?"
7.	Anwarul Islam	General Manager, Production Marketing	Mr. Islam mentioned that the Demand forecast is one of the main issues. "As of now we don't have any integrated plan,

		Petrobangla	physically we are integrated, but documentarily we don't have one. He raised the concern regarding energy demand forecasting. To make a true functional master plan we need to have energy demand for the next 30 years. JICA is doing the energy demand based on the fuel but the sectoral divisions have not been taken into consideration. He suggested to assess the service energy demand. For residential energy sector, the study is considering how much electricity they're consuming, instead they could have considered how much energy is needed for cooking, lighting, cooling, etc. with this information the energy projection can also be done rather than knowing about the demand only. For future demand forecasting we should consider the service sector as well.
8.	Yeakub Elahi Chowdhury	ED, Planning and Development Power Grid Company of Bangladesh	Mr. Chowdhury appreciated the approach by JICA. However, he mentions that we should limit the cross-border import within 15% of the total demand and on a single point it should be within 10%. The point of interaction should be carefully defined. He said that they have shared the case files with JICA but recommended to have the latest accurate data to avoid any errors. Another suggestion is to consult separately with both transmission and generation entities. Also avoid the construction of such transmission line which will be not useful in the future.
9.	Rukhsana Nazma Eshaque	Managing Director Gas Transmission Company Ltd.	The fuel mix in the master plan the share of natural gas was in high demand which is not possible with the current transmission line. She said that we need to estimate the power demand that will indicate us to get a production target. In addition to this, she mentions about the difficulty of building gas transmission lines under the rivers for which private sectors need to explore the sub-sea level for the line to be sustainable. For efficient energy management we need to audit the need of the meeting of peak hour energy demand.

10.	ZJulfiqar Tahmid	Chief Engineer, planning and design DESCO	In the distribution section he wants to include the following issues: As Dhaka is densely populated city the companies are planning to go for underground line, so a separate study is needed for the feasibility of the underground connection. This should also include road cutting issues, space for equipment, financial issues. This can be included in the study to have a comprehensive study. Study of the distribution voltage level, should it be increased from 11 KV to upwards. As NLDC and BKMI are given the responsibility to review and problem identification and they also need to know where are the shortcomings from their end. He raised his concern regarding the cybersecurity issue as a result of automation in the system and asked the team to carefully assess. Responded By: The cyber security issue has already taken into consideration. Responded By: Mr. Rahman, DG, Power Cell

After the discussion session, the special guest Dr. Ahmed Kaikaus and the chief guest for the afternoon session Dr. Tawfiq-e-Elahi delivered their speech and enlightened the audience with their knowledge and vision.

Speech by principal secretary of PM Dr. Ahmed Kaikaus (Special Guest)

Dr. Kaikaus started his speech by addressing the minister, distinguished guests and the audience for attending the meeting.

He thanked JICA for partnering in all the development projects of Bangladesh in both the gas sector master plan and power sector master plan and he said that it is the best thing that JICA is also partnering in this integration plan. He suggested the teams carefully reviewing what has been done to avoid repetitive work and to reduce the workload. The following points have been mentioned by Dr. Kaikaus after his thorough observation into the project:

1. He starts off with the energy demand model and says that the modelling of energy demand is quite difficult especially when talking about the econometric model. “We always discuss in the academic field the error variance which can contaminate the model. The problem is that when you want to have an econometric model, the question is which is the dependent variable; is it the electricity or the GDP? We call it simultaneity; in Bangladesh we see there is growth in electricity demand. So, when plotting in the graph when electricity demand is growing, the GDP is also growing. Now which is the dependent variable is very difficult to identify but there is a strong correlation between these two”. He recommended the study team carefully take this into consideration.
2. He said his next point towards segregation is even more difficult. Because the demand pattern varies from country to country, if the study considers the demand for Bangladesh, the demand curve will flatten from stiff for a certain time. Also, the urbanization in Bangladesh is different from many states of US or European countries. This needs to be taken into consideration. When we are talking about demand we need to burn coal, gas and also renewables; here the growth of the urban centers should be taken into consideration. The demand for electricity is not growing the same in all the urban centers. The pattern is different due to multiple factors. All these factors need to be taken into consideration, otherwise there is a possibility of miscalculation.
3. Renewable energy is an emerging concept. Even though some people consider him anti-renewable, Mr. Kaikaus calls himself practical. According to him, “we cannot make promises without knowing where we are going, we have to be very careful. In the Mujib prosperity plan we made a promise of 40% reduction of CO2 reduction. Technically at this moment it is impossible. It is going to destabilize the system completely. People who are working in the power grid will never agree. We want to save the earth as we are the victims of climate change. If others are doing something wrong, we are left with two options, either blame them and suffer or adapt policies measures through which we can also protect ourselves, and one of the examples is the Delta plan 2100”. He adds “While making plans we sometimes become romantic, we instead need to be elastic while planning”.
4. According to Dr. Kaikaus if we consider the overall service sector; its contribution in GDP is the highest at the moment. So, the service sector needs to be considered in the planning as Bangladesh’s demand is concentrated in the service sector. However, a positive thing about the service sector is that the demand for energy in this sector is less than other sectors. But as the sector is growing, we need to consider the impacts of the service sector in the master plan. Another point is the consideration of agriculture, as the

pattern is changing with more mechanization and the value chain for agriculture is going to be very fast. He recommends calculating carefully while planning for agriculture.

5. Mr. Kaikaus mentions CO_2 emissions, which we need to reduce. However, CO_2 emissions are dependent on two factors; the importation of coals/other fuels from the global market as depending on the local demand and the focus on importation; the level of CO_2 emission will vary. Another factor is the concentration on our local resources, as we will go for deep sea exploration for resources. He adds here, "since we are making a long-term plan, we need to have elasticity and range of variability so that we can incorporate all these factors. Regarding the climate change issues our honorable Prime Minister has already mentioned that climate change or environmental issues are built-in our projects. We are moving towards the 4th IR so we need to consider adding them into our management system which is very important".
6. He mentions that in Bangladesh the transmission or energy is very much dependent on natural gas. He poses a question on how we are going to make the transmission line usually done by GTCL as it will depend on two factors. For example, in the long term we don't know whether we will get gas in our country or if we have to import gas. So, the gas transmission will depend on whether we get indigenous gas or we have to import it. He says he hasn't seen that so this is something that needs to be considered.
7. Our power and energy are dependent on local demand and supply and then globally, it is very much dependent on price fluctuation both locally and globally. Whenever we plan, we need to be very careful about the price elasticity.
8. Both the gas and power sector are very much technology dependent. There are providers of service, business, or technology. So, we need to be careful while planning so that there is a wide competition. He says that we don't want to make a plan where only a few business people can enter it should be open for better competition and wide participation.

Finally, Mr. Kaikaus mentioned that there is a project signed with JICA today that has the highest amount of loan in the energy sector after the Ruppur project, so he thanked JICA for that.

After the speech by the special guest, the chief guest Dr. Taufiq-e-Elahi was requested to give his speech.

Speech by Dr. Tawfiq-e-Elahi Chowdhury (Bir Bikram), Advisor to the Prime Minister (Chief Guest)

The Chief guest Mr. Tawfiq-e-Elahi Chowdhury (Bir Bikram) started his speech by addressing the chair state minister Nasrul Hamid, Special guest Dr. Kaikaus, his excellency Mr. Ito Naoki Ambassador of Japan, the JICA chief representative, others on the podium and the invited guests.

He expressed his pleasure in attending this meeting.

The adviser had endorsed the points made by Dr. Kaikaus and put up the supplemental points regarding the IEPMP, which might be interesting to the audience.

He mentioned that he had a discussion with the team and made some elaborate points. Aligned with Dr. Kaikaus he also mentioned the difficulty of determining the simultaneity of energy demand and GDP. One way to look at it is to see the lag response; for example, the energy that is produced and delivered today will determine the need for the next day and onwards if we lag, we will be able to capture some of the realities of economic operations. He says "The simple way of looking at things is in aggregation, if we look at the countries with similar income or 10-20% higher than ours, the inter country comparison will show some energy intensity. So that energy intensity can be an average path for us we don't have to discover in aggregate. Then we can have another path of energy intensity which is higher or lower than that. This will form the basis for projecting total energy demand (primary and secondary). When we have this, we can disaggregate into sectors and sub sectors.

The next point the adviser mentions is that we often concentrate more on the power side and forget that the energy side that responsibly determine the power to be produced while making an integrated plan. He adds "once we go for energy intensity, disaggregate into major sectors then we can focus energy needs and proceed in the future. However, there are some caveats here, as we move along the technology will change significantly, so the plan must have a mechanism to detect and incorporate the changes into the system as the future unravels before us. These challenges will come in the future".

The next thing is energy mix, as most of the energy we import is from other countries. Both the quantity and price Bangladesh takes from the outside. The reason for mentioning the quantity is that there might come a time when the price might be irrelevant but the difference will be made in the quantity that we need. He gave the example of Germany importing gas from Russia which became an issue of quantity relevance instead of price relevance. The global energy scenario might change in such a way that the relative price will have less importance and it will be shifted towards quantity. "When we are price takers, we don't have much choice of relative price. This needs to be taken into the model and emphasize quantity and not on price as most of our sector is public sectors. We don't know the price in the future so if we confine ourselves in quantity planning, we will be able to express our expectations and make our plans accordingly." The energy mix surely will be gas, some liquid fuels, some coal and nuclear power and then renewables. He mentions the fact that the study hasn't taken note of nuclear power which is a zero emission energy system. We are not looking for renewable vs nonrenewable, instead we are looking for less

emissions. Possibly in future Bangladesh might have to consider nuclear power and the emerging technology called small modular reactor. This will be low emission and price competitive and will make us less dependent on fossil fuels.

He expressed his disappointment regarding some reports on coal. He says that there is no choice for Bangladesh to phase out coal at the moment. Pointing out the positive side of coal use, the adviser mentioned the use of finest technologies in the coal-based power plants to reduce the environmental pollution and compared it with the plants in the US. He also mentions that the reports are coming as a result of ignorance. While talking about the technological improvement in the coal-based plants, he mentions the reduction of Nox, SOx emissions with the state-of-the-art technology use. The Matarbari power plant was taken as an example of the latest of such technology. To meet our energy needs using coal is a choice for us. Talking about the renewable energy, he mentions it is intermittent and also limited to solar only in our country and that it isn't capable of meeting the peak demand. Other than advancement in technology for renewables such as hydrogen fuel (blue, green or pink), and going from solar to hydrogen, fossil fuels to hydrogen which can be used in the transportation. He expects the study to tell us the viable option for the future, for example in 5 to 10 years' time.

The adviser mentioned talking to the ambassador about the Carbon Capture and Storage where the coal-based plants can take the carbon underground; he would like the study to consider such environmental technologies to be considered in the study. He invites the organizations such as the energy research council, SREDA to learn about the technological advancement that will take place in the future and find out those which we can use in short- and medium-term planning.

He emphasizes the need to carefully look at the top primary fuel supply network. If the country has to have a network of i.e. gas in the western part of Bangladesh the next question is where do we have the supply? If it is going to be a land-based LNG then how we make it technologically viable, etc.

Along with this, the question of regional trade comes. Trade is the correct term, but it should not be a dependent relationship regardless of the country (India, Nepal, Bhutan). Interdependency is a key issue here.

He then moves to clarification of a question on 10-15% import of energy, he says "but the term should be trade. The trade should go both ways, it could be power or primary energy if we have a good network on the southern side, we will be able to go to the western side of Bangladesh beyond the border". He requested the regional trade be considered two-way traffic rather than one way, mentioning the arrows in the presentation pointing towards Bangladesh only. Those who are experts in the transmission network, we need to be very efficient while being a part of an

integrated system. The matter of losing control in an integrated system and how this can pose threats like cyber security was also mentioned. This needs to be taken into consideration while planning.

One idea he shared is behavioral change. Much of the world focuses on things independent of behavioral change. He mentions this concept is not usually taken into consideration. Taking the example of our honorable Prime Minister who always switches off lights while leaving rooms, which is a practice of optimum resource use, Dr. Elahi encourages these kinds of behaviors to be widely practiced. That kind of behavioral change is critical, and it has the potential for growth by concentrating behavior from sectors like energy and food which have a wastage issue. The behavioral change will make a huge difference immediately in the short run. As it is a medium to long-term plan it should consider the possibility of behavioral change such as work from home, reducing unnecessary driving, changes in educational institutions in the form of online learning. We need to consider these choices learned from the pandemic. We should consider all the possibilities and tap the most potential ones to be incorporated in the master plan.

At this point he mentioned LNG use and transport. “When we talk about EV and fast charging stations but we forget about the 3 million electric vehicles. All tri wheelers capable of transporting both passenger and cargo. We have talked to the energy and power research council, SREDA to change the design. Now they don’t come in the highways because of dense population if they can move around 2km circle it would be good option to make this vehicle viable. If we provide fast charging stations for these vehicles and give incentive while charging during the daytime the load can also be minimized. We need to come up with creative solutions”. When the JICA team talks to the local people he believes many more innovative ideas will come.

Looking at the future we should see if we can leapfrog. Then he explains the term like this: the normal path of domestic fuel has been improved cook stoves, LPG and latest electric cooking. “We are connecting the whole country by the grid network. If we can incentivize people to use these newer technologies (induction cooker) in the daytime, we will be able to improve load factor, decrease electricity cost, and improved cooking”. So, it is important to see what choices we have that can be viable in the future.

He finishes off his speech by thanking everyone present and also welcomes discussion on anything with him if anybody wants.

Closing of the meeting:

It was suggested that the points raised by the participants at the meeting will be taken into consideration by the study team. Therefore, not all the questions/queries were addressed at the

meeting. As this was the first stakeholder meeting and there will be more opportunities to interact with each other during the whole study period, notes were taken where necessary by the study team. At this point of the meeting Mr. Md Habibur Rahman, the secretary of the Power Division, gave the closing speech. He thanked the team and all the distinguished guests for coming and sharing their valuable insight in this stakeholder meeting. He especially thanked JICA for being a development partner for Bangladesh in various projects, mainly this integrated power and energy system master plan. Bangladesh has many masterplans in the energy, energy efficiency and gas sector master plan but now the country with its growth rate needs the integration of these plans to formulate the country's development plan both in the long and short term. Mr. Rahman took the opportunity to thank the JICA team and other government and non-government entities related to this project to have a successful integrated master plan for power and energy sector.

Minutes of the First Stakeholder Meeting on Integrated Energy and Power Master Plan (IEPMP) for Bangladesh (Evening Session)

Date: November 23, 2021

Location: Grand Ballroom (11th F), Sheraton Dhaka Hotel, (44, Kemal Ataturk Avenue, Banani, Dhaka 1213)

Starting Time: 5:45 PM

End Time: 9:00 PM

Participants: See appendix section for participant list

Objective of the Meeting:

The Government of Bangladesh has established long-term plans for each energy sub-sector, such as the Power System Master Plan 2016 (Revisiting PSMP2016), the Energy Efficiency and Conservation Master Plan (EECMP2016), and the Gas Sector Master Plan (GSMP-2017). However, it has become necessary to revise the energy plans in response to the current situation such as changes in demand assumptions and the growing global trend toward low-carbon and decarbonization. The Institute of Energy Economics, Japan (IEEJ or "JICA Survey Team") has been conducting the Study for the "Integrated Energy and Power Master Plan Project in Bangladesh" which is financed by the Japan International Cooperation Agency (JICA). In the Survey, IEEJ will develop several scenarios on power development in Bangladesh. Under this study, a Strategic Environmental Assessment (SEA) will be carried out and reflect the environmental and social consideration on policy making and planning at an early stage. During the master plan preparation, several stakeholder meeting will be held on master plan and SEA session. The objective of the SHM is to introduce the project scope, approach, methodology and

way of the engagement with key actors in Bangladesh, including academia/thinkers and development partners.

The chief guest for the evening session was Mr. Nasrul Hamid, State Minister, Ministry of Power, Energy and Mineral Resources. Secretary, Power Division Mr. Md. Habibur Rahman, Additional secretary Mr. A.K.M Fazlul Haq was present as the special guest. The panel was joined by his excellency the ambassador of Japan Mr. Ito Naoki. The session was chaired by Mr. Ichiro Kutani from the JICA study team.

Opening of the meeting: The meeting was moderated by Ms. Morsheda Ferdous, Deputy Secretary EMDR and Mr. Mohammad Hossain, Director General, Power cell. Unlike the afternoon session, the evening session was tailored especially for the civil society representatives from academia, think tank, and also the utility sector and sector specialists. There was l99 total participants, of which 12 were female representatives. There was also an online platform, where many academicians and researchers have added their opinions.

Presentations

For this session the presentations were divided into two categories: General and Technical.

General Presentation

The general presentation consists of the overview and workflow of energy and power sector master plan integration and also the basic idea of SEA and its benefits.

Presentation-1

The general presentation on the overview of Energy and Power Sector Master plan was given by Mr. Ichiro Kutani. The presentation covered the overview of the project and the workflow. The initial 12 months master plan formulation workflow was shown at the beginning. Initially the study team will go through the relevant policy of the country and also data from the different utility companies. This will help formulate the possible future scenarios. After the evaluation of the scenarios by consulting with the responsible authorities, a master plan will be formulated. This time the presentation was shortened as it has been already given once in the afternoon session.

Presentation-2

The second presentation was given by Mr. Seiichi Sasaki, Senior Consultant from ERM Japan. He shed light on what a Strategic Environmental Assessment is, why is it necessary and how it can be done with the help of data collected from the local stakeholders to have a better understanding of the country profile and its goal. He described how the energy sector will take into account the social issues and incorporate it into the master plan. Mr. Sasaki mentioned that

through SEA the sustainability principle will be incorporated into the policy making. According to the plan there will be two more stakeholder meetings in the master plan preparation which will be held on March 2022 and May 2022.

Technical session:

This session included papers with more focus on the technical issues. The second session was on the presentation of technical papers by the JICA Study Team.

Presentation-1

The first presentation was on the discussion on Demand forecast, specifically the methodology and scenario settings. This was presented by Mr. Ichiro Kutani instead of Mr. Suihiro who was supposed to join online but couldn't join due to a technological glitch. He presented the demand forecast model, its econometric basis, the components of the model, the relation of GDP with energy demand, energy consumption by different sectors such as industry sector, transport sector, building sector, agricultural sector, etc.

Presentation-2

The second technical paper on supply side forecast was presented by Mr. Ichiro Kutani. This presentation highlighted the fact that due to the diminishing reserve of the indigenous fuel in Bangladesh the import dependency on coal or oil might rise. This presentation also shed light on the process of work which will first determine the demand forecast and the production forecast from which the import requirement will be quantified. While importing the fuel the consideration will be given on coal import terminal capacity, oil refinery and terminal capacity and natural gas pipeline import capacity and LNG import capacity. The most viable option would be then chosen for primary energy supply of the country.

Presentation-3

The third technical paper on Energy System Planning was presented by Mr. Shinichi Suganuma. The major focus of the presentation was on generation planning, transmission planning, and distribution planning. He talked about the basic workflow of the technical working group-2 with four different tasks such as- generation, transmission, distribution, and power system development. For the generation planning the consideration was on LOLE (loss of load expectation) and LOLP (Loss of Load Probability). The derated capacity problem is one of the problems in Bangladesh. This is caused by poor maintenance of generator. To minimize these

issues both technical and institutional measures should be taken. He talked about the fundamental concept of Merit Order operation that dictates the type of generator to be selected.

Mr. Suganuma also highlighted the challenges related to energy efficiency and decarbonization that included:

- The inclusion of Coal will be an important base load power in the future as Bangladesh is running out of natural gas reserve and also wants to reduce carbon.
- Promotion of RE is also an important consideration for Bangladesh. As the RE sources such as wind and solar are not consistent all over the country it is a challenge.

Presentation-4

Mr. Masanao Egawa gave the fourth presentation on the transmission planning of energy in Bangladesh. This presentation highlighted the possible ways to move forward in the future regarding the power transmission system. He pointed out three key factors to make a sustainable power transmission system. The factors included: Increase of South to North power flow; Reliability improvement of supply network to Dhaka, and international interconnection with Nepal and Bhutan. The challenge he mentioned here was the national security while planning the interconnection.

Presentation-5

The presentation on the distribution master plan was supposed to be presented by Mr. Suhiki, one of the experts from JICA Study Team via an online platform. However, due to technical difficulty, Mr. Suganuma presented it on behalf of Mr. Suhiki. It focused on three major points to be considered while planning for the distribution facility in the master plan. The factors include: enhancing reliability, operation and maintenance efficiency, and dealing with the renewable energy introduction in the power system. He also highlighted the challenges of proper voltage management, complication of long-term planning, utilization of maximum RE. The paper also suggested taking measures such as automation in RE introduction, adoption of distribution management system for voltage maintenance and so on.

Discussion session

After the presentation the floor was open for discussion or comments from the guests and participants.

The following table shows the discussions or comments from the participants. Since this was the first stakeholder meeting, many comments and suggestions are addressed by the participants and

there was no specific answer session given due to the time constraints.

Sl. No	Name	Designation Organization	Question/Comment
1.	Dr. Abdul Hasib Chowdhury	Associate Professor Department of Electrical and Electronic Engineering Bangladesh University of Engineering and Technology	Dr. Chowdhury stated that the JICA team recommended that the international interconnection be built on Bangladesh's northern border. He, on the other hand, advised that we look at our country's east side. Renewable integration may lower the power factor for the distribution utilities. Because the local renewable energy generation will supply the real power. So, the discompose will have to supply the reactive power and that will affect their revenue as well. There should be reactive power reserve margin consideration for our system. He added that we do not have any distribution code yet which is absolutely necessary for a long-term planning for energy and power in our country. About the reliability aspect, there is not sufficient reliability related data. We may target this reliability data for certain Loss of Load Expectation (LOLE). For this, a long-term planning should be made stay on guard. He requested the JICA team to consider the impact of certain different aspect of technologies on Bangladesh and how this will affect the future load requirement. He concluded by recommending that the JICA team to have more stakeholder consultation with the academicians.
2.	S. Shahnawaz Ahmed	Professor Department of Electrical and Electronic Engineering Bangladesh University of Engineering and Technology (BUET)	Dr. Ahmed said that electricity is the end target or product of all forms of energy. The demand for electricity is created by the consumers. As a result, they should begin with the distribution side. Recent energy efficiency technologies include smart grid, demand response, electric vehicles, and renewable integration. How much would the genuine demand be when all of these factors are taken into account? Their main strategy is top-down, whereas the best way is bottom-up. He added that, on the demand side, they should forecast real demand first, followed by year-by-year forecasting of all the available resources and reserves. Another consideration for the JICA team is to determine how much demand was expected in 2016 versus current demand. They must

			identify the shortcomings of the previous master plan so that they are not replicated in the upcoming integrated plan. He recommended that our target for the Loss of Load Expectation (LOLE) should be similar to Sri Lanka and India. At any given time, generation, connectivity, and imported power should not exceed 10% of the indigenous capacity. He recommended forecasting demand from the demand or issuance side, synchronizing resource availability (renewable and non-renewable), and then planning transmission lines.
3.	Dr. Muhammad Riazul Hamid	Consultant (Short term) Monitoring Mission at KfW	Rooftop solar, according to Dr. Hamid, is a challenge for utility providers because residential and educational institutions have more space for rooftops. He argued that as a national goal, there should be a strategy to reward utility companies and allow people to generate as much power as possible from rooftops. He added that the capacity is much higher than we can harness under this guideline.
4.	Dr. M. Rezwan Khan	Professor & Executive Director – IAR	Dr. Khan believes that when it comes to renewable energy technology, Bangladesh will most likely benefit from solar PVs. Due to limitation of plans, we must consider Agro PV which means generating both crops and electricity from the same field. As a result, policy guidelines must be developed alongside an understanding of the systems. He also suggested that irrigation pumps might provide power to the grid whenever the system required it because pumping could be stopped or delayed. Lastly, he recommended that incorporating technologies will probably decrease the consumption and bring changes in the demand forecast.
5.	Dr Khondaker Golam Moazzem	Research Director Centre for Policy Dialogue (CPD)	Dr. Moazzem said that it is already mentioned in COP-26 that our government has a firm commitment of 40% of the renewables by 2040. He suggested that this should have to be taken into consideration while going for the master plan. He recommended that the team should consider reviewing Solar energy related document prepared by SREDA and Mujib Climate Prosperity Plan (MCPP). He requested to have a complete energy mix projection for the next 10 years as the energy

			mix is constantly changing. He suggested to rather have the complete demand projection for the longer term. He also suggested that we should not be projecting future technologies at this moment which are not yet fully been operational even in the developing countries. Instead of projecting a net zero target he requested to consider clean energy related target. He demanded that a detailed information regarding how much carbon emission will occur in different scenarios for different years be included in the comprehensive environmental assessment. He also demanded to build in this environmental emission issue in the main model to see the optimum option in terms of economic cost and environmental cost. He recommended to review the existing power plants. Also, asked to consider the retirement of the inefficient plants instead of their rehabilitation plan. He discouraged to consider coal as an option. Rather, he requested to consider renewable energy in a robust manner.
6.	Sadrul Hasan	Special Correspondent UNB - United News of Bangladesh	Mr. Hasan asked about the specific plan for Energy conservation and Energy efficiency.
7.	Dr. Badrul Imam	Honorary Professor Department of Geology University of Dhaka	Dr. Imam mentioned that the JICA team has shown coal as major component of the future energy mix. Since the world is moving away from coal as per the COP-26, how will their study be impacted from the negative mentality of coal use in the coming days in terms of these environmental issues?
8.	Jari Väyrynen	World Bank	Mr. Jari shed some light to their work experiences on decarbonization pathways model for electricity sector, climate resilience on power system, rural distribution master plan that may facilitate the master plan.

After the discussion session Mr. Habibur Rahman thanked all the guests and participants for

coming. After that the honorable minister the chief guest Mr. Nasrul Hamid was requested to deliver his speech.

Speech of the Chief Guest Mr. Nasrul Hamid MP, State Minister

He showed his gratitude to the JICA and the institution and companies working in collaboration with the Ministry of Power, The ambassador of Japan, power secretaries, additional secretaries and to the audience. The session has stakeholders from different NGOs, activists, ministries and universities.

The member of the Climate Parliament Forum provided their views and opinions in the stakeholder meeting. The Climate Parliament Forum is one of the strongest committees working for implementing actions for programs on climate resilient. JICA is one of the most important bilateral development partners of Bangladesh working for infrastructure, urban development and private sector development. With the support of JICA, Bangladesh developed a dynamic power system master plan which has been updated by factoring in the current state of globe. He congratulated for hitting targets with defined numeric value like generation, Losses, SAIFI, SAIDI, etc. We have a long way to go in ensuring the promise of affordable and reliable power supply and the journey so far has been satisfactory. Companies in energy helped Bangladesh in finding a mix of primary energy resources although the current up flow of energy bytes has been hard on us. But we need to remain steadfast in ensuring the energy supply of Bangladesh.

He says “the bygone generation believe that to be successful we need a plan but in the current reality with the world moving so fast that having a static plan is a requirement. The Master plan has turned out to be a beautiful concept, noting that it constantly evolves and is to be revised along with the help of experts and industry professionals. This also make it a critical condition how the next evolution could arrive. He has attended the COP 26 Glasgow Summit for the last 3-5 weeks. The first document was UN IPCC report summary which outlined few alarming trends.

Firstly, to stabilize the world at a 1.5-degree Celsius, drastic measures need to be taken. If we don’t act, the melting of tipping point may occur and the earth would not be same as before.

Secondly, Bangladesh is the 7th most vulnerable country to climate change both in terms of climate induced disaster and rising sea levels. However, we emit the lowest CO2 per capita in the world. In fact, the richest 1% have to reduce their emission by a factor of 30 and the poorest 50% can increase their carbon footprint by a factor of 3 and still maintain the 1.5-degree target.

Third, Europe is moving towards carbon pricing and as our second most important export

destination we as a nation must worry on how to decarbonize out industries and remain competitive in the near future.

It has been fundamentally proven that climate change is the cause of burning fossil fuels. To contribute in the reduction of greenhouse gas emission falls under the accountability of the Power and energy sector as well. Bangladesh submitted Nationally Determined Contributions for the reduction of greenhouse gases to the UNFCC through the ministry of environment and forestry. Power and energy sector combinedly must contribute to almost 48.9%. to the reduction of GHG by 2030. Some of the most important initiative for this decarbonization of the ministry of power and energy and mineral resources are Power Sector Master Plan, National Solar Energy Roadmap 2021, 2041, National Action Plan for Clean Cooking (2020–2030), Energy Efficiency and Conservation Master Plan up to 2030, Renewable Energy Initiatives. These are all under our jurisdiction.

NDC states that we must achieve Clean Co renewable energy target of 4200 MW, prepaid meters, implementation of energy efficiency and conservation master plan targets. If we look towards the conditional target, we would require additional funding of 21 billion dollars.

Another big sector of the Ministry of Power energy and Mineral Resources is transportation. The Transport sector has a target of 12% emission deduction, and to support that we need a large amount of financial support as well.

In the past the land of Bengal was a very pioneering part of the world. But after the colonization and occupation we have turned to a reactionary economy. Low-cost production for human resources is our key input. But in our own way we can contribute toward climate change mitigation. Beyond out targets to the NDC and UNFCC we can take much more actions. We have a young population who is very passionate about climate change mitigation. The Bangladesh population is now more disaster resilient.

In a mini documentary of Richard Vally the experts were saying that Germans could learn about the flood management from Bangladesh and mentioned that BD was lead in energy integration in South Asia. BD is promoting hydro power share, we have the largest distributed solar program in the world and have a large number of make-shift electric vehicle transporting millions of people in rural area of Bangladesh. We have startups which can show the way for climate change mitigation in the future. We can be a global leader in renewable energy share, integrated renewable energy, small electrical vehicles adoption. We don’t want to follow any rich country to save us for climate change. We have to find out our own unique way by utilizing our own strength.

We have realized that climate change would be a threat and we need to factor each and every

policy and actions considering the impact of climate change. Hence the Power sector master plan of this year takes into account all of this and turned out to be a very forward thinking yet today in Bangladesh. As Bangladesh needs to improve, we need more fossil-based power. Our Founding father Bangabandhu Sheikh Mujibor Rahman said that "গ্রাম কে গ্রামের মত রাখ কিন্তু শহরের সুবিধা দাও।" He envisioned the harmony of development and nature. Realizing that we must do our own part for climate Justice. Yes, Justice has begun in Bangladesh. It is not only my own view but this is also the political views of Prime Minister Sheikh Hasina's, what she has mentioned mostly in the COP 26 in the Climate Vulnerable Forum meeting. Lot of questions have arrived here in this session. He would like to answer some of the questions.

We have done some coal-based power plant. We can compare these coal-based power plants with the American practices for coal-based power plants traditionally. We have a team on coal technology and it has been started working on this. We have taken the finest examples of technology in this power plant and we need to get access to the affordable tariff for our consumers. That is one of the big challenges which we now facing. Of course, we need clean energy and the best Carbon Emission Technology we have to find out. Technology is changing rapidly so what we need is not to make anything too long for a plan but of course we can make a vision of the plan according to the Prime Minister. We need to mitigate the problem that we are facing right now. Demand for more affordable power, in need of very proper baseload power immediately. Secondly, reliable electricity, renewable energy and of course affordable. It must be affordable for everyone even in the future also.

After the Covid the whole situation has been changed globally. Pricing of every item is increasing and it is also one of the important concerns. Activists and Experts always throws question on why not produce power in a bigger way in the solar. Since there are some more activists in this session, I would like to answer this question. Bangladesh is occupying for 60% on wetlands with the densest population. To put up a solar plant of 100MW we need 350 acres of non-agricultural land which is impossible to produce. I have given more than 60 projects already and only 3 projects were taken into consideration for last 10 years. None of them were successful. Still within these 3 projects the price was given more than 10% like 10 cents, 16 cents, 17 cents are also there. Whereas with coal we are producing at a rate of 5 cents. Who is going to pay this money? How much the government is going to subsidize in the future? We can't rely on only one item to produce every power from solar as it's a variable electricity it cannot be a based zone. Pattern of behavior of using power is different from Europe and in Bangladesh. In BD we use more power from evening to 1AM after midnight. In Europe they use more power in the daytime. So that is feasible to use solar for power in the European country but not in BD.

The master plan by JICA has shown to share power from the neighboring countries so it can be from south to north and north to south to balance the electricity so that we can get uninterrupted power from there. If somebody comes over, we cannot say that we can share 10%. Technical considerations and analysis need to be taken whether we are able to produce the remaining requirement of 90% power from what sources for the future of industry growth in Bangladesh we need stable power and this should be the aim. So, the questions from the academicians, activists and participants should be more practical. He finished his speech with his wish for the best future for Bangladesh.

Closing of the meeting:

Ms. Murshida thanked Mr. Nasrul Hamid for delivering his speech and ending it on a positive note.

B1. Minutes of Meetings for the SEA Scoping Meeting (Second Stakeholder Meeting)

Minutes of the Second Stakeholder Meeting on Integrated Energy and Power Master Plan (IEPMP) for Bangladesh

Date: July 3, 2022

Location: Grand Ball Room, Hotel Intercontinental Dhaka, Minto Road

Starting Time: 2:45 PM

End Time: 5:30 PM

Participants: See the attached list

Objective of the Meeting:

The Ministry of Power, Energy and Mineral Resources and JICA Study Team organized the Second Stakeholder Meeting (2nd SHM) for the project entitled "Integrated Energy and Power Master Plan (IEPMP) Project in Bangladesh". The objective of the 2nd SHM was to introduce demand forecast scenarios, potential for LNG legal framework, and identification of environmental and social impacts through Strategic Environmental Assessment (SEA). The meeting was held in accordance with the agenda provided below.

Number of Participants: Total participants (Physical & On-line): 248
Physical- 184
Online- 64

Opening Remark by Mr. Md. Habibur Rahman, Secretary, Power Division

He first thanked chief guest Dr. Tawfiq-e-Elahi Chowdhury, BB, Honorable Adviser to Prime Minister for Power, Energy and Mineral Resources Affairs, special guest his excellency Mr. Ito Naoki, Ambassador of Japan to Bangladesh, senior secretary Mr. Md. Mahbub Hossain and all the respected participants. Since after the liberation of Bangladesh, has formulated the power sector master plan with the help of ADB in 1995 and subsequently revised the plan in 2010 and later on 2016 with the help of JICA.

To give it a more visionary to our policy related power and energy sector along with an integrated approach Honorable State Minister opined the integrated energy and power master plan with the help of JICA. Due to depleting condition of fuel, gas and volatile fuel markets, we are always in hardship to adjust our energy supply. He gave his generous gratitude to JICA as they have been friendly working since the emergence of Bangladesh in power and energy sectors. He then gave some project initiation information like the IEPMP first signed in 14th March of 2021 and first coordination meeting on 18th July 2021. He said that, we the power division of MoPEMR believe that, this study is inclusiveness in policy formulation which ensures the perfection. With this aim, we have arranged this program in collaboration with JICA and IEEJ involving different stakeholders from the civil society, academia and development partners along with power and energy division of MoPEMR. Power division of MoPEMR has achieved the 100% electrification and got awarded the independence award in 2022 for the first time in Bangladesh.

Now power division has set target to a step forward to achieve an uninterrupted, affordable and reliable power supply for all. To achieve the goal of 2030 and 2041, we have miles to go, he added then. As he mentioned depleting natural resources, volatile fuel market, climate change issues, conservation of environment, global resentment on the use of fossil fuel, challenges in the fuel mix, scarcity of land for renewable energy generation systems, that all to be addressed in the next master plan that is IEPMP, during our journey to become as a developed country. He then concluded his remarks seeking attention to JICA study team to incorporate the solutions of all those issues in the next IEPMP and gave thanks to all.

Speech by Mr. Hayakawa Yuho, Chief Representative, JICA Bangladesh Office

He first thanked chief guest Dr. Tawfiq-e-Elahi Chowdhury, BB, Honorable Adviser to Prime Minister for Power, Energy and Mineral Resources Affairs, special guest his excellency Mr. Ito Naoki, Ambassador of Japan to Bangladesh, senior secretary Mr. Md. Mahbub Hossain, Md. Habibur Rahman, Secretary of Power Division and all the respected participants.

He believes that, this master plan is the backbone of the development this country. JICA is derived of this part of this endeavor. This study is not only to upgrade the master plan in long term

sustainability of power and energy sector of Bangladesh, but also to see way forward towards low carbon energy of the society. Furthermore, it is also addressing the rapidly changing concern like climate change, public private partnership and a stable with affordable supply of energy and introduction of advance technologies. In addition to that other factor like efficient use of energy, reduction of system loss and replacement of inefficient facilities.

Solution to this problem of the power and energy sectors of Bangladesh, is varies depending on the available clean technology, willingness to pay by the people, he added. Mujib climate prosperity plan on which Bangladesh government has been working on suggest ambitious target of energy sector's de-carbonization including the substantial share of the renewable energy to total power generation by 2041, he said.

Additional options with some advance technologies have been considered for this master plan such as green hydrogen power generation, ammonium, TCS etc. all are these are the developed technologies have some pros and cons though. We all have to overcome the challenges and achieve goal, he mentioned lastly.

Updating the project progress by Mr. Ichiro Kutani, Team Leader, JICA Study Team

He thanked everyone and said this is good opportunity for all to share the thoughts, barriers to input in the interim report and sharing through stakeholder meeting. I will briefly explain the progress of the report, he said. We have come up the interim report to be shared by June 2022, mainly to forecast the demand of 2050, and the next delivery we are expecting is to share the draft master plan by October 2022 and deliver the master plan by April of the net year. We have collected data on environment, energy supply and power and energy consumption and review existing relevant policies of Bangladesh. According to the information we have so far, we have formulated the energy model of this country and how we calculate the energy demand and developed the future scenarios of the demand. There is a lot of uncertainty we predict the magnitude of the changes. As you can see in the middle of the workflow of the slide, we estimate the future demand with Primary Energy Mix and Power Mix, that we have concluded as a result so far and suggestion and comment can be made from all stakeholders in this regard. After having this result, we have tried to identify the supply side that how we meet the energy demand by supply side like supply oil coal, gas, electricity, renewable energies like nuclear, solar, hydrogen etc. we have also tried to identify the economic impact of that supply demand. Beside of these demand and supply issues we will also conduct three other issues like data management issues, as Bangladesh has this system and we will analyze the system's potentiality to be improved and implement in an integrated manner. The second issue is the legal framework of LNG import and supply system of this country as there is an increasing demand of LNG importing and we will

analyze the potential improvement area of the LNG legal framework of this country. The last and crucial important part is Strategic Environmental Assessment of the power and energy development of this country and ow the development would be under the conservation of natural environment. We will combine all of these issues in the draft master plan and will discuss in another stakeholder meeting by this year hopefully. We are welcoming comments and suggestion regarding all of these issues to be incorporated in the draft master plan and let us know your suggestions.

Presentation-1: Primary Energy and Power Demand Forecast by Mr. Ryohei Ikarii, JICA Study Team

He made his gratitude to all and said good afternoon to all. In the first SHM we have discussed about the methodologies of the demand forecast and following the methodologies we have derived tentative result by scenarios. In this today's 2nd SHM, we would like to ask you to consider which scenario is better for Bangladesh. In addition, the result is not the draft or the final one, rather we would say it is an interim report. Today we will discuss more on the energy supply and the power plant supply. Primary energy supply is estimated by aggregating fuel inputs to the power generation and non-electricity demand in FEC, and CO2 emissions are calculated by fossil fuel supplies in the total primary energy supply (TPES), as he said. Three scenarios are Reference Scenario (REF), Advanced Technology Scenario (ATS) and the Net Zero Scenario (NZS-2050), he added then. REF scenario is based on the past trend on the energy and power consumption and demand. ATS has been considered only for the extent of the energy and power sector with introduction of advanced technologies over the existing policies and environment. The NZS-2050 is the only back casting approach to achieve NZS by 2050. Technologies to reduce greenhouse gas emissions to net zero in 2050. Then, timing and amount of introduction of each technology are assumed by a back casting approach in the NZS-2050 scenario.

We would like to give the brief of the methodologies of the economic model for the demand forecasting, he said. Conduct regression analyses and obtain demand functions for electricity/non-electricity (gas, oil, coal, etc.) demands by sector, in relations to GDP, energy prices and other relevant factors applying historical data, mainly of IEA on energy, added. We have considered the external assumptions/projections for future GDP, energy price scenarios and other factors. We have been tried to estimate the future demand for the total primary energy supply (TPES) aggregating the non-electricity final energy consumption (FEC) by sector and the energy inputs for electricity supply in the power sectors. Each scenario has three GDP cases- GDP Growth, GDP Composition and GDP Growth Rate. NZS and ATS scenario have also considered the energy conservation and electrification in each sector assuming technology settings.

Further, we have considered simulation model along with the integration processes of different models, on demand and supply operation to optimize operation patterns of power plants by using daily load curve, various generator data such as heat rate, capital and fuel cost scenarios by source (gas, oil, coal, renewables, etc.) to accommodate the electricity demand estimated by the econometric model. In ATS, the international oil price is expected to rise from 2020 to 2030 backed by the sustained demand recovery from COVID-19, assuming International Energy Price. While the international natural gas price rose in 2021, ATS assumes that the price will decline toward 2050 since developed countries will reduce fossil fuel consumption, and their natural gas demands will decline, he added at this stage with showing graphs from the lecture slide. In the technology settings (demand side) slide he said, the net emission will be reduced to 43.2% in 2050 from the REF level, where the reference level has been considered the world average and the historical experiences of other Asian countries. In the ATS, industrial energy consumption will be reduced to 24.5% in 2050 from the REF level. In the Road, Residential, Commercial sectors energy consumption will also be reduced as shown in the graph and 100% electrification will be achieved in the commercial sectors by implementing NZS scenario.

In the technology settings from the supply side, he exhibits the power sector's flourishment under different scenarios of NZS, ATS and REF. Renewable energy sectors will introduce Solar PV (Solar Park, Irrigation, rooftop), Offshore wind etc., he said. He is assuming 50% ammonia co-firing around 2030 and 100% ammonia single-firing around 2042, even though the capacities will be the low, under the NZS and ATS scenario. 100% hydrogen single-firing will start around 2035 and replace 80% of gas-fired power through 2050, under the NZS and 100% hydrogen single-firing will start around 2035 and replace 20% of gas-fired power through 2050, under the ATS scenario.

Next, he explained the different renewable energy demand and introduction capacities for 2050. The expected demand for solar park, roof top solar, on-shore and off-shore wind energy will be 6GW in ATS and 16 GW in NZS, 12GW in ATS/NZS, 5GW in ATS/NZS and 15GW in ATS and 50GW in NZS respectively, which can be expressed as a tentative outcome of the interim report. Coal-fired power with ammonia co-firing is proposed to start from 2030 only for a few power plants. Hydrogen single-fired power is proposed to start from 2035, he said. Hydrogen incl. ammonia for ATS PP2041 will be 3 MT – H2 in 2050, which is the Japan's target to procure in 2030.

Estimated total final energy consumption (FEC) will be in the order of REF > ATS > NZS, he said to explain the final energy consumption by sectors with graphical plots. Industrial sector will be largest demand sector for all scenarios in both 2041 and 2050, followed by the residential and the road sectors.

The volume of power generation differs because of different price effect, energy conservation effect and electrification effect while income effect is common in the three scenarios, he said in the power generation slide. Natural gas will be the largest source of energy as of 2050 for REF and ATS. Although potentials of cleaner energy such as renewables are limited, increases are expected in offshore wind, nuclear, and solar PV. In NZS, hydrogen will be the largest energy source as of 2050 to realize net-zero emissions.

We compared the power generation with the past MPs. Power generation for REF and ATS with GDP PP2041 Case is close to that for Base Case of the Revisiting PSMP 2016. Power generation for NZS with PP2041 Case exceeds that for BAU of Revisiting PSMP 2016, he explained. Demand size of ATS and NZS will be smaller than that of REF because more intensive energy conservation is assumed and adoption of advanced energy technologies will raise the end-use energy cost (and dent demand), he remarked. In REF and ATS, oil will grow to be the second largest energy source because of its demand growth in the road, the residential (LPG is for mainly residential sectors) and the other transport sectors and so on.

Natural gas has the least environmental impact among fossil fuels. No significant differences among the three scenarios through 2035. Demand for ATS PP2041 will be close to Low Case of GSMP2017, while the demand for REF PP2041 will be close to Mid Case of GSMP2017. Then he explained the Energy Saving Index which is Primary Energy Supply divided by the GDP as shown in his figure in the slide.

CO_2 emissions from energy consumption as of 2050 will be in the order of REF > ATS > NZS reflecting the differed volume of fossil fuel use. In REF, the emissions will be more than 500 million tons as of 2050.

To mention the Decarbonization Index which is estimated by the CO2 emissions divided by the primary energy supply, as showed in his slide.

Lastly, he would like to mention the scenario Evaluation (tentative). In terms of environmental sustainability, REF is fair, ATS is good and NZS is excellent. JICA Study Team thus recommends the Bangladesh government to have ATS scenario as the main scenario, he remarked and finished his presentation.

Presentation-2: Scoping Strategic Environmental Assessment by Mr. Seiichi Sasaki, JICA Study Team

Mr. Sasaki presented the scoping of Strategic Environmental Assessment for the IPEMP based on the Advanced Technology Scenario recommended by the JICA technical team for Bangladesh to consider the realistic long-term energy policy. In view of SEA objective, IPEMP works toward

Year 2050 that is the period of transition for Bangladesh to become Decarbonization ready" country for eventual achievement of carbon neutrality. He discussed the current challenges and opportunities which Bangladesh may overcome technical and institutional gaps by 2050, including the new RE laws, regulations, EHS guidelines to ensure the project sustainability in the future. He also presented potential environmental and social impacts associated with the energy infrastructure project such as gas-, oil-fired, LNG, distribution, and transmission., focusing on impacts on climate change, air and water pollutions, waste management as well as land requisition which may cause involuntary resettlement. JICA study team will present mitigation measures at the next stakeholder meeting, proposing risk reduction measures identified during the scoping stage.

Presentation-3: Analysis of LNG Legal Framework by Mr. Toshiyuki Yoshida, JICA Study Team

We will discuss about the Natural Gas, liquefied natural gas (LNG) in Bangladesh, Introduction of Federal Energy Regulatory Commission (FERC) and its Practice, Sharing Knowledge and Experience of LNG in Japan, Introduction of Good Practice, legal and procuring issues in LNG and way forward.

Natural gas has contributed to economic development of Bangladesh as the major energy supply source since it gained independence. Bangladesh has already developed nation-wide pipeline network and natural gas utilization infrastructure such as gas-fired power plants. But Bangladesh has been facing declining domestic gas production. Imported LNG needs to be utilized effectively as an alternative source of gas, he said. Natural gas and LNG continue to play a critical role in the transition toward net zero emission as the least carbon intensive fossil fuel.

BERC (Bangladesh Energy Regulatory Commission) roles are critical in regulating LNG import and gas distributions to support investment by industry participants including foreign investors. Investors need to see reasonable and predictable energy regulations in making investment and conduct business in Bangladesh.

FERC in the US is a good model for BERC in administering energy regulations in Bangladesh, and FERC has a long history broader range of LNG and gas regulatory frameworks that can be good for Bangladesh administrative knowledge enhancement.

In the next slide he compared the BERC and FERC in the table and showed relevant chapters and subchapters of BERC in comparison to FERC.

Then he explained the mission and visionary difference between BERC and FERC, showing in a comparison table. Among which the most important point is the second one, (in the right-hand side of the table) the due process and transparency which says the paramount in all of its proceedings are the commission's determination to be open and fair to all participants. On the BERC side it is transparency in energy sector management, cost rationalization & tariff determination. He was also mentioned the Timeliness as another important things have been practicing by the FERC as their business is moving quickly and dramatically, in comparison BERC may take time to make decisions and needs to overcome here.

Then he mentioned the FERC regulations regarding natural gas and the procedures for approving the LNG or natural gas exporting or importing. FERC make ensures the environmental, water resources, socio-economics and other impacting factors to be considered in the approval processes, he explained. There is a separate agency who govern the pipeline regulations that monitored the terminal and transmission processes and approval of pipeline networks.

For operational, legal and commercial issues in LNG import and gas distributions – buyers in Japan sharing knowledge and experience of LNG. Safety which is important to BERC, should comprise Reliability, Availability and Flexibility; and under Operational and commercial issues should be considered like competitive LNG procurement and efficient and optimized LNG terminal operations.

Sharing Comments from Focus Group Discussion with CSO, Academia and Development partners

Sharing comments from the Utilities

Open Discussion

SL. No	Name	Designation/ Organization	Question/Comment
1.	Mr. Sharif Jamil	General Secretary, Bangladesh Poribesh Andolon (BAPA)	Mr. Sharif Jamil addressed concerns about energy security by importing the fuels. Questions was how much import the Bangladesh government could tolerate? He also asked about how much is suitable for a nation? He also addressed concerns about mercury pollution, and PM 2.5 model prepared by the Matarbari phase-1 project. Lastly, the opportunity for Bangladesh to generate renewable energy sources are not fully sought.

SL. No	Name	Designation/ Organization	Question/Comment
			We found that this policy is threatening the energy sovereignty and security of the nation in long term by importing the fossil fuel, not only that, it is also blocking the enormous potentiality we have as an untamed energy mind in Bangladesh to produce our energy security or ensure our energy potential to produce renewable energy, so it is blocking our potentiality.
2.	Mr. Golam Rabbani	Joint Secretary (BPMI- Member Directing Stuff)	Mr. Golam Rabbani said that the same energy modeling was used for this project as the previous PSMP. So, all energy modeling is not sufficiently matched with all countries. He was also interested in how much deviation between the projected and actual demand is observed in the previous PSMP.
3.	Mr. Alauddin	Ex. Chairman, SREDA	Mr. Alauddin said about Offshore wind-NZS Scenario. He pointed out that how the project team come up with 50 GW offshore wind potential. He also pointed out about the National Solar energy roadmap, which is not an approved document. It is fair to say that it is a draft version report while it is not even a draft. An anonymous speaker dispatched it. Finally, he said about solar park & solar irrigation. it struggles to find a viable business model even with even 50% grants. So, this question needs to be sorted out as to how well JICA arrived at this figure.
4.	Dr. Moazzem Hossain	Center for Policy Dialogue (CPD)	Dr. Moazzem Hossain mentioned four specific questions. These are given below: His 1st question was about the demand projection. He stated that govt has politically targeted to reach the middle-income country by 2041 means 12000+ USD per capita income. But he thinks most importantly, it is essential to target more of a short-term target like a higher middle-income country nearer to 2031. Where we are like to give importance, here is to not very far targeting issues but rather more of a near targeting issues near 2031. The immediate target is to reach the 4500 USD per capita income so that that could be better projected, analyzed, and targeted from an energy point of view. Otherwise, we often see the vested group has used long-term projections to invest more now

SL. No	Name	Designation/ Organization	Question/Comment
			that kinds of reserve capacity have no value. Now we are struggling, having a vast reserve capacity, but we couldn't use it much thought it could have a future value. So, it's better to target a near and achievable target and thereby project accordingly instead of targeting 2050. His 2nd question was about the assumption taken. We have repeatedly mentioned that there should be an additional deduction of 40% of RE by 2041, as PM announced in the last 26th COP meeting. He thinks this is an important assumption that should be built into this model and try to see what sorts of changes need to be taken to achieve this target. Unfortunately, this request is not yet duly accounted for and not accepted; rather net-zero emission target is there. His 3rd question was about the price assumption. Their price assumption is considered very simplistic in that LNG price, and others will be balanced in the coming year, and the model has been considered. Another variant should be regarded as price volatility issues instead of normalization issues. So, the higher price of LNG and petroleum in the future market will give a newer version, newer target, and newer challenges in this demand model. The advanced technology model seems to be based on a gas-based technology model. However, in the discussion, LNG was not mentioned; instead, it focused more on gas-based technologies. And those technologies don't yet apply globally, regularly, and commercially. So, I request to take into account the more proven technologies of clean energy on renewable technologies of RE and thereby try to see an overall technological model of 40 percent of RE by 2041. His 4th point was about the coordination with ministries. We see here in Bangladesh that one ministry disregards the policies and documents of other ministries and departments. We appreciated, and so far, this body is appreciated the RE draft policy. Now we are seeing that it is indicated that this policy is not acceptable to other ministries. How is it possible that one ministry is disregarding the

SL. No	Name	Designation/ Organization	Question/Comment
			policy of others? Even we see a tendency to show that Mujib Climate Prosperity Plan will not be accepted. We should coordinate with the other ministries and understand two important policies: the Mujib Climate Prosperity Plan and the renewable energy-related draft plan, before finalizing the IEPMP.
5.	Ms. Chiara Vidussi	Program Manager (European Union Delegation to Bangladesh)	Ms. Vidussi would like to know about the extent of the application of energy storage technologies. This has been considered regarding grid integration of renewable energy and support to one scenario services like voltage support, frequency control, and failure of distribution and transmission appliances.
6.	Mr. Bikash Dewan	Managing Director DPDC	Mr. Bikash Dewan said he had gone through the JICA study report and found that JICA has considered the cross load for the total area (Viz-Dhaka Zone). Mr. Dewan suggested that, as the Dhaka zone is comprised of DPDC, DESCO, and REB, so to forecast the exact cross load for the Dhaka zone JICA team should collect all the data from each one. Mr. Dewan also added endeavors, and the ATS case proposed that they will generate 60 MW from rooftop solar within 2050. He thinks it is optimistic and wants to know how they will incorporate their strategies should be clear and suggested following the national building code. Mr. Dewan also found a short description regarding electricity tariff and long-term financial outlook, which was not mentioned. He requested to mention the financial aspects.
7.	Mr. Md. Zakir Hossain Khan	Chief Executive-Change Initiative	According to Mr. Jakir Hossain, all the demand projections are GDP based. He requested to consider another environment, disaster shock, and the pandemic situation when the demand site has started falling. He also suggested considering the affordability of the low-income group as some of the group may hamper. So, in that case, what will be the alternative demand scenario Mr. Hossain wants to bring into the overall estimation. Mr. Hossain added that in terms of pricing the energy or feasibility of any new technology option, JICA should consider the economic cost of environmental or other hazards that were frequently ignored. He also said the price of fossil fuel is lower in terms of

SL. No	Name	Designation/ Organization	Question/Comment
			financial cost, which is too expensive in terms of economic costs. He requested to explore the demand in the different policy mixes regarding the renewable option. Whether the same policy discrimination has been equally applied to the renewable investors and other investors should be considered. Mr. Hossain said that environmental enforcement is significant for energy investment or energy production generation, and this should be kept in mind when we propose any policy option. Finally, he said that Japan had stopped finance on fossil fuels; he thought the same principle should be followed for the country like Bangladesh and other LDCs as it has a detrimental impact on the Environment.
8.	Mr. Md. Mahbubur Rahman	Chairman-BPDB	During the industrialization process, Bangladesh's daily load carp pattern will ship from evening Pick to day pick in the future; as per Mr. Rahman, it should be specified with proper justification from which year the carp transition may ship towards the peak time. Mr. Rahman said that, as mentioned by the JICA, 50% ammonia mixing with the coal by the year 2030 and 100% ammonia firing after 2040, so in this case, his suggestion is to start the process of integrating the ammonia combinedly. Regarding 50% firing, we need to initiate the process from now; it would be challenging considering the practical situation, so JICA needs to review the issues. Among the new technologies viz- Hydrogen, ammonia co-firing, carbon capture, and storage system, which are considered for future power generation, Mr. Rahman suggested that the overall technological and commercial aspects of the international market regarding the new technologies shall be justified. Currently, the grid-based generation of Bangladesh is near about 80 PWS, but in the report, JICA assessed that by the year 2030, it would be 222 PWS, and, it will be 696 PWS by the year 2050. Mr. Rahman thinks it is too high and needs proper review.
9.	Mr. Anwar Hossain	Life and Nature Safeguard	Mr. Anwar Hossain talked about the following two points: First, he said that no national experts were involved in this project.

SL. No	Name	Designation/ Organization	Question/Comment
		Platform (LNSP)	Finally, he questioned whether that Nuclear power is considered clean energy or not. Water contamination will be addressed. But it was not quantified. So, water and soil pollution trends should be addressed. Otherwise, our nation will be affected by different types of pollution.

Closing Remark

Special Guest Speech by H.E. Mr. Ito Naoki, Ambassador of Japan to Bangladesh

Firstly, he thanked the chief guest and distinguished guests. He appreciates the series of meeting arrangements to get ideas concerning the environmental and other concerns. This master plan will play an essential role in addressing climate change, low carbon energy, and decarbonized energy supplied. He found today's discussion very stimulating, constructive and exciting. This IEPMP goes beyond different stakeholders to be involved in this study, and they can make it a successful master plan. We need to promote dialogue to make clean and sustainable power and energy plans. He pointed that, Transparency International, Bangladesh (TIB) made a report that may came out this year. Japan works in Bangladesh as a dumping site of obsolete technologies, he would say this has not been found to be practical and suggests TIB come up with some evidence while publishing this kind of report.

The Matarbari USC coal-fired plant by JICA is designed with the latest technology and making less emission to the environment. The second phase of Matarbari 3rd and 4th unit will not be assisted by JICA after the consultation with government and JICA. He believes that, this IEPMP will be more meaningful and go forward to achieve sustainable development. Thank you all.

Chief Guest Speech by Dr. Tawfiq-e-Elahi Chowdhury, BB, Honorable Adviser to Prime Minister for Power, Energy and Mineral Resources Affairs

At the beginning, Dr. Tawfiq-e-Elahi Chowdhury made his sincere gratitude to all stakeholders present in the meeting on 3rd July, 2022. In his introduction, he wants to point out some technical issues, but he didn't have the answers of them, he remarked as well.

Firstly, he mentioned that, COP-26 had lots of aspiration and agendas, but they have gone out with the window, he asked "why?" at the same time. Then he continuing his speech saying that he is going to clarify it. Listening to his explanation, we found that, when in contact with reality, both the ambitions and reality, contrast each other. After that, to be more precise he said, the IEPMP planning has been done more in terms of quantity, like how much power we need, what

kind of energy we need and what kind of hybrid energy we need, but prices are so atrocious that, the quantity planning would go down the range. He insists on looking at the case of the Europe now. After the commitments of the COP-26, there is a huge hike in price, a war in Europe and lo and behold, Europe is going to start their old coal-fired power plants. He compliments this statement with an example like, you give a prescription to whatever suits you (a Bengali proverb).

Dr. Tawfiq-e-Elahi Chowdhury, then urged that, when Europe is going back to coal fired power plants, when we have invested a lot of money on our coal-fired power plants in Matarbari 1320MW Ultra Super Critical (USC) coal-fired power plant the state of the art, to be abated by the developing country like Bangladesh, how do we deal with these two decisions or it is contradictory, he said. He tried to pay his kind attention to his excellency of Japan ambassador to Bangladesh and the study team, to get rid of this Net Zero Emission (NZE 2050) scenario from the study, as Bangladesh gas a very small carbon footprint in the ocean of global emission, say we are making carbon pollution less than a metric ton per annum, whereas Europe or other developed countries produces 10-20 metric tons per annum. He then expressed that, our Honorable Prime Minister being a visionary, to lead Bangladesh become a middle-income country by 2030 and a developed country by 2041. But this will not be happened in that way unless we don't use the facility of the mixed power generation systems, he contends. In addition, this will help us to fight against other wars like poverty, deprivation and the challenges in terms of prosperity which the Government of Bangladesh is planning.

This net zero emission is required for western countries who made the promises in subsequent COPs and, some assumptions which are applicable for other countries but may not be applicable for Bangladesh. According to his statement, he requested to JICA and others involved in this study, to drop-off this net zero emission by 2050 (NZS 2050) concept from IEPMP, as this goal is not aligned with our goals.

Secondly, he tried to point out the renewable energy concept should not be mixed with the clean energy, because it is not about the technology, we should use rather the uses of carbon emission reduction process with the technology, which we have been seeking for like nuclear power energy. Nuclear power energy is a significant part of the clean energy and produces a vast amount of power rather than other renewable energy like solar energy which is also a part of the clean energy, he implied. Some other clean energy will be pop-up to Bangladesh in very near future, as there are some examples of other countries like Australia, Japan and Saudi Arabia might already have been started to be used with the green hydrogen power, he signifies to his excellency Mr. Ito Naoki, Ambassador of Japan to Bangladesh and others about this matter.

Some other options of zero emission technology can be adopted in the small town and rural

area of Bangladesh, as some day mode of life might be changed, he gave a deep thought to audience by this statement. Battery operated tri-wheeler may have a better option in rural areas and towns, as they serve in terms of mode of transportation of goods and communications. He requested the power and energy research council of Bangladesh to innovate a design that permits rural and remote town areas to get less power with efficient electric transportation, also he argued to SREDA authority to innovate the facility of fast charging stations for that transport media, consequently which will bring revolution in transportation system of Bangladesh lead to a role model in the world.

The next thing he wanted to make as a suggestion is that the study should go for some stress-test on power and energy sectors in Bangladesh. The stress-test is likely stressing our economy, considering how much hiked-price we can afford, and if we are not able to afford that high price, then how should we allocate our energy so that we can maintain momentum on economy and some equity in society at the same time. He also admitted that, he has no answer for this question, but takes this scenario from the Ukraine war as an eye opener and it allows him to rethink this stress-test concept and requested to study team to give it a deep thought. Even Europe and other fast rate minds were not prepared with this wild card to deal with the energy market. He came up with some suggestions like, the introduction of smart grid and smart power systems which will be much more efficient to allocate the ration efficiently with a minimal resource in such a stress condition. The other thing he wanted to address was that, do not go with the draft report to make other bodies deem it a decided thing, unless the government approves it.

The third point he wanted to figure out over the meeting was that, to examine the power and energy system of Bangladesh, we should start looking at the whole supply chain of the systems. In a sector of agriculture, water, and fertilizer, transportation are parts of the agriculture system that requires energy consumption for its production, so if we make efficient reduction mechanism for the demands of inputs that will make the energy saving system of the country and the environment as well, he explained as an example of his supply chain concept. Again, he also insists on energy efficient power and food storage system development and improvement, structural design with an energy saving concept to utilize the minimal resources of the world and make the supply chain system alive and efficient.

The last point he would like to discuss is energy efficiency. He suggested taking some integrated approach that could include all types of consumer levels to reduce the consumption and power waste activity. The study should also incorporate the significant part of respective authority to promote the energy responsibility, like SREDA has been trying to do this. One last issue he wanted to discuss in addition to today's discussion was that, confusion on the excess capacity of power systems. Our power generation system is built on what is called peak chasing,

he mentioned. For example, in summer our country has peak demand for irrigation and at the same time peak demand for Ramadan (Muslim's fasting month) activity, and there is a very short period between these two high peaks. So, if we average the peak demand in that case, it will be meaningless, as the average made the peak values being outliers, but we must meet the all-peak demands. Beside this, when we do not have that peak in some season, the capacity would be idle, as everyone think like so. But the other countryside has vast industrial and economic activities and the next flourish years will also made Bangladesh more economic activities, so that means no plant will be sit for idle, he implied strongly. But on the contrary, we are trying to curb our demand curve, especially in daytime by adopting electric facility in the household works like cooking, solar irrigation and charging station using our own grid system and consequently flatten the demand curve in daytime, he argued and suggested study team to consider all of those things in an efficient way to make it a successful and remarkable integrated energy and power master plan for Bangladesh context. He remarked lastly.

Thank you very much. "Joy Bangla".

Closing Remark by Mr. Md. Mahbub Hossain, Senior Secretary, Energy & Mineral Resources Division

He first shared his sincere gratitude. He mentioned that this IEPMP study will formulate and secure the country's energy demand. We have taken several mega projects in power and energy sectors, like several big power plants, nuclear power, ultra-super critical coal fired power plant and LNG terminals, etc. Our primary focus on to formulate a long-term master plan to meet the demand towards achieving a developed country by 2041. Imported items market should be as low as possible, he said. To ensure the uninterrupted supply of power and energy, we have to explore our own resources. We are working with international environmental and climate treaties like Paris agreement and others COPs to reach a low carbon emission. We should not dependent only on the natural gas and fuels, we have to make diversified energy portfolio and other options of renewable and clean energies like hydrogen power, and energy efficiency all are to be addressed in the master plan. Moreover, time bound monitoring and action plan should be incorporate in the master plan. Indigenous resource mapping and research on energy and power is needed to secure at an international level energy security. Finally, I would like to thank the Government of Japan and JICA to formulate this master plan for Bangladesh.

B2. Minutes of Meetings for the SEA Meeting (Third Stakeholder Meeting)

Minutes of the Third Stakeholder Meeting on Integrated Energy and Power Master Plan (IEPMP) for Bangladesh

Date: December 13, 2022

Location: Hotel Intercontinental, Dhaka

Starting Time: 2:00 PM

End Time: 6:00 PM

Participants: See the appendix section for the participant list

Objectives of the Meeting

The Ministry of Power, Energy and Mineral Resources and JICA Study Team organized the 3rd Stakeholder meeting on December 13, 2022 to disseminate the draft final report of the Integrated Energy and Power Master Plan (IEPMP).

Number of Participants: Total participants (Physical & On-line): 267

Physical- 222

Online- 45

Opening of the meeting

The meeting started at 2:00 pm after the lunch session and was moderated by AKM Mohammad Shamsul Ahsan, Joint Secretary of Power Division.

Presentation-1: Primary Energy and Power Demand Forecast by Mr. Ichiro Kutani, JICA Study Team

He presented the primary demand forecast model, its econometric foundation, its components, the relationship between GDP and energy demand, and the consumption of energy by various sectors, including the industrial, transportation, building, and agricultural sectors.

Presentation-2: Power system plan by Various Speakers, JICA Study Team

This session included various presentations related to power systems, including gas turbine combined cycle system configuration, a Proposal to introduce NH3 co-firing and clean energy.

- Renewable energy sources; solar park, rooftop solar PV, wind power, biomass, and candidate sites, etc.

- Planning of electricity transmission in Bangladesh, outlining (1) potential expansion of the power transmission system; (2) increased electricity flow from the south to the north, (3) increased supply network reliability to Dhaka, and (4) international connections with Nepal and Bhutan.
- Planning of power development, outlining (1) optimizing electricity demand, (2) targeting reserve capacity rate, and (3) introduction of timing of decarbonization technologies, clean energy ratio, etc.
- Planning of distribution system in Bangladesh, outlining distribution facility planning. Enhancing reliability, improving operation and maintenance efficiency, and addressing the entrance of renewable energy into the power system. Voltage fluctuation is a long-term challenge to balance the constant energy supply and its configuration of the distribution system is a key to improve its efficiency and operational optimization.

Presentation-3: Primary energy supply by Mr. Yoshikazu Kobayashi, JICA Study Team

Outlook of domestic natural gas production by 2041 was presented, recommending that Bangladesh seeks new sources (onshore and offshore) but the offshore potential needs to be tapped. LNG import will be expected to increase but additional pipeline and updating network connecting to Dhaka and terminals will be also needed. He pointed out policy recommendations introducing business plan/model to tap the new domestic natural gas resources, highlighting creation of two loop pipeline systems. In addition, a proper plan for petroleum supply capacity, including refining, product import, and pipeline should be developed in view of long-term investment.

Presentation-4: Energy efficiency policy by Ms. Miki Yanagi and Ms. Songhee Kim

Two presenters proposed recommendations on improving energy efficiency and conservation measures, highlighting implementation of EECMP2016, and EEC policies toward 2050. To improve energy efficiency, Bangladesh needs to work with industry associations to collect sound reports of energy consumption and digitize the cross sector information, as well as provision of necessary capacity budding on maintenance of energy supplies, and mobilize the finance enabling to invest in high efficiency equipment.

Presentation-5: Analysis of LNG Legal Framework by Mr. Toshi Yoshida, JICA Study Team

For legally facilitating the LNG import, Bangladesh needs to invest in developing the energy regulations making sound investment come and conduct business in the country. It is critical that

Bangladesh improves operational, legal and commercial capabilities through easing the LNG tender procedure, purchase contract and negotiation process. Recommendations includes that Bangladesh studies long lasting legal, administrative and commercial systems, training of BERC staff regarding FERC operations in the US, and enhancing collaboration with Japanese LNG buyers.

Presentation-6: Strategic Environmental Assessment by Mr. Seiichi Sasaki, JICA Study Team

Strategic Environmental Assessment was conducted in accordance with the JICA guidelines, and three stakeholder meetings were held since 2022, with a total of over 600 participants taking part in this consultation meeting. Alternative considerations of the three scenarios were examined in view of economic, environmental, and social and energy security. Based on the proposed diversification of energy mix, potential environmental and social impacts are predicted and industry specific mitigation measures were introduced such that any future investment and infrastructure development projects take into account the measures and environmental and social management plans in accordance with the international practices. Recommendations includes that economic instrument facilitating the clean energy transition in Bangladesh as well as development of the guidelines for environmental, social and health measures tailored to solar, wind, biomass, hydrogen and ammonia co-firing applications.

Discussion session

After completion of all the presentations, the floor was open for discussion or comments from the guests and participants. The following table shows the discussions or comments from the participants.

S/L	Name	Designation Organization	Question/Comment
1.	Sadrul Hasan	Journalist	Mr. Sadrul Hasan said that he had been following the power and energy sector for more than 25 years. He appreciated all the presentations. He mentioned that the Project team have set a target to generate 40% of electricity from the source of clean energy which our honorable advisor mentioned but how could you achieve fulfill this 40% of electricity? Especially, considering the current capacity of renewable energy limited by 1%, how Bangladesh can achieve 10% by 2030 as it sounds too ambitious target. Response: Yes, as for the achievement so far is smaller than expected. However, if this country can implement appropriate systems to

S/L	Name	Designation Organization	Question/Comment
			support the development of renewable energy. Bangladesh Government and JICA think of the target and set the goals to achieve the target. Responded by: Mr. Ichiro Kutani
2.	Yeamin Sazid	Business Standard	He said that he had two questions. One was that in the winter season our demand remarkably falls down but at that time there was a huge demand for electricity in the northern part of India. So, was there any plan to export or exchange electricity in the northern part of India? Another question is the renewable energy is more costly compared to the neighboring country India. On the other hand, if you compared the cost of thermal power energy, it is lower in India. So why don't you recommend importing Thermal energy from India and also why discouraging this? Response: This masterplan is the power development plan which recommends what kind for of power mix can be developed in the future, emphasizing that this master plan is not the end, but this is the start of the development of energy systems. Responded by: Mr. Ichiro Kutani
3.	Mohamad Muktaruzzaman	CEGIS	He said that Bangladesh is a low-lying land and most of the people depend on agricultural land. The solar power plant is the best way to the renewable energy sector. But to establish the solar plan, there was a need for huge land. So, he asked that are there any locations to establish solar power plants. Response: He ensured that the JICA team also acknowledged the agricultural land. They do not hamper food security. They choose the place which is unfertile and char land. Responded by: Mr. Ichiro Kutani
4.	Abul Fathe Mohammad Shafiqul Islam	Deputy Secretary & Council Officer, Coordination-1, Power Division	He said that he would know about the carbon-capturing system in our power sector in the near future. Response: Yes. He said that they would think about the carbon capturing system in the power development sector. Responded by: Mr. Ichiro Kutani

Speech by H.E. Mr. Ito Naoki, Ambassador of Japan to Bangladesh

His Excellency, Mr. Ito Naoki, the Japanese Ambassador to Bangladesh delivered his welcome speech. The ambassador addressed the guests and thanked the Energy and Power divisions for their efforts. He emphasized Bangladesh and Japan's long-standing friendship by informing them about an agreement signed by the two countries. This contributes to COVID-19 crisis response and resident health system realization, as well as the acceleration of economic growth through the development of core infrastructure, which is to support two ongoing projects: Metro Rail Transport line 1 and the Matarbari power plant. He is excited to expanding such cooperation between the two countries as they celebrate their 50th year of friendship in 2022.

He stated that this master plan will be critical for the country because it will need to multitask and adapt to changing realities as the country changes in the future and has praised Bangladesh for its efforts to address disaster management and climate change issues through NDCs despite the need for the development. Given the current scenario of Bangladesh's growth and the requirement to decarbonize society, the master plan for the energy and power sector needs to be revised as required. He expressed his hope that Bangladesh would have a long-term sustainable integrated energy and power master plan thanks to the support of Japan's expertise and the cooperation between the two nations.

Speech by Chief Guest Dr. Tawfiq-e-Elahi Chowdhury (BB), Advisor to the Prime Minister

The Chief guest Mr. Tawfiq-e-Elahi Chowdhury (Bir Bikram) started with appreciating the chair by Mr. Nasrul Hamid, the State Minister, his excellency Mr. Ito Naoki Ambassador of Japan, the JICA chief representative, and others.

He mentioned that he had a discussion with the team and made some elaborate points. In response to some coal-related reports, Bangladesh currently has no choice but to phase out coal. He emphasized the employment of best technologies in coal-based power plants to reduce environmental pollution, focusing on reduction of Nox and Sox emissions with the usage of cutting-edge technology. The most recent technology was used as an example, the Matarbari power plant. He also mentioned talking points shared by the ambassador of Japan about the Carbon Capture and Storage where the coal-based plants can take the carbon underground. He would like to study such environmental technologies and invited the organizations such as the energy research council, SREDA to learn about the technological advancement that will take place in the future and find out those which we can use in short- and medium-term planning.

He mentioned changing one's behavior as an idea. Most of the world is preoccupied with issues unrelated to changing behavior. He notes that this idea is not typically taken into account. Dr. Elahi promotes these types of behaviors and uses our honorable Prime Minister as an example. Our honorable Prime Minister always turns off the lights when leaving a room, which is a practice of optimal resource use. This type of behavioral modification is crucial and has the ability to benefit much by focusing behavior from industries like energy and food that have a problem with wastage. The short-term impact of the behavioral adjustment will be profound. He finished off his speech by thanking everyone present and also welcomes to discuss anything with him if anybody wants.

Speech by the Chairperson, Mr. Nasrul Hamid MP, State Minister, Ministry of Power, Energy and Mineral Resources

He first expressed his gratitude to the JICA and the institution and companies working in collaboration with the Ministry of Power, Energy and Mineral Resources, Ambassador of Japan to Bangladesh, power secretaries, additional secretaries and to the audience. The Master plan has turned out to be a beautiful done, but constantly needs to be evolved as we live in fast changing the world. We have built some coal-based power plants and taken the finest technology in these and also need to deliver power and energy with the affordable tariff for our consumers. That is one of the big challenged which we now face. Of course, we need clean energy and the best Carbon Emission Technology we must find out. Technology is changing rapidly so what we need is not to develop a plan but also can make a vision of the plan. First, demand for more affordable power and energy needs very proper baseload immediately. Secondly, reliable electricity, renewable energy, which must be also affordable. Thirdly, to balance the stable energy supply, we need consistent power from the surrounding countries as the master plan suggested, importing energy and power supply from the neighboring countries. For the future development of Bangladesh's industries, we need steady power and strive to source the required power from renewable sources as much as possible. He wished Bangladesh the best of luck in the future as he concluded his remarks.

Attended Participants in the 3rd Stakeholder Meeting:

Items		Number of Participants
Power Division (PD)	:	90
Energy and Mineral Resource Department (EMRD)	:	47
Civil Society Organizations (CSO)	:	12
Academia	:	07
Japan International Cooperation Agency (JICA)	:	10
IEEJ	:	10
European Union	:	04
World Bank	:	04
News and Telemedia	:	29
Others	:	02

B3. Result of a Call for Opinions

■Procedure

Subjected report: Draft Master Plan Report Ver.4 including Appendix

Reviewer: Academia (AC), Civil Society Organization (CSO), and Development Partner (DP) from those who were invited to past 3 stakeholder meetings.

Period: form 24 January 2023 to 5 February 2023

Method: Simultaneous send-out by e-mail. Individual responses received.

■Major comments and responses

	#	Opinion received	Response
Demand outlook / Energy efficiency	1	PP2041 GDP case seems too ambitious thus resulted energy demand may be too large. (CSO)	Discussion with the GoB defined central GDP case. Analyzed In-between GDP case as lower deviation.
	2	Appreciate analyze energy efficiency of transport and agriculture sector. Suggest deepening their analyses. (CSO)	Recommending enhancement of data survey system as the said analysis require detailed data.
	3	Suggest deepening analysis of energy efficiency in residential and commercial sectors. (DP)	Recommending enhancement of data survey system as the said analysis require detailed data.
Power system	1	Only renewable energy shall be defined as clean energy since hydrogen or ammonia are expensive. (CSO)	Discussions with the GoB defined clean energy.
	2	Suggest stating that "clean energy" has been re-defined by the GoB. (DP)	The MP described the definition of clean energy.
	3	Wind power has not been fully investigated to date, thus development potential is uncertain. Meanwhile, solar power has potential for irrigation pumps and other applications. (DP)	The MP recommends formulating a roadmap to materialize the development of clean energy, including wind and solar.
	4	Seems the prospect for solar PV is conservative. On the other hand,	Discussion with the GoB defined prospect of solar PV development.

		additional study may be needed in the future to determine the potential of wind power. (DP)	Agree to necessity of additional study on wind potential.
	5	Suggest consider establishing supply priorities according to customer segments and using automation technology to increase supply reliability. (AC)	The issue may be discussed in another project targeting distribution systems.
	6	Implementation of automation and storage technologies in distribution systems will be essential for a supply stability in the future. (DP)	Agree to the point. The issue may be discussed in another project targeting distribution systems.
	7	Suggest include storage battery to analysis. (DP)	It would increase its role in the future, but necessity is small up until 2050.
Primary energy supply	1	From the perspective of energy security, suggest promote the development of domestic coal by due considering the environment and resettlement issue. (AC)	Discussion with the GoB define the plan presented.
	2	Suggest avoiding promote development of domestic coal. (CSO)	Discussion with the GoB define the plan presented.
	3	There is a risk in LNG suppl when looking at recent situation. Therefore, suggest promoting development of domestic natural gas. (CSO)	The MP recommends prioritizing promotion of domestic natural gas development. At the same time, however, Bangladesh needs to move forward with LNG imports because of the risk of domestic development failure.
	4	Suggest emphasis on the development of domestic natural gas, which is expected to have a variety of benefits. (DP)	The MP recommends prioritizing promotion of domestic natural gas development. At the same time, however, Bangladesh needs to move forward with LNG imports because of the risk of domestic development failure.
	5	Suggest focus on hydrogen produced	Green hydrogen is unlikely since

		from renewables or nuclear. (AC)	there will be no surplus of renewable electricity in Bangladesh. Nuclear-based hydrogen needs to be assessed for future commercialization in the world.
	6	Rapid increase in oil demand, especially for automobiles, is a major challenge. (DP)	Agree to the point.
Others	1	Adaptation is important as well as mitigation. Suggest discussing climate resilience. (CSO)	Adaptation is an issue to be considered during the next Master Plan review.

C. The Environmental and Social Baseline

C.1.1 Climate Condition of Bangladesh

Bangladesh extends from 20°34'N to 26°38'N latitude and from 88°01'E to 92°41'E longitude. Except for the hilly southeast, most of the country is a low-lying plainland. It is surrounded by the Assam Hills in the east, the Meghalaya Plateau in the north, the lofty Himalayas lying farther to the north. To its south lies the Bay of Bengal, and to the west lie the plainland of west Bengal and the vast tract of the Gangetic Plain.

Bangladesh is located in the tropical monsoon region and its climate is characterized by high temperature, heavy rainfall, often excessive humidity, and fairly marked seasonal variations. The most striking feature of its climate is the reversal of the wind circulation between summer and winter, which is an integral part of the circulation system of the South Asian subcontinent. From the climatic point of view, three distinct seasons can be recognized in Bangladesh - the cool dry season from November through February, the pre-monsoon hot season from March through May, and the rainy monsoon season which lasts from June through October. The month of March may also be considered the spring season, and the period from mid-October through mid-November may be called the autumn season. The dry season begins first in the west-central part of the country by mid-December, where its duration is about four months.

The pre-monsoon hot season is characterized by high temperatures and the occurrence of thunderstorms. April is the hottest month when mean temperatures range from 27°C in the east and south to 31°C in the west-central part of the country. In the western part, summer temperature sometimes reaches up to 40°C. After the month of April, the temperature dampens due to increased cloud cover. The pre-monsoon season is the transition period when the northerly or northwesterly winds of the winter season gradually changes to the southerly or southwesterly winds of the summer monsoon or rainy season (June-September). During the early part of this season, the winds are neither strong nor persistent. However, with the progression of this season wind speed increases, and the wind direction becomes more persistent.

The cloud cover in Bangladesh has two opposing seasonal patterns, coinciding with the winter and summer monsoons. As a result of the flow of cold-dry winds from the northwestern part of India during the winter season, the cloud cover is at a minimum. On an average, the cloud cover in this season is about 10% almost all over the country. With the progression of the season, the cloud cover increases, reaching 50 to 60% by the end of the pre-monsoon hot season. During the summer monsoon season, which is also the rainy season, the cloud cover is widespread. In the months of July and August, which is the middle of the rainy season, the cloud cover varies from 75% to 90% all over the country. However, it is more extensive in the southern and eastern parts

(90%) than in the northwestern part (75%). After the withdrawal of the summer monsoon, the cloud cover decreases rapidly, dropping to 25% in the northern and western parts, and 40-50% in the southern and eastern parts.

Rainfall during the rainy season is caused by tropical depressions that enter the country from the Bay of Bengal. These account for 70% of the annual total in the eastern part, 80% in the southwest, and slightly over 85% in the northwestern part of Bangladesh. The amount of rainfall in this season varies from 100cm in the west central part to over 200cm in the south and northeast. Average rainy days during the season vary from 60 days in the west-central part to 95 days in the southeastern and over 100 days in the northeastern part. Geographic distribution of annual rainfall shows a variation from 150cm in the west-central part of the country to more than 400cm in the northeastern and southeastern parts. The maximum amount of rainfall has been recorded in the northern part of the Sylhet district and in the southeastern part of the country (Cox's Bazar and Bandarban districts). Figure C.1-1 represents the climate zone of Bangladesh.

C.1.2 Topography of Bangladesh

Bangladesh is a small country, but it has considerable topographic diversity. It has three distinctive features: (i) a broad alluvial plain subject to frequent flooding, (ii) a slightly elevated relatively older plain, and (iii) a small hill region drained by flashy rivers. On the south, a highly irregular deltaic coastline of about 600km fissured by many estuarine rivers and channels flowing into the Bay of Bengal. The alluvial plain is part of the larger plain of Bengal, which is sometimes called the Lower Gangetic Plain. Elevations of the plains are less than 10m above sea level; elevation furthers decline to near sea level in the coastal south.

Figure C.1-2 represents the topography map of Bangladesh. The southeastern region of Chittagong has the highest land elevation in the country starting at 30m up to 800m. The Chittagong Hills constitute the only significant hill system in the country. It rises steeply to narrow ridgelines with elevation ranges between 600m and 800m above mean sea level. In between the hilly ridges lie the valleys that generally run north to south. West of the Chittagong hills is a narrow, wet coastal plain lying parallel to the shoreline.

C.1.3 Geology of Bangladesh

(1) Coastal deposits

Coastal deposits are restricted to a narrow zone along the western edge of the tectonically active Fold Belt. The strand extending south from Cox's Bazar is the longest continuous beach in the world.

(2) Deltaic deposits

Nearly 85 percent of Bangladesh is underlain by deltaic and alluvial deposits of the Ganges, Brahmaputra, and Meghna river systems. The deltaic deposits are sediments that are deposited on the active delta, which is defined as the area south of the Ganges River and mostly west of the Meghna estuary. Most of the delta is less than 15 m above mean sea level, and the tidal zone is generally less than 3 m above mean sea-level.

The delta is crossed by parallel south-southeast-trending distributary channels. The land gradient is approximately 1 meter per 20 kilometers. The historically stable delta front and presence of artifacts found below the water table suggest that large areas of the middle and lower delta are subsiding.

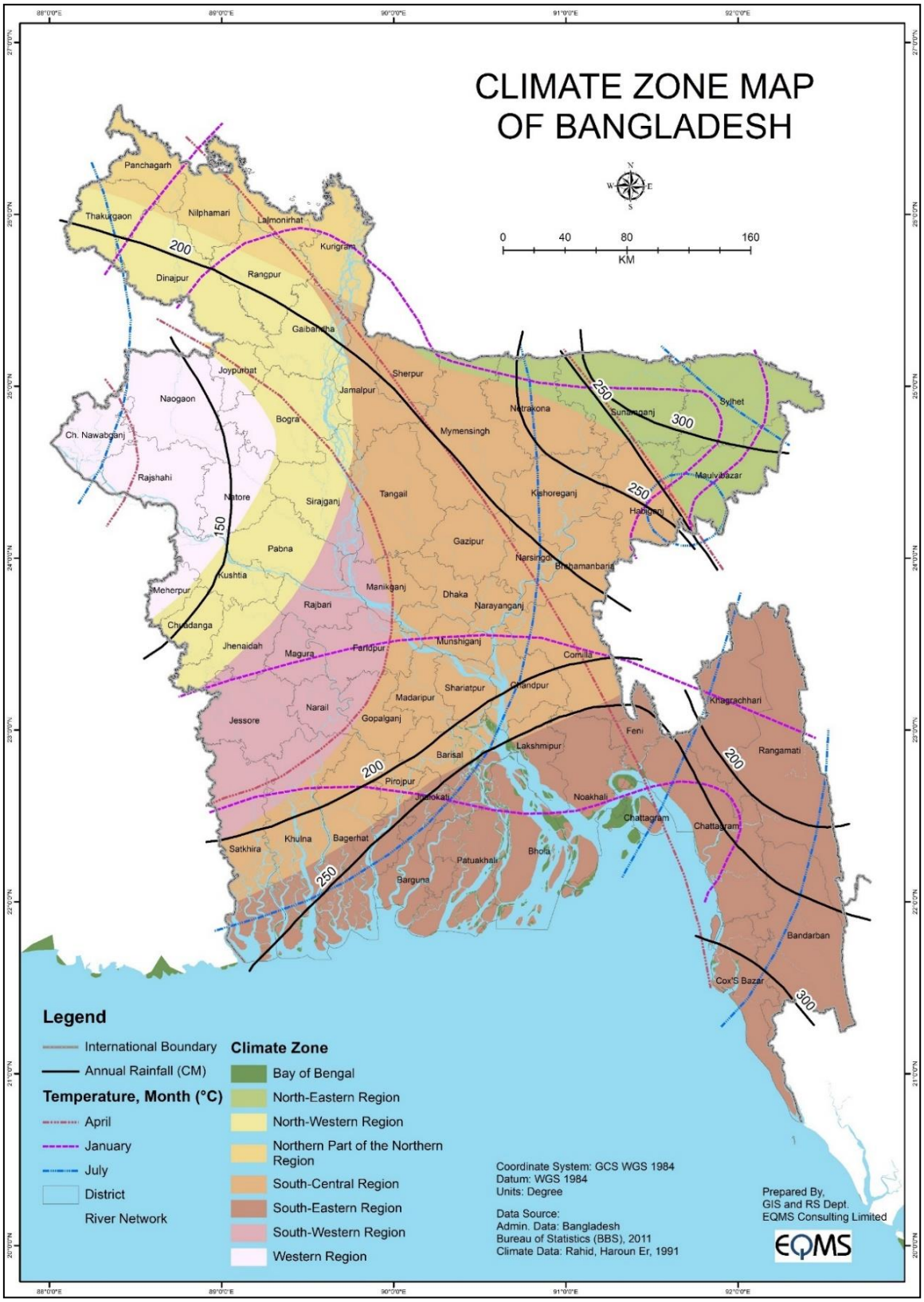
Mangrove swamp deposit—Dark-grey to black silt and clay deposited in the active tidal zone, which is dominated by woody, organic-rich, mangrove swamps. Areas between tidal channels covered with as much as 1 m of brackish and saline water during high tide and area uncultivated and covered by natural mangrove forest.

(3) Alluvial deposits

Alluvial deposits range from flood sand to overbank silt and ponded clay. The Brahmaputra River valley is inset between active and Pleistocene fan deposits and contains a very wide, braided channel. The Ganges River flows between the active delta and deposits of the Barind Tract. Meghna Rivers have wide meandering channels. All three rivers flood annually in response to the monsoon as they merge to the Meghna estuary, which passes the world's annual discharge and sediment.

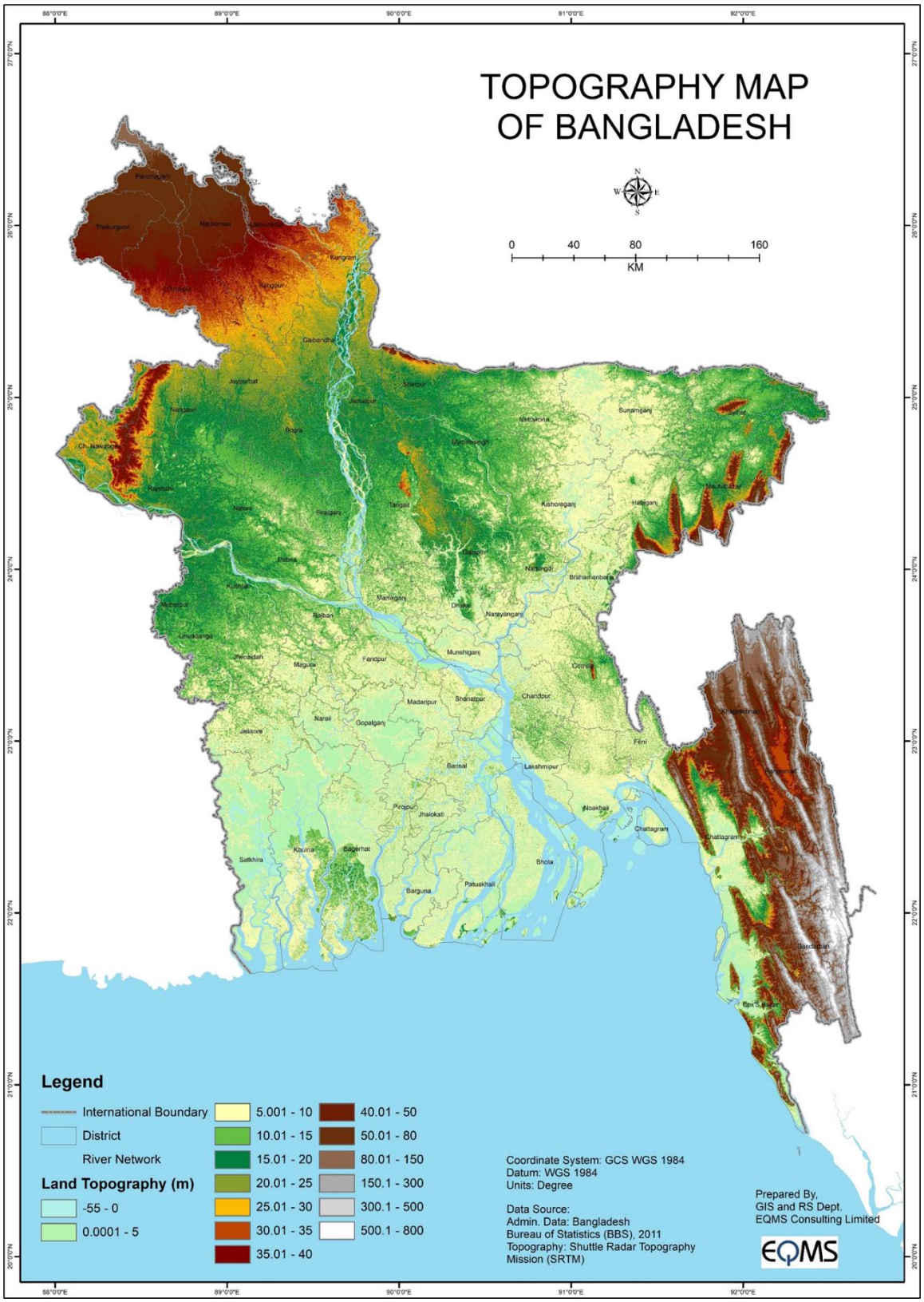
(4) Soil of Bangladesh

The major part of Bangladesh is on the delta formed by the three major rivers Brahmaputra, Gangs and Meghna. These rivers and many of the country's other minor rivers originate outside the national boundary of the country and make up the Ganges-Brahmaputra-Meghna River system. The system drains a basin of some 1.76 million sq. km and carry not only snowmelt water from the Himalayas but also runoff water from some of the highest rainfall areas of the world. Over millennia, the sediments carried by the huge discharges of these rivers have built a broad delta, forming most of the large area of Bangladesh and the submerged delta-plain in the Bay of Bengal. These sediments are the major sources of formation of 80% soils of the country. The remaining 20% of soils have been formed in Tertiary and Quaternary sediments of hills (12%) and in uplifted Pleistocene terrace (8%). Figure C.1-4 shows the soil map of Bangladesh.



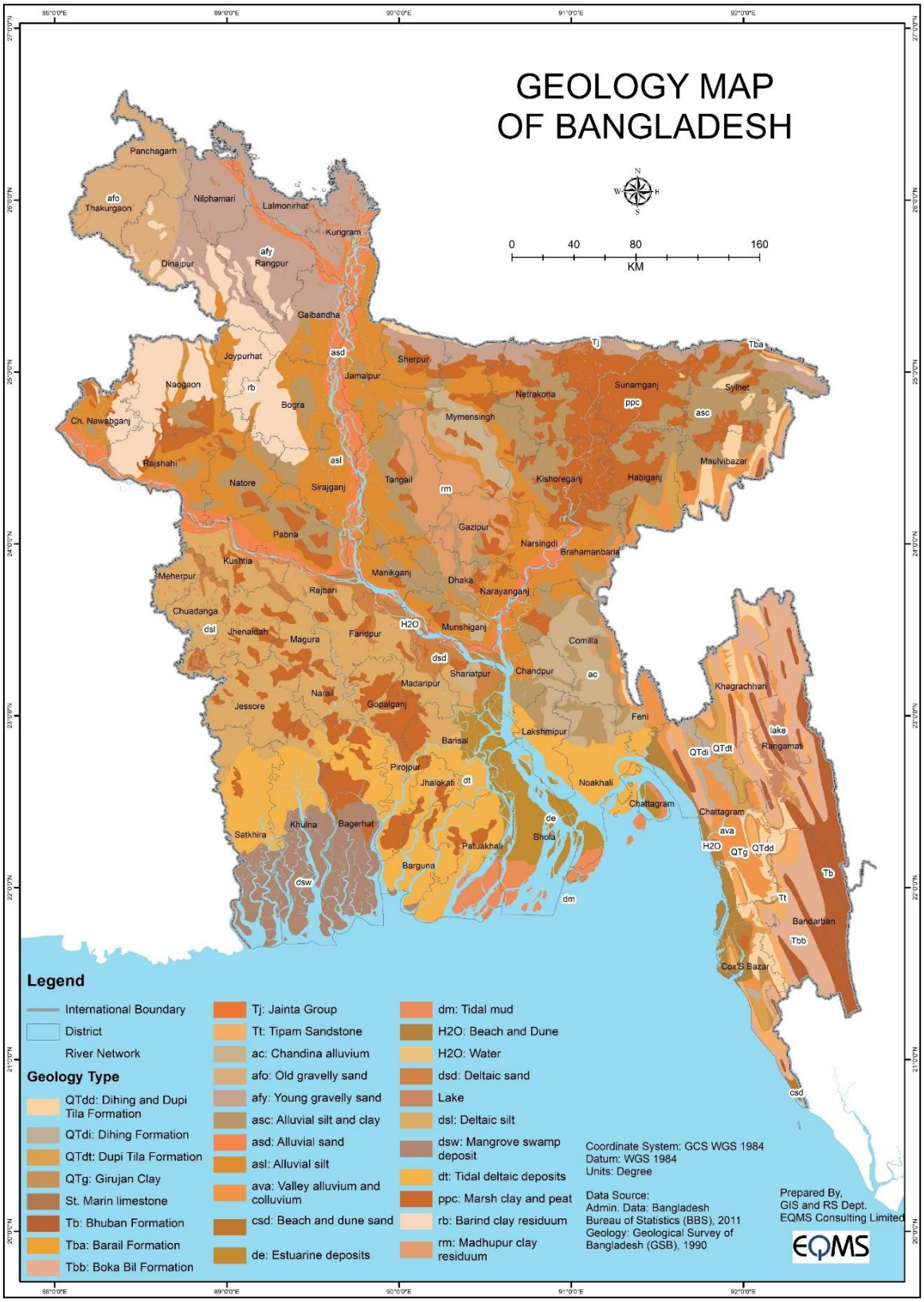
Source: EQMS based on the information of BBS, 2011, Rashid, 1991

Figure C.1-1 Climate Zone of Bangladesh



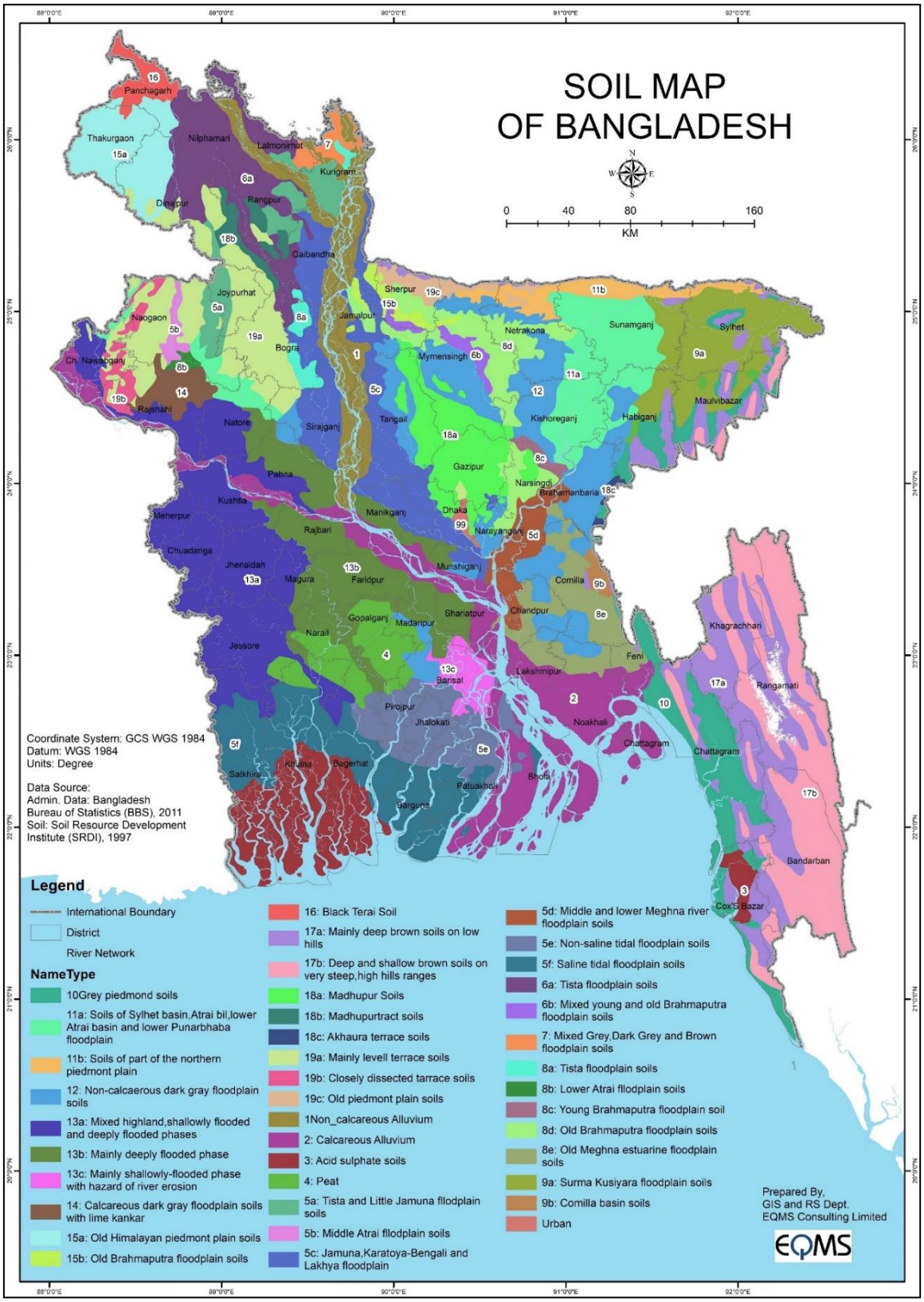
Source: EQMS based on the information of BBS, 2011, SRTM 2015

Figure C.1-2 Topography of Bangladesh



Source: EQMS based on BBS, 2011, GSB 1990

Figure C.1-3 Geology of Bangladesh



Source: EQMS based on the information of BBS, 2011, SRDI 1997

Figure C.1-4 Soil of Bangladesh

C.1.4 Land Use

The land use of Bangladesh where the uses of land has been divided into waterbody, agricultural land, settlement with homestead area, char area, forest area. The total forest area of Bangladesh is 2.6 million hectares, which is nearly 17.4% of the total land area of the country.

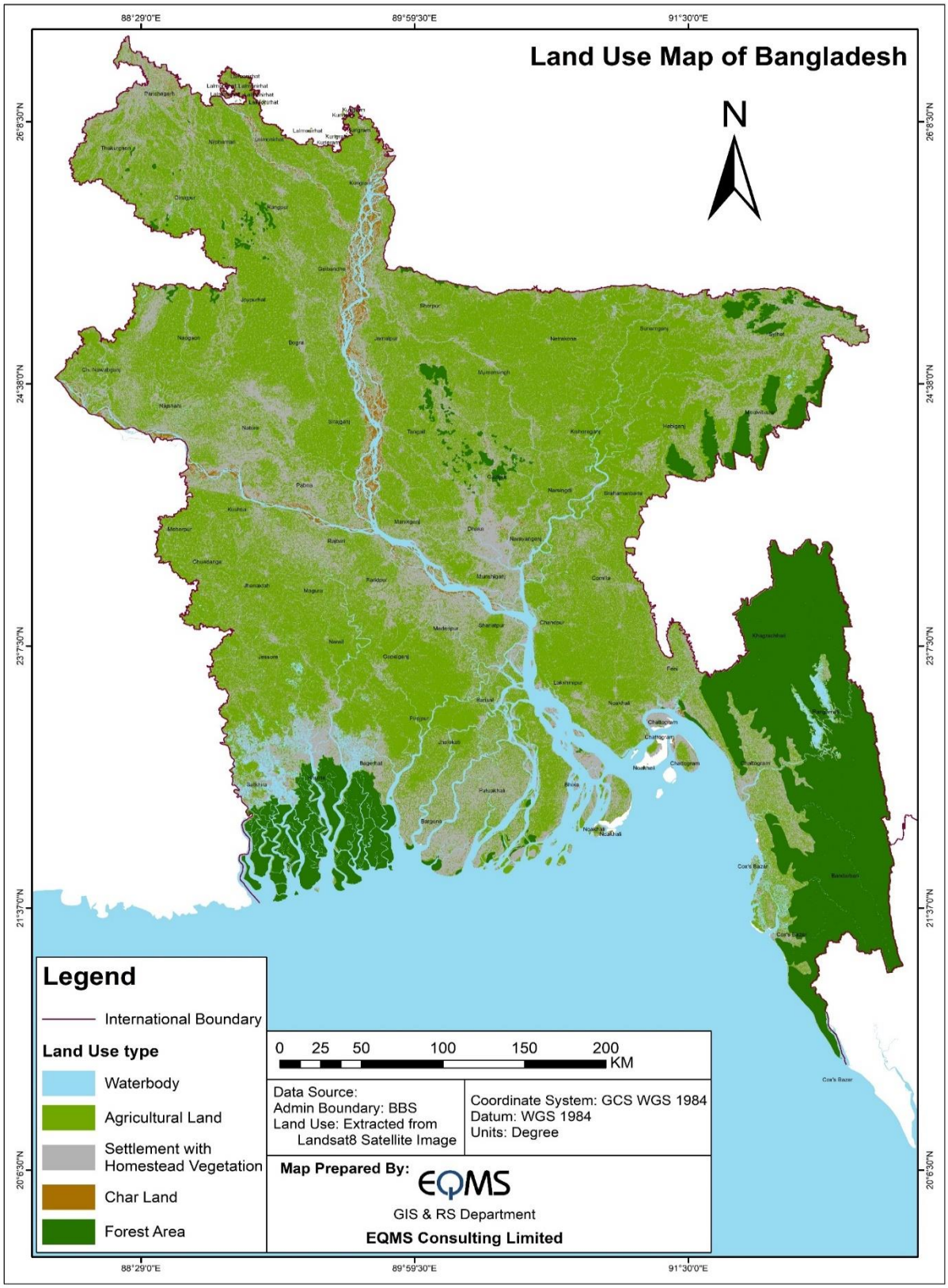


Figure C.1-5 Land Use of Bangladesh

C.1.5 Natural Hazards

(1) Earthquakes

On the basis of distribution of earthquake epicenters and morphotectonic behavior of different tectonic blocks, Bangladesh has been divided into four generalized seismic zones. The northeastern folded regions of Bangladesh are the most active zones and belong to the zone-IV. In Bangladesh, national building code (BNBC) identifies four significant types as shown in the table below. The table below shows seismic zone coefficient Z in town. Figure C.1-5 shows the seismic map of Bangladesh.

Table C.1-1 Description of Seismic Zones

Zone	Location	Seismic Intensity	Seismic Zone Coefficient Z
1	Southwestern part including Barisal, Khulna, Jessore, Rajshahi	Low	0.12
2	Lower Central and Northwestern part including Noakhali, Dhaka, Pabna, Dinajpur, as well as Southwestern corner including Sundarbans	Moderate	0.20
3	Upper Central and Northwestern part including Brahmanbaria, Sirajganj, Rangpur	Severe	0.28
4	Northeastern part including Sylhet, Mymensingh, Kurigram	Very Severe	0.36

Source: BNBC, 2020

Table C.1-2 Seismic Zone Coefficient Z for Some Important Towns of Bangladesh

Town	Z	Town	Z	Town	Z	Town	Z
Bagerhat	0.12	Gaibandha	0.28	Magura	0.12	Patuakhali	0.12
Bandarban	0.28	Gazipur	0.2	Manikganj	0.2	Pirojpur	0.12
Barguna	0.12	Gopalganj	0.12	Maulvibazar	0.36	Rajbari	0.2
Barisal	0.12	Habiganj	0.36	Meherpur	0.12	Rajshahi	0.12
Bhola	0.12	Jaipurhat	0.2	Mongla	0.12	Rangamati	0.28
Bogra	0.28	Jamalpur	0.36	Munshiganj	0.2	Rangpur	0.28
Brahmanbaria	0.28	Jessore	0.12	Mymensingh	0.36	Satkhira	0.12
Chandpur	0.2	Jhalokati	0.12	Narail	0.12	Shariatpur	0.2
Chapainababganj	0.12	Jhenaidah	0.12	Narayanganj	0.2	Sherpur	0.36
Chittagong	0.28	Khagrachari	0.28	Narsingdi	0.28	Sirajganj	0.28
Chuadanga	0.12	Khulna	0.12	Natore	0.2	Srimangal	0.36
Comilla	0.2	Kishoreganj	0.36	Naogaon	0.2	Sunamganj	0.36

Cox's Bazar	0.28	Kurigram	0.36	Netrakona	0.36	Sylhet	0.36
Dhaka	0.2	Kushtia	0.2	Nilphamari	0.12	Tangail	0.28
Dinajpur	0.2	Lakshmipur	0.2	Noakhali	0.2	Thakurgaon	0.2
Faridpur	0.2	Lalmanirhat	0.28	Pabna	0.2		
Feni	0.2	Madaripur	0.2	Panchagarh	0.2		

Source: BNBC, 2020

(2) Tsunamis

Bangladesh has implemented a number of measures to support planning and management in disaster-prone coastal areas. After the 2004 tsunami event, the government conducted a tsunami vulnerability assessment of the country. Taking into consideration tectonic factors, basin configuration, geological boundary conditions and ground characteristics, the Geological Survey of Bangladesh has divided zones into three Tsunami Vulnerability Belts. It has been estimated that at least 4.7 million people live in the most tsunami-vulnerable area of Coastal Belt I and 12.9 million people in Coastal Belt II.

1) Tsunami Vulnerability Coastal Belt I of the Chittagong–Teknaf coastline: Most vulnerable. The intra-deltaic coastline is very close to the tectonic interface of the Indian and Burmese plates. The active Andaman–Nicobar fault system is often capable of generating tsunami waves.

2) Tsunami Vulnerability Coastal Belt II of the Sundarban–Barisal coastline: Moderately vulnerable. This old deltaic belt is extremely vulnerable to local tsunamis due to the presence of Swatch of No Ground nearby.

3) Tsunami Vulnerability Coastal Belt III of the Barisal–Sandwip estuarine coastline: Low vulnerability. The estuarine coastal belt is considered to be less vulnerable due to the presence of numerous islands and shallow mudflats in the upper regime of the continental shelf.

(3) Climate Risk

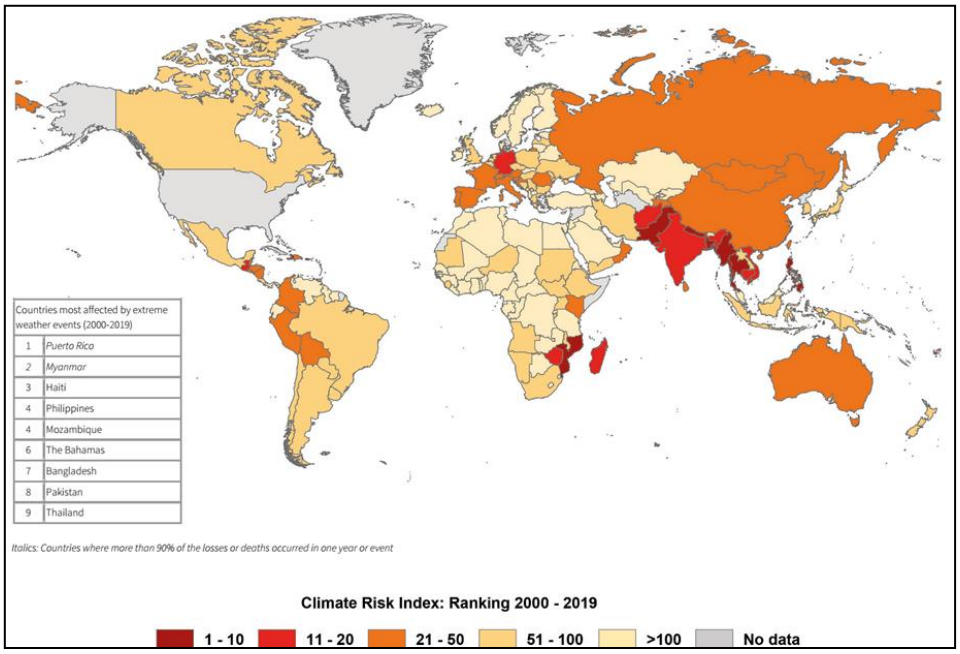
The Global Climate Risk Index 2021 analyses and ranks to what extent countries and regions have been affected by the impacts of climate related extreme weather events (storms, floods, heatwaves, etc.). The figure below shows the World Map of the Global Climate Risk Index 2000 – 2019 where Bangladesh ranks between 11 and 20 on the risk index. The countries most affected in 2019 were Mozambique, Zimbabwe as well as the Bahamas. For the period from 2000 to 2019 Puerto Rico, Myanmar and Haiti rank highest. Bangladesh is ranked 7th in the 10 most affected countries considering the Long-Term Climate Risk Index (CRI) from 2000 to 2019. Bangladesh

ranks 9th in annual fatalities among all countries analyzed in this study, 37th in Fatalities per 100 000 inhabitants, and 13th in losses and 37th in losses per unit GDP.

Table C.1-3 The Long-Term Climate Risk Index (CRI): The Top 10 countries most affected from 2000 to 2019 (annual averages)

CRI 2000-2019 (1999-2018)	Country	CRI score	Fatalities	Fatalities per 100000 inhabitants	Losses in million US$ PPP	Losses per unit GDP in %	Number of events (2000-2019)
1 (1)	Puerto Rico	7.17	149.85	4.12	4 149.98	3.66	24
2 (2)	Myanmar	10	7 056.45	14.35	1 512.11	0.8	57
3 (3)	Haiti	13.67	274.05	2.78	392.54	2.3	80
4 (4)	Philippines	18.17	859.35	0.93	3 179.12	0.54	317
5 (14)	Mozambique	25.83	125.4	0.52	303.03	1.33	57
6 (20)	The Bahamas	27.67	5.35	1.56	426.88	3.81	13
7 (7)	Bangladesh	28.33	572.5	0.38	1 860.04	0.41	185
8 (5)	Pakistan	29	502.45	0.3	3 771.91	0.52	173
9 (8)	Thailand	29.83	137.75	0.21	7 719.15	0.82	146
10 (9)	Nepal	31.33	217.15	0.82	233.06	0.39	191

Source: Global Climate Risk Index 2021



Source: CRI. 2020

Figure C.1-6 Climate Risk Map

(4) Flooding

Bangladesh is a land of many rivers. It is prone to flooding due to being situated on the Brahmaputra River Delta (also known as the Ganges Delta) and the many distributaries flowing into the Bay of Bengal. Considering it is less than 5 m above mean sea level, Bangladesh faces the cumulative effects of floods by water from nearby hills, the accumulation of the inflow of water from upstream catchments, and locally heavy rainfall into main rivers. 80% of Bangladesh is floodplain and it has an extensive sea coastline and Bangladesh faces this problem almost every year.

While permanent defenses are built with reinforced concrete to protect against flooding, many levees are constructed by local residents using soil and grass. Flooding normally occurs during the monsoon season from June to September. The convectional rainfall of the monsoon is added to relief rainfall caused by the Himalayas. Meltwater from the Himalayas is also a significant input.

Each year in Bangladesh about 26,000 square kilometers (10,000 sq mi) (around 18% of the country) is flooded, killing over 5,000 people and destroying more than seven million homes. The floods have caused devastation in Bangladesh throughout history, especially in 1951, 1987, 1988 and 1998. The 2007 South Asian floods also affected a large portion of Bangladesh.

According to the Bangladesh Agricultural Research Council (BARC), Bangladesh is divided into flood prone zones. In the coastal zone, severe tidal surge zone is identified. It is classified mostly in the riverbank of the major rivers such as Meghna, Padma and Brahmaputra. Severe flash flooding can be observed in the eastern part of Bangladesh.

(5) Cyclone Track

Devastating cyclones hit the coastal areas of Bangladesh almost every year usually accompanied by high-speed winds, sometimes reaching 250 km/hr. or more and 3-10 m high waves, causing extensive damage to life, property, and livestock. Cyclones in the Bay of Bengal occur in two seasons, April-May and October-November. Cyclones enter the Bay as the remnants that originate in the South China Sea. They gain moisture and latent heat from the Bay of Bengal, and consequently rejuvenate into full-blown phenomenon. Following a curvilinear path, they reach the coast of Myanmar, Bangladesh or East Coast of India.

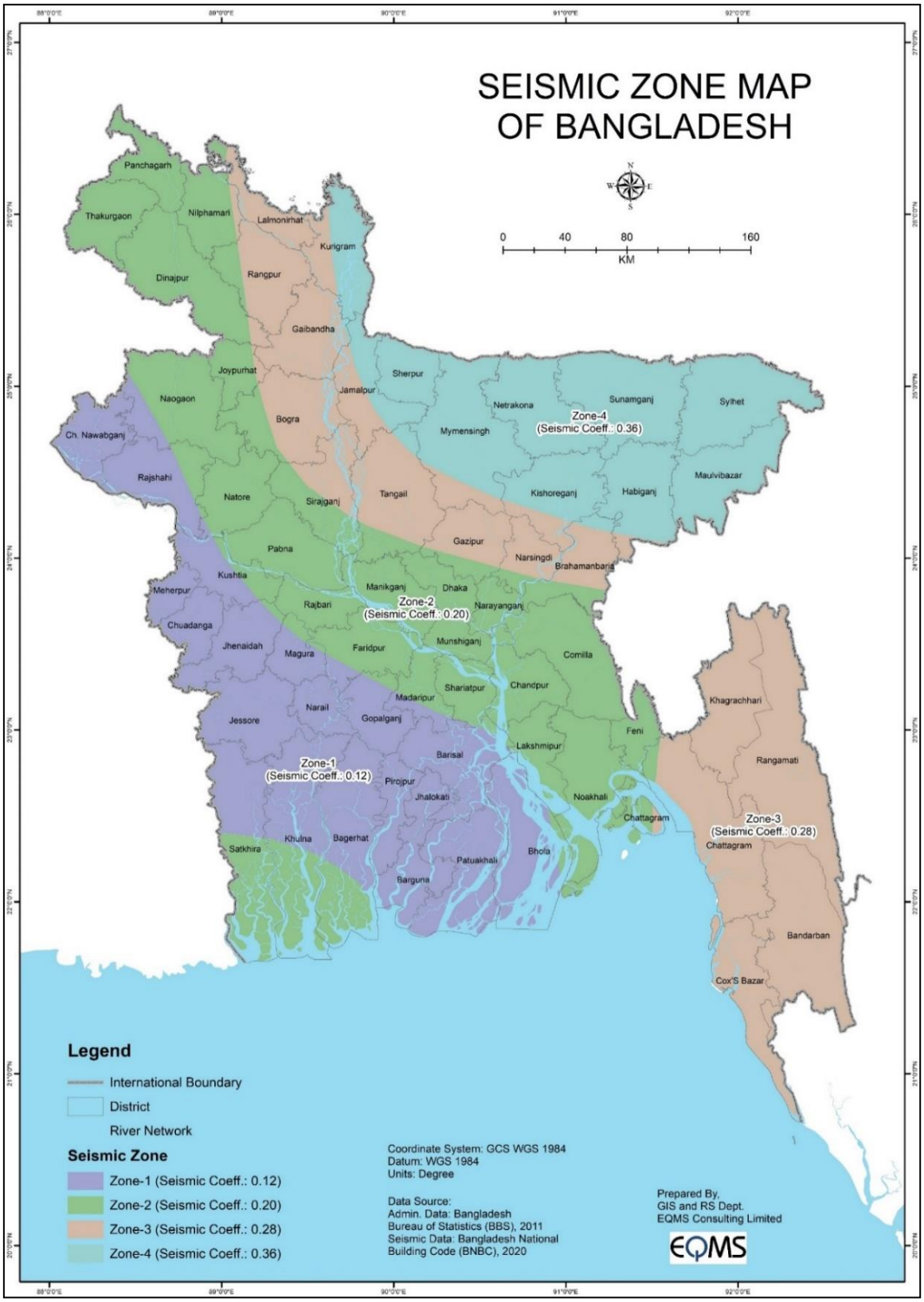
Because of the funnel shaped coast, Bangladesh repeatedly becomes the landing ground of the cyclones formed in the Bay of Bengal. The Bay cyclones also move towards the eastern coast of India, towards Myanmar and occasionally into Sri Lanka. But they cause the maximum damage when they come into Bangladesh and West Bengal of India. This is because of the low flat terrain, high density of population and poorly built houses.

Most of the damage occurs in the coastal regions of Khulna, Patuakhali, Barisal, Noakhali and Chittagong and the offshore islands of Bhola, Hatiya, Sandwip, Manpura, Kutubdia, Maheshkhali, Nijhum Dwip, Urir Char and other newly formed islands.

Figure C.1-9 represents the cyclone zone map of Bangladesh containing the cyclone affected zone and historical cyclonic tracks. In the influence of the Bay of Bengal, these regions are considered high-risk areas having a surge height of less than 1 m.

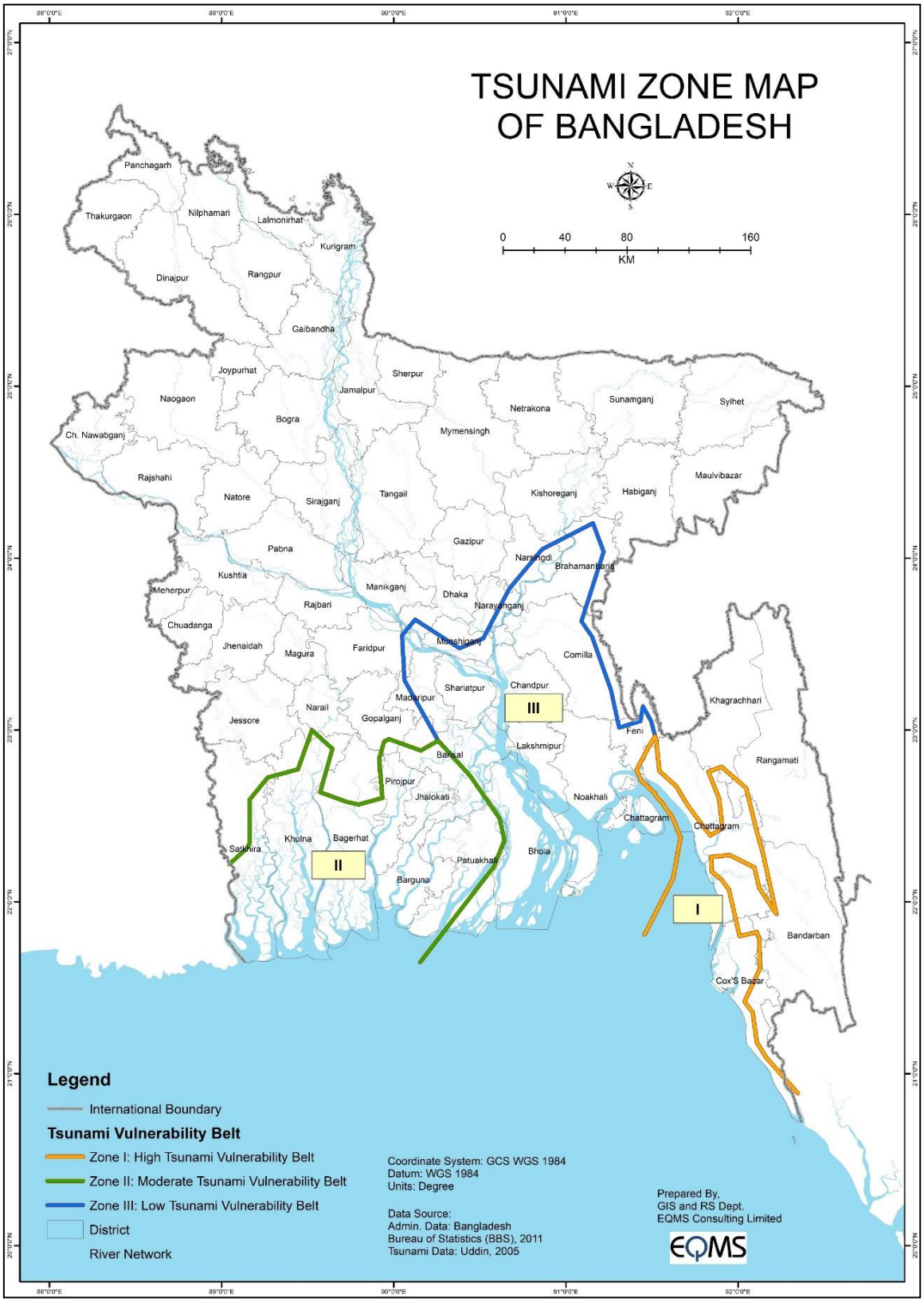
(6) Types of Natural Hazards

The country has long been exposed to various climatological, hydrometeorological and other geophysical (e.g., landslides and erosion) hazards. Its funnel-shaped southern coast makes it susceptible to cyclones and storm surges, medium to high levels of soil salinity, and sea level rise. The northern and northeastern sides of Bangladesh also experience frequent droughts. Figure C.1-10 shows the natural hazard map of Bangladesh.



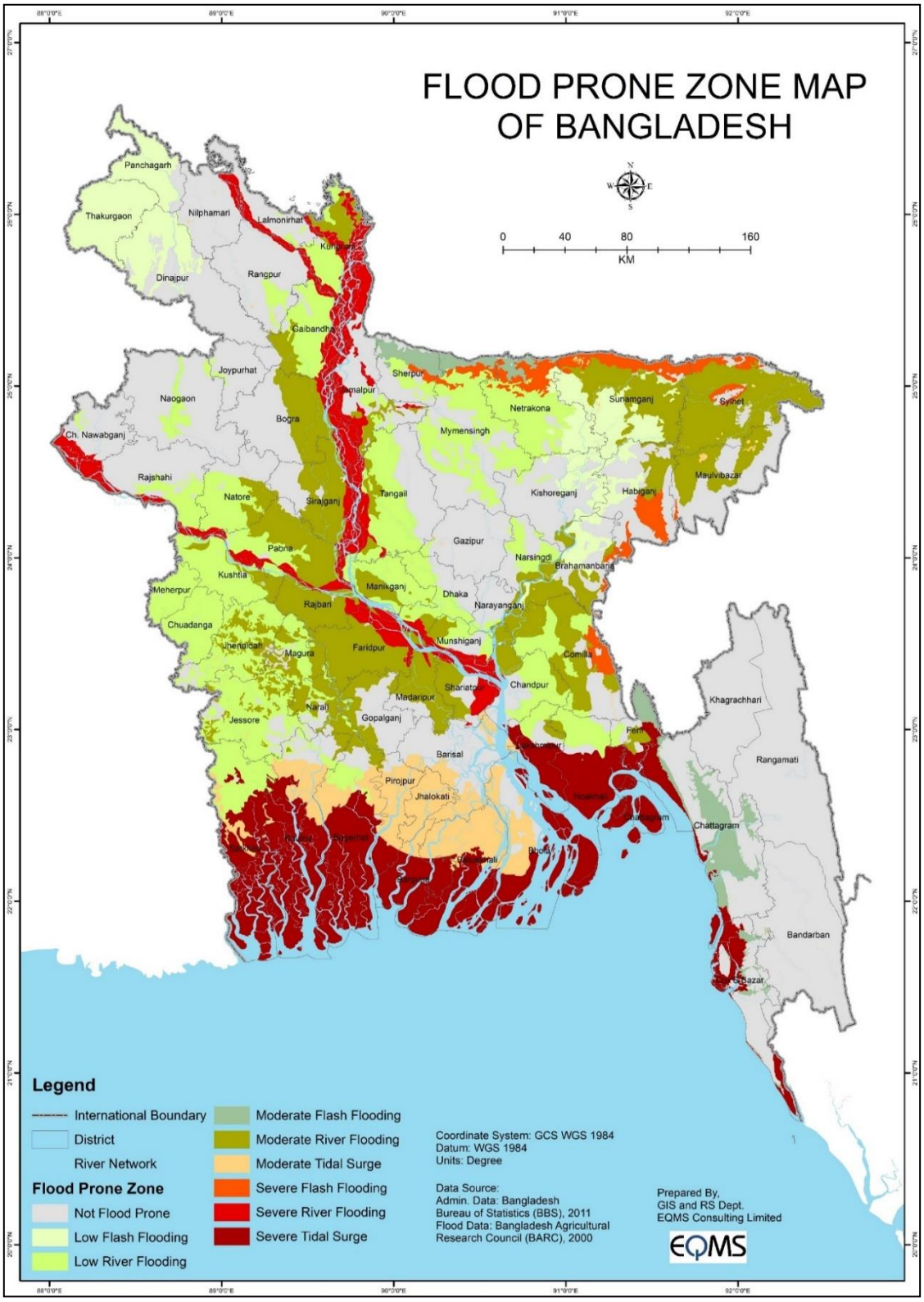
Source: EQMS based on the information of BBS, 2011 and BNBC 2010

Figure C.1-7 Seismic Zone of Bangladesh



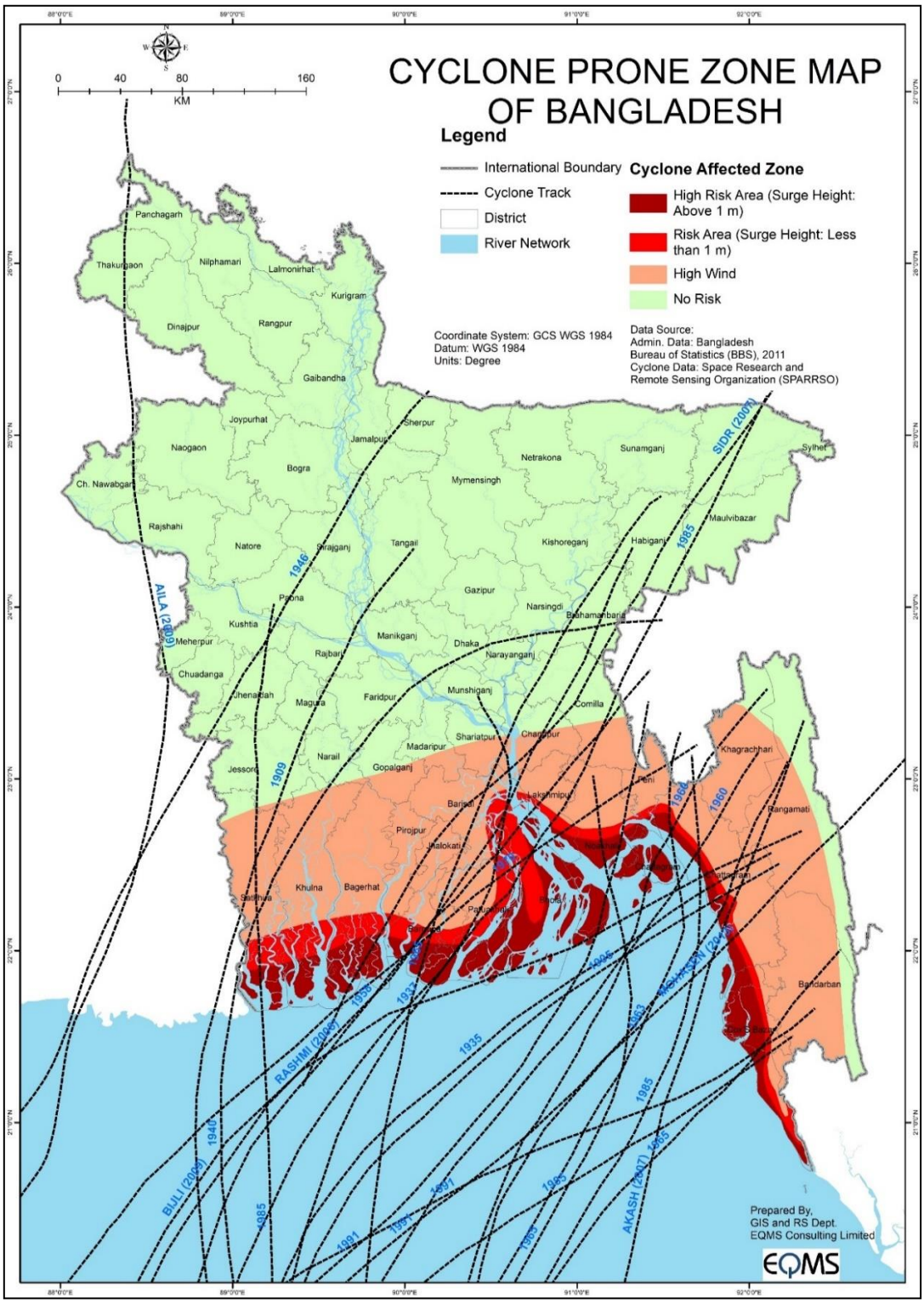
Source: EQMS based on the information of BBS, 2011 and Uddin 2005

Figure C.1-8 Tsunami Zone Map of Bangladesh



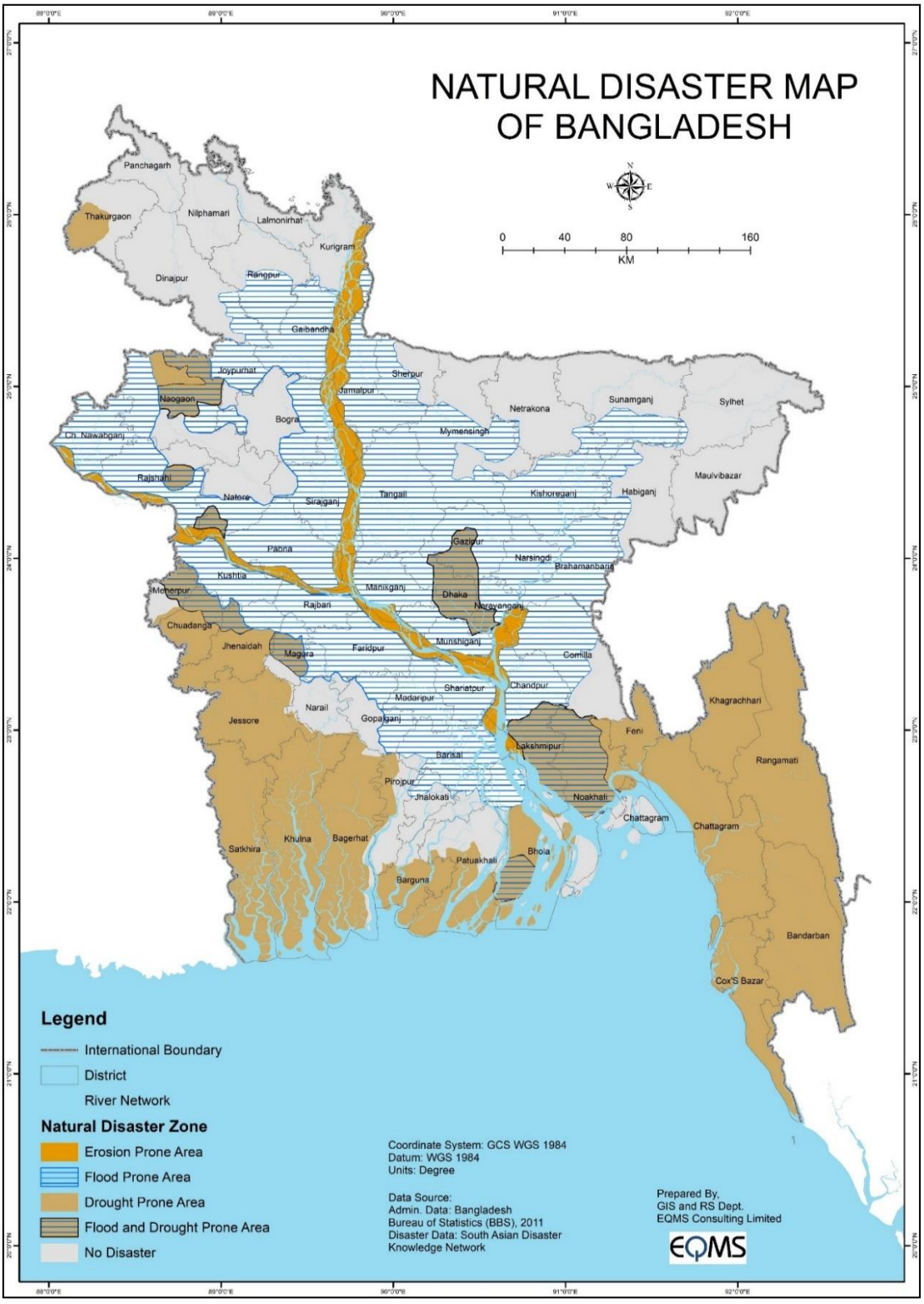
Source: EQMS based on the information of BBS, 2011, BARC, 2000

Figure C.1-9 Flood Prone Zone of Bangladesh



Source: EQMS based on the information of BBS, 2011, SPARRSO

Figure C.1-10 Cyclone Prone Zone Map of Bangladesh



Source: EQMS based on the information of BBS, 2011, South Asian Disaster Knowledge Network

Figure C.1-11 Natural Disaster Map of Bangladesh

C.1.6 Water Resources

Bangladesh consists of seven major surface geologic units mapped in the Holocene plain lands which are (1) alluvial fan deposits, (2) alluvial deposits, (3) deltaic deposits, (4) Pleistocene terraces and (5) coastal deposits, (6) Holocene depression deposit and (7) tertiary deposit as shown in Figure C.1-12. Brahmaputra is the 22nd longest (2,850 km) and the Ganges is the 30th longest (2,510 km) river in the world. River of Bangladesh is shown in Table C.1-4 and river network in Figure C.1-11.

Table C.1- 4 Rivers of Bangladesh

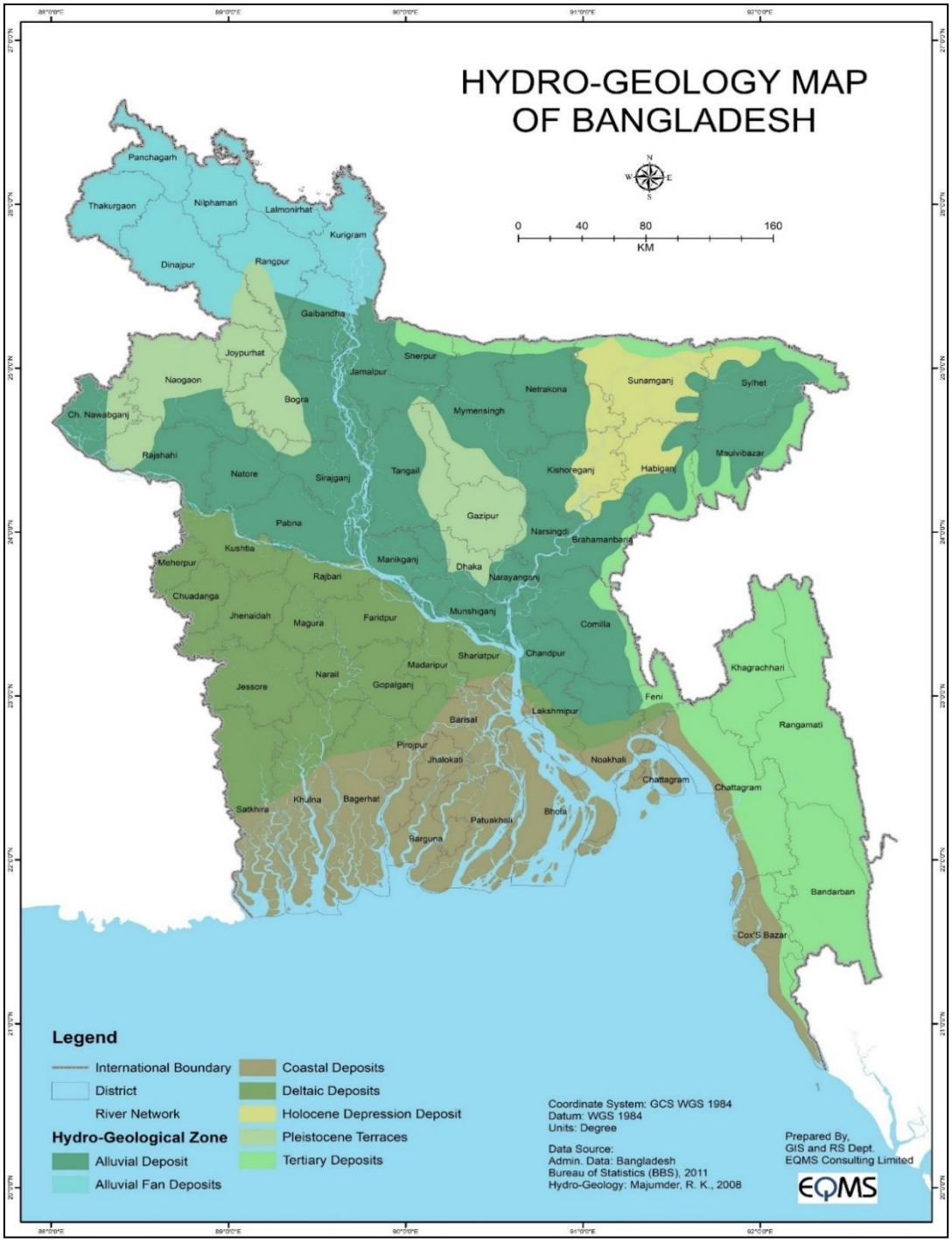
River	Length (km)	Area covered (old districts) in km
Arial Khan	160	Faridpur (102) Barisal (58)
Bangshi	238	Mymensingh (198) Dhaka (40)
Betna-Kholpotua	191	Jessore (103) Khulna (88)
Bhadra	193	Jessore (58) Khulna (135)
Bhairab	250	Jessore, Khulna
Bhogai-Kangsa	225	Mymensingh (225)
Brahmaputra-Jamuna (Jamuna 207)	276	Rangpur (140) Pabna (136)
Buriganga	27	Dhaka (27)
Chitra	170	Kushtia (19) Jessore (151)
Dakatia	207	Comilla (180) Noakhali (27)
Dhaleshwari	160	Mymensingh, Dhaka
Dhanu-Baulai-Ghorautra	235	Mymensingh (126) Sylhet (109)
Donai-Charalkata-Jamuneshwari-Karatoya	450	Rangpur (193), Bogra (157), Pabna (100)
Ganges-Padma (Ganges 258, Padma 120)	378	Rajshahi (145), Pabna (98), Dhaka and Faridpur (135)
Gorai-Madhumati-Baleshwar	371	Kushtia (37), Faridpur (71), Jessore (92), Khulna (104), Barisal (67)
Ghaghat	236	Rangpur (236)
Karatoya-Atrai-Gur-Gumani-Hurasagar	597	Dinajpur (259), Rajshahi (258), Pabna (80)
Karnafuli	180	Chittagong HT, Chittagong
Kobadak	260	Jessore (80) Khulna (180)

River	Length (km)	Area covered (old districts) in km
Kumar	162	Jessore, Faridpur
Kushiyara	228	Sylhet (228)
Little Feni-Dakatia	195	Noakhali (95) Comilla (100)
Lower Meghna	160	from Chandpur to the Bay of Bengal
Matamuhuri	287	Chittagong HT and Chittagong
Mathabhanga	156	Rajshahi (16), Kushtia (140)
Nabaganga	230	Kushtia (26) Jessore (204)
Old Brahmaputra	276	Mymensingh (276)
Punarbhaba	160	Dinajpur (80) Rajshahi (80)
Rupsa-Pasur	141	Khulna (141)
Sangu	173	Chittagong (80), Chittagong Hill Tracts (93)
Surma-Meghna	670	Sylhet (290), Comilla (235), Barisal (145)
Tista	115	Rangpur (115)

Data Source: Banglapedia, 2021

Source: EQMS based on the information of BBS, 2011, Landsat 8 Imagery, 2019

Figure C.1-12 River Network of Bangladesh



Source: EQMS based on the information of BBS, 2011, Majumder, R. K., 2008

Figure C.1-13 Hydro-geological Map of Bangladesh

C.1.7 Air Quality of Bangladesh

Air pollution has been taking its toll on Bangladesh for successive years, causing death and economic losses as well as environmental hazards linked to pollution. Air pollution-related deaths and diseases have been on the rise in recent years, exacerbating people's troubles, particularly children, women, and the elderly.

Air pollution is a serious environmental health hazard affecting the population of Bangladesh due to motorization, industrial emissions, and the use of biomass fuels during cooking with poor ventilation. Industries are mainly concentrated in major urban metropolitan areas such as Dhaka, Rajshahi, the seaport cities such as Chittagong and Khulna, the inland port city Narayanganj, and other divisional towns.

Apart from unplanned industrial development in these areas, the severity of the pollution is increased mainly due to exhaust from two-stroke engine and diesel-run vehicles. In the rural areas of Bangladesh, the danger of air pollution has not yet turned into a point of concern. The following table shows the ambient air quality standards in Bangladesh and their comparison with WHO and United States (US) standards. Agro based industries like sugar, pulp, paper, tanneries and value-added industries like textile, garments, pharmaceutics, oil refineries, and fertilizer and chemical industries are also contributing to air pollution.

Other than industrial emissions, there are many brick-making kilns operated seasonally, mainly in dry season all over Bangladesh. More or less all of these kilns use coal and wood as their prime sources of energy, resulting in the emission of particulate matter, oxides of sulfur, and volatile organic compounds. Additionally, to these usual sources of fuel, used rubber wheels of vehicles are also burnt, which produce black carbon and toxic gases.

The tremendous force of population has made it almost unfeasible to maintain a clean environment in the capital city of Dhaka. Dhaka has been identified as the second worst city to live in for the second consecutive time, according to a survey of the Economist Intelligence Unit (EIU) affiliated with the UK-based weekly The Economist.

Table C.1-5 Ambient air quality standards in Bangladesh from July 2005 and their comparison with WHO and US standards*.

Pollutant	Pollutant (observation realized)	Bangladesh standard (µgm-3)	WHO guideline (µgm-3)	US standard (µgm-3)
Carbon Monoxide (CO)	8 hr.	10000	10000	10000
	1 hr.	40000	30000	40000
Lead (Pb)	Annual	0.5	0.5	0.15
NOx	Annual	100	-	-
SPM	8 hr.	200	-	-
PM10	Annual	50	20	-
	24 hr.	150	50	150
PM2.5	Annual	15	10	15
	24 hr.	65	25	35
Ozone O3	1 hr.	235	-	-
	8 hr.	157	100	157
Sulfur dioxide	24 hr.	365	20	-

Source: ECR 1997 (amendment 2005), WHO Air Quality Guidelines Global Update, 2005, EPA, 1990

The urban areas of Bangladesh have been suffering from a heightened level of particulate matter in the air, especially in dry season (November – April) when this region experiences scarce rainfall, northwesterly wind and low relative humidity. The Government in 2005 issued a set of limit values for the criteria air pollutants (PM, Pb, SO_2, CO, NOx and O_3). Measures were taken such as the removal of lead from gasoline in 1999, (b) a phase-out of 2-stroke 3-wheeled baby taxis from Dhaka in early the 20's, (c) introduction of cleaner fuel CNG to the transport sector in the early 90's, (d) enlargement of the chimney height of the fixed chimney kiln (FCK) for brick production, and recently (e) adoption of a new brick burning and control law – 2013 (revised) which prohibits energy-extensive FCKs in the brick manufacturing sector. These interventions instantly improved the air quality during the time of implementation. However, the massive influx of population in urban centers in the following years, and consequently the requirement and use of excessive fuel canceled out the benefits gained from those measures.

C.1.8 Noise Pollution Bangladesh

Noise Pollution is man-made noise harmful to health and welfare. In Bangladesh noise pollution is a major health hazard. In fact, millions of people in Bangladesh are exposed to a number of health risks - from deafness to heart attacks. On city streets noise pollution can be caused by hydraulic horns of vehicles, microphones and cassette players. The hydraulic horns used by buses, trucks and scooters in the crowded city streets are dangerous for human beings. This is also how noise pollution in Dhaka City is affecting the hearing power of thousands of children every day.

Table C.1-6 Standards of noise level by the Environmental Conservation Rules (1997), DoE

Category of areas	Standards determined at dBa unit (*1)		IFC-WHO	
	Day	Night	Day	Night
Silent zone	50	40		
Residential area	55	45	55	45
Mixed area (mainly residential area, and also simultaneously used for commercial and industrial purposes)	60	50		
Commercial area	70	60	70	70
Industrial area	75	70	70	70

Source: (*1) Noise Pollution Control Rules, 2006 (Schedule-1)

(*2) IFC Environmental, Health, and Safety (EHS) Guidelines: Noise Management

C.1.9 Water Quality of Bangladesh

Bangladesh's streams and rivers are also home to a wide variety of aquatic flora and fauna. The volume of water they carry vary widely depending on the season, heavy summer rainstorms, upstream diversion of water flow and dry winter months. Rivers are important features of Bangladesh's landscape where hundreds of rivers are crisscrossing the landmass and playing role of artery and veins for the maintenance of the ecosystem of the country.

Rivers are mainly used for irrigation, fisheries, drinking water, navigation and industrial purposes. The Department of Environment (DoE) has been monitoring surface and ground water quality since 1973. The surface water quality-monitoring program of DoE is supposed to include 66 stations of 28 rivers in Bangladesh. The monitoring involves in making field measurements (only pH at some stations) and collecting water samples for laboratory analyses. Six divisional offices measured ten parameters such as pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solid (SS), Total Dissolved Solid (TDS), Electrical Conductivity (EC), Chloride, Turbidity and Total Alkalinity for analyses.

While the major rivers such as Padma, Meghna, Jumuna, Dhaleshwari, Surma, Korotoa were found within the limit of Environmental Quality Standards (EQS) in 2016, rivers around greater Dhaka were highly polluted, especially in terms of DO, BOD and COD values. DO was almost zero from January to April at different locations of Buriganga, Shitalakhya and Turag River. High levels of Turbidity (120 mg/1), TDS (586 mg/1), BOD (50.20 mg/1) and COD (212.62 mg/1) were found in the Buriganga river from January to December in 2016. In Meghna, DO and BOD

level were found within the EQS which varied from 0.8 to 7.1 mg/1 and 0.2 to 8.4 mg/1, respectively. In Jamuna DO and BOD levels were found from 4.6 to 8.5 mg/1 and 1.2 to 4.2 mg/1, respectively. High levels of Chloride, TDS and Turbidity were found in the Moyuri, Rupsha, Pashur and Kakshiali rivers. The highest level of Chloride (7,228 mg/1) and TDS (11,521 mg/1) was found in the Pashur river. The highest value of Turbidity (124.46 NTU) was found in the Kakshiali river. High COD (516 mg/1) was found in the Kamapuli river. During dry seasons water quality becomes worse. On the contrary, river water quality improved greatly during the wet seasons indicating a clear relationship between increased flow of rivers and river water quality[6].

Table C.1-7 Effuluent Standards in Bangladesh and Worldbank/IFC

Parameter	**Unit**	**Bangladesh***	**WB/IFC****
pH	-	6-9	6-9
Total Suspended Solids (TSS)	mg/l	150	50
Oil and grease	mg/l	10	10
Total residual chlorine	mg/l	-	0.2
Chromium (total)	mg/l	0.5	0.5
Chromium (as hexavalent Cr)	mg/l	0.1	-
Copper	mg/l	0.5	0.5
Iron	mg/l	2.0	1.0
Zinc	mg/l	5.0	1.0
Lead	mg/l	0.1	0.5 mg/l
Cadmium	mg/l	0.5	0.1
Mercury	mg/l	0.01	0.005
Arsenic	mg/l	0.2	0.5
Ammonical Nitrogen (as elementary N)	mg/l	50	-
Ammonia (as free ammonia)	mg/l	5	-
BOD5 at 20C	mg/l	50	-
Boron	mg/l	2	-
Chloride	mg/l	600	-
COD	mg/l	200	-
Dissolved Oxygen (DO)	mg/l	4.5 - 8	-
Electro-conductivity (EC)	Micro mho/cm	1200	-

[6] Surface and groundwater quality report, 2016 by the Department of Environment, Bangladesh

Parameter	Unit	Bangladesh*	WB/IFC**
Total Dissolved Solids	mg/l	2100	-
Fluoride (as F)	mg/l	2	-
Sulfide (as S)	mg/l	1	-
Total Kjeldahl Nitrogen (as N)	mg/l	100	
Manganese (as Mn)	mg/l	5	-
Nickel (as Ni)	mg/l	1.0	-
Nitrate (as elementary N)	mg/l	10.0	-
Phenolic Compounds (as C6H5OH)	mg/l	8	-
Selenium (as Se)	mg/l	0.05	-
Cyanide (as Cn)	mg/l	0.1	-
Temperature increase at the edge of the mixing zone	°C	40 (summer) 45 (winter)	Site specific requirement to be established by the EA. Elevated temperature areas due to discharge of once-through cooling water (e.g., 1°C above, 2°C above, 3°C above ambient water temperature) should be minimized by adjusting intake and outfall design through the project specific EA depending on the sensitive aquatic ecosystems around the discharge point.

Note:

* Schedule 10 (Standards for Waste from Industrial Units or Projects Waste) in Inland Surface Water of the Environmental Conservation Rules, 1997.

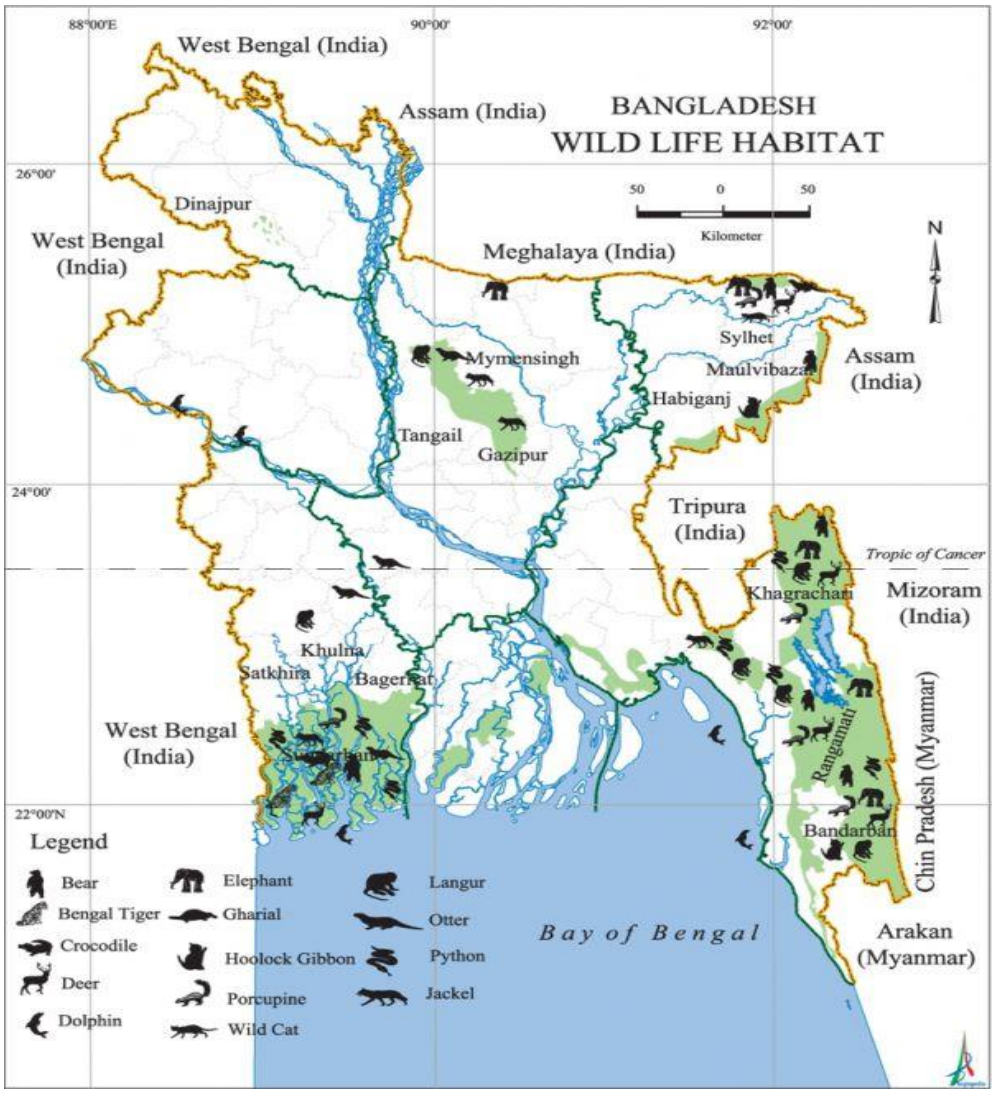
** Effluent Guidelines, WB/IFC EHS Guidelines for Thermal Power Plants.

C.1.10 Biodiversity, Ecosystem

(1) Distribution of the Faunal Species

Bangladesh is a biodiversity-rich country, given its location in the subtropical belt at the confluence of two major biotic sub-regions of the oriental region: Indo-Himalayas and Indo-China. This strategic location makes Bangladesh one of the most ecologically significant and biologically

diverse landscapes in terms of migratory species, stepping stones, staging grounds and flyways for wildlife movements of the region. The hilly area in the southeast of Bangladesh forms part of the Indo-Burma Biodiversity Hotspot. In the figure below, the faunal species distribution of Bangladesh in the different regions across the country is shown.



Source: Adopted from Banglapedia, June 2021

Figure C.1-14 Wildlife Habitat of Bangladesh

The following summarizes the types of the wildlife in different forests and a list of species is provided in Annex E.

a. Grove Forest and the Sundarbans:

The dominant wildlife species of the Sundarbans are the Bengal Tiger, Masked Finfoot, Mangrove Whistler, Mangrove Pitta, Ruddy Kingfisher, Estuarine Crocodile, Mangrove

Snake, Sundarban Crow Butterfly, etc.

b. Mixed-Evergreen Forest:

Many species of forest frogs, lizards, skinks, snakes and many birds and mammals such as the Hoolock, Gaur, Mainland Serow, Bear, Binturong, Stump-tailed, Pig-tailed, Assamese Macaques, Spectacled Langur, Capped Langur, Tree Shrew, Giant Squirrel, Orange-bellied and all flying squirrels are restricted to the Mixed-Evergreen forest. The majority of the elephants do live in this forest with just one tiny population in the Shal forest of Jamalpur and Sherpur Districts bordering Indian forests under Meghalaya State.

c. Sal Forest:

Notable living species are the Capped Langur, a dozen or so Elephants, Rhesus Macaque, Barking Deer, occasional civets, jackal, mongoose, some birds, reptiles, amphibians, and butterflies are seen but their numbers are insignificant.

Homestead Forest, Countryside Forest, Village Woodland or Village Groves and Crop Fields: Although more than 80% of Bangladesh people live in the countryside, the rest live in man-made cities, towns and centers of business and commerce that are nothing more than concrete jungles with less than two percent of such areas having any greenery. The capital city of Bangladesh, Dhaka, still is home to mongooses, bats, rodents, jackals, civets, many birds, reptiles, amphibians and butterflies. Also, part of these fields could be underwater during the southwest monsoon or flood season. Fields that are not annually inundated by floodwater support a good population of rodents, mongoose, jackal, jungle cat, etc. Flooded fields support otters when some rodents can thrive in floating vegetation. The Hanuman Langur is the only large mammal that does not live in forests but only in villages and semi-townships in some western districts. Rhesus Macaque is the second primate that lives both in forests and some villages as well as in Dhaka and Narayanganj towns. Certain species of carnivores, rodents and bats, many birds, reptiles, amphibians, some fishes and crustaceans and many butterflies live in the countryside villages or groves and crop fields and in marshlands.

Wetland Habitats

Freshwater rivers and all wetlands in these water regimes are home to almost all freshwater turtles and tortoises as well as otters and the Ganges dolphin. They are also home to the migratory and resident waterfowls, waders and other waterbirds as well as cormorants, herons and egrets, many species of snakes, monitors and some water snakes. A few specimens of the Gharial that are occasionally seen in the country live in the Padma-Jamuna River systems only.

The Bay of Bengal and Coastal Areas:

The coastal fauna of Bangladesh consists of a total of 453 species of birds, 42 species of mammals, 35 reptiles and 8 amphibian species. Among the endangered species, there are five mammals, 25 birds, 14 reptiles (one crocodile, eight turtles, four lizards and one snake) and two amphibians (frogs). In addition, 7 species of turtles and tortoises, 10 frogs, 3 crocodiles, 24 snakes, 3 otters, 1 porcupine, 9 dolphins and 3 species of whale found in Bangladesh territorial water. The Bay of Bengal is also home to all the saltwater dolphins and the lone living species of whale in Bangladesh, the Bryde's Whale. Oceanic birds such as the Skua, some gulls and terns live in the deep sea although the largest population of gulls and terns are found along the coastal areas during winter. One of the largest populations of the Indian Skimmer lives along the coastal areas, particularly in the coastal rivers by the Hatiya Island and the Nijhum Dwip.

(2) Distribution of the Floral Species

The floral diversity of Bangladesh is extraordinary. The 'Encyclopedia of Flora and Fauna of Bangladesh' recorded 3,611 angiosperm taxa from the country, whereas the number increased to 3,723 due to recording of many new plants in 2015. Considering genetic diversity, some agricultural crops possess rich genetic resources (e.g., jute and allied fibre crops (6,012 accessions), 9,925 accessions of 137 agri-horticultural crops by BARI). Forest genetic resources are also rich (e.g., 2,260 plant species are reported from the Chittagong region and 1,048 tree species including the gymnosperm, dicot and monocots reported from the country)[1]. Also, homesteads play a vital role in providing timber, fuelwood, fodder, and fruits. A record of 70% of timber, 90% of fuelwood, 48% sawn and veneer logs and almost 90% of bamboo requirement is available from home gardens of Bangladesh[7]. Some observed floral species in our forest land areas are listed below[8] and in Annex E.

a. Tropical wet evergreen forest plants:

   This is a multi-storied forest. The principal evergreen tree species are Chapalish (*Artocarpus chaplasha*), Jam (*Syzygium* spp), Sutrong (*Lophopetalum fimbriatum*), and Ramdala (*Duabanga sonneratioides*). Their associated species are Garjan (*Dipterocarpus* spp), Telsur (*Hopea odorata*), Chandul (*Tetrameles nudiflora*), Sal (*Shorea robusta*), Hargoja (*Dillenia pentagyna*), Simul (*Salmalia* spp.), and Koroi (*Albizzia* spp.).

[7] Uddin, M.S., M.J. Rahman, M.A. Mannan, S.A Bagum, A.F.M.F. Rahman & M.R. Uddin. 2002. Plant biodiversity in the homesteads of saline area of southeastern Bangladesh. Pakistan Journal of Biological Science. 5(6): 710-714.

[8] BFD & CEGIS 2013: Forest Information Generation and Network System Project.

b. Pical semi evergreen forest plants:

Three strata of this multistoried forest are significant and distinct at many sites. The major species of top canopy are Garjan (*Dipterocarpus* spp), Civit (*Swintonia floribunda*), Narikali (*Pterygota alata*), Koroi (*Albizzia spp*.), Chandul (*Tetrameles nudiflora*), Champal (*Michelia excelsa*), etc. The list of plants is presented in Appendix B from Rampahar Natural Forest Reserve in Rangamati South Forest Division, Bangladesh covering tropical wet evergreen forest plants and tropical semi evergreen forest plants.

c. Tropical moist deciduous forests plants:

The major species is Sal (*Shorea robusta*), most of its current crops are degraded coppice growth. Other species found as associates of sal, are Jarul (*Lagerstroemia flos reginae*), Sidha (*Lagerstroemia parviflora*), Joginichakra (*Gmelina arborea*), Kaikha (*Adina cardifolia*), Chambol (*Artocarpus chaplasha*), Amloki (*Phyllanthus emblica*), Ajuli (*Dllenia pentagyna*), Polash (*Butea cutangu*), Sonalu (*Cassia fistula*), Kurchi (*Holarrhena antidysenterica*), etc. The list of other species under this forest plant is presented in Appendix C from Madhupur National Park covering tropical moist deciduous forests plants.

d. Mangrove forest plants:

This forest formation, known as the Sundarban, spills over into the State of West Bengal in India, is the largest single tract of such forest in the world. Here trees grow in the intertidal zones where the forest floors are inundated regularly by high tides. While in most other major mangrove forests, species of the family Rhizophoraceae are dominant, the most extensively occurring species in the Sundarban are Sundri (Heritiera fomes), and Gewa (Excoecaria agallocha). The list of plants has been presented in Appendix D from the Sundarbans covering mangrove forest plants.

e. Freshwater wetland forests:

A much smaller area of seasonally inundated freshwater forest occurs in the haors of Sylhet. The major tree species are Hijal (*Barringtonia cutangular*), Koroj (*Pongamia pinnata*), Borun (*Crataiva murvala*), Kadam (*Anthocephalous cadamba*) and *Salix tetrasperma*. Currently, no management interventions, other than the protection of these trees are carried out. The checklist of major and associated species is presented in Appendix E from Ratargul swamp forest covering freshwater wetland forests.

Species of Medicinal Values

Species provide different functions to an ecosystem and can service as producers, decomposers, as nutrients or can provide financial resources and also can help regulate climate. Floral species provide food directly and additionally, provide the raw materials for many types of timber, pharmaceuticals and drugs. A list of some of the common medicinal plants is listed in the table below.

Table C.1-8 List of the Major Medicinal Plants Commonly found in Bangladesh

Sl. No.	Scientific name	Common name	Therapeutic use
1.	*Adhatoda vasica*	Vasak	Expectorant coughs asthma
2.	*Aloe indica*	Gritakumari	Purgative, cooling agent, stomach diseases, preparation of lotion
3.	*Andrographis paniculata*	Kala megh	Hepatitis; antihelminthic dysentery; fevers & stomach trouble
4.	*Asparagus racemosus*	Shatamuli	Diuretic; measles; pox and diarrhea; energetic (tonic)
5.	*Azadirachta indica*	Neem	Tonic, antispasmodic; insecticide
6.	*Boerhaavia diffusa*	Punorvoba	Asthma, Diuretic, skin diseases
7.	*Centella asiatica*	Thankuni	Energetic (tonic); nerve diseases; (fairer)
8.	*Ocimum sanctum*	Tulsi	Cough, fever, dysentery, stomach diseases, mosquito repellent
9.	*Dillenia indica*	Chalta	Diarrhea and dysentery
10.	*Eclipta alba*	Keshraj	Skin diseases and jaundice
11.	*Ficus hispida*	Dumur	Diabetes
12.	*Phyllanthus emblica*	Amloki	Rich in vitamins (components of Triphala)
13.	*Saraca indica*	Ashok	Female diseases, dysentery
14.	*Terminalia arjuna*	Arjun	Heart diseases (a component of Triphala)
15.	*Terminalia bellirica*	Bohera	Stomach diseases
16.	*Terminalia chebula*	Haritaki	Stomach diseases

Source: (Khan & Rashid, 2006, Rahman et al., 2012, Bardhan et al., 2018)[9,10,11]

[9] Khan, N. A., & Rashid, A. M. 2006. A study on the indigenous medicinal plants and healing practices in Chittagong Hill Tracts (Bangladesh). African Journal of Traditional, Complementary and Alternative Medicines, 3(3), 37-47.

[10] Rahman, M.O., Antara, R.T., Begum, M., & Hassan, M.A. 2016. Floristic diversity of Dhamrai upazila of Dhaka with emphasis on medicinal plants. Bangladesh J. Bot. 41(1):71-85.

[11] Bardhan, S., Ashra, S., & Saha, T. 2018. Commonly Used Medicinal Plants in Bangladesh to treat Different Infections. J Immunol Microbiol. 2(1):1-3

(3) Status of Threatened Species

A threatened species is defined as a species whose numbers are significantly declining because of a loss of habitat or human disturbance and unless they are protected, they will become an endangered species. On the other hand, any species which is vulnerable to endangerment in the near future is generally categorized as a threatened species. According to IUCN, *Critically Endangered* (CR), *Endangered* (EN) and *Vulnerable* (VU) species are considered to be threatened with global extinction where in descending order of threat, the IUCN Red List threat categories are as follows:

1) RE: Extinct or Extinct in the Wild
2) CR: Critically Endangered, Endangered and Vulnerable: species threatened with global extinction
3) VU: Near Threatened: species close to the threatened thresholds or would be threatened without ongoing conservation measures
4) LC: Least Concern: species evaluated with a lower risk of extinction
5) DC: Data Deficient: no assessment because of insufficient data
6) NE: Note Evaluated

Faunal species of the country that are categorized under the threatened category are given below:

a. Mammals

Of these, 11 are already Regionally Extinct, 17 Critically Endangered, 12 Endangered and 9 Vulnerable. Mega species such as the Bengal Tiger, Asian Elephant, Western Hoolock, Hanuman Langur, Ganges River Dolphin, Bryde's Whale, etc. are under conservation concern according to IUCN Bangladesh 2015.

b. Birds

According to IUCN Bangladesh 2015, 19 bird species are evaluated as Regionally Extinct, 10 Critically Endangered, 12 Endangered and 17 Vulnerable covering 39 species as under the Threatened Category. Several migratory and waterbird species like the Spoon-billed Sandpiper, Spotted Greenshank, Indian Skimmer, Masked Finfoot, Baer's Pochard, Asian Dowitcher and a couple of species of eagles and vultures are under this category.

c. Reptiles

38 species of reptiles are found to be in threatened categories, of which 22 species are of Testudines, 14 species of Squamata (lizards and snakes) and 2 species of Crocodylia (IUCN

Bangladesh 2015).

d. Amphibians

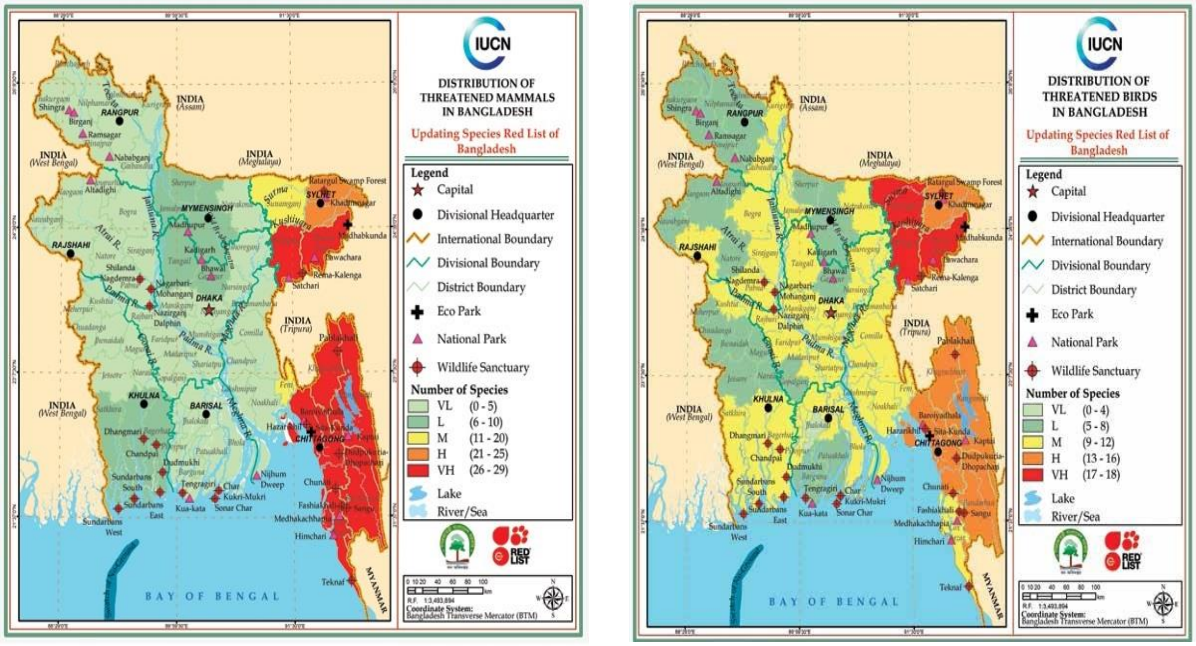
2 species of amphibians are CR, 3 pieces are EN and 5 species are VU and the rest is shown in Table C-1-9.

Table C.1- 9 Summary of the Red List of Bangladesh 2015

Sl. No.	Categories	Mammals	Birds	Reptiles	Amphibians
1.	Regionally Extinct (RE)	11	19	1	0
2.	Critically Endangered (CR)	17	10	17	2
3.	Endangered (EN)	12	12	10	3
4.	Vulnerable (VU)	9	17	11	5
5.	Near Threatened (NT)	9	29	18	6
6.	Least Concern (LC)	34	424	63	27
7.	Data Deficient (DD)	39	55	27	6
8.	Not Evaluated (NE)	7	0	20	0
	Total	**138**	**566**	**167**	**49**

Source: IUCN Bangladesh, 2015

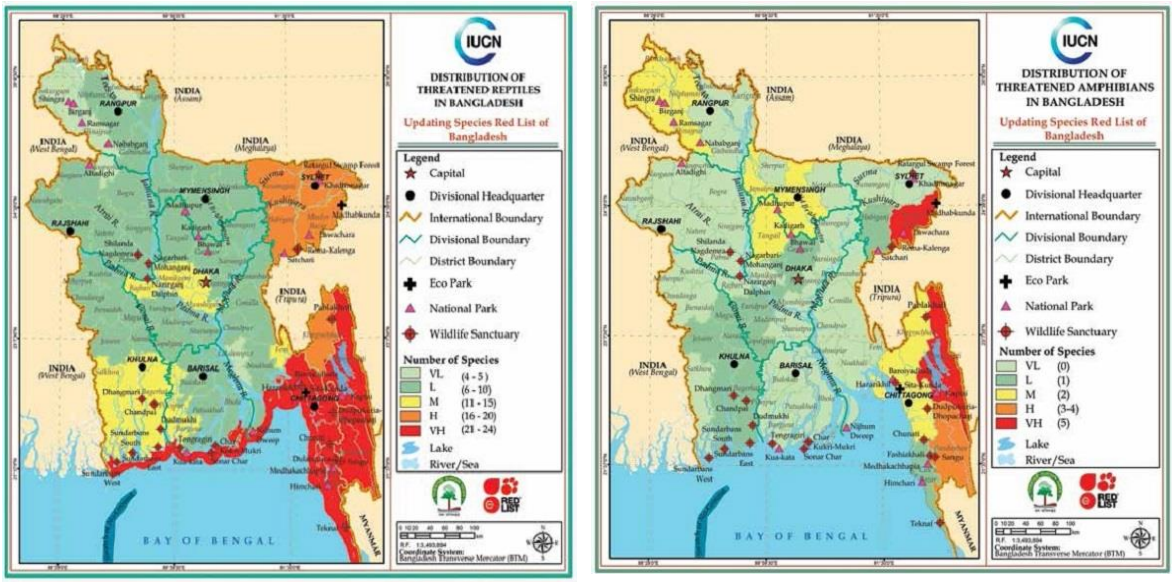
According to the IUCN Red List 2015 database, the distribution of endangered faunal species is shown in the figures where they are classified as the threatened species of each of the group into four categories-Very Low (VL), Low (L), Medium (M), High (H) and Very High (VH) numbers of species. For mammals, the Very High number of threatened species distributed in the Chattogram region whether for Birds, the Very High numbers are in the Sylhet region.



Source: Adopted from IUCN Bangladesh, 2015

Figure C.1-15 Distribution of Threatened Mammals & Birds in Bangladesh

Threatened reptile's species are 'Very Highly' distributed from the southwestern to south-eastern region of the country. However, threatened amphibian species are distributed in different regions of Bangladesh.

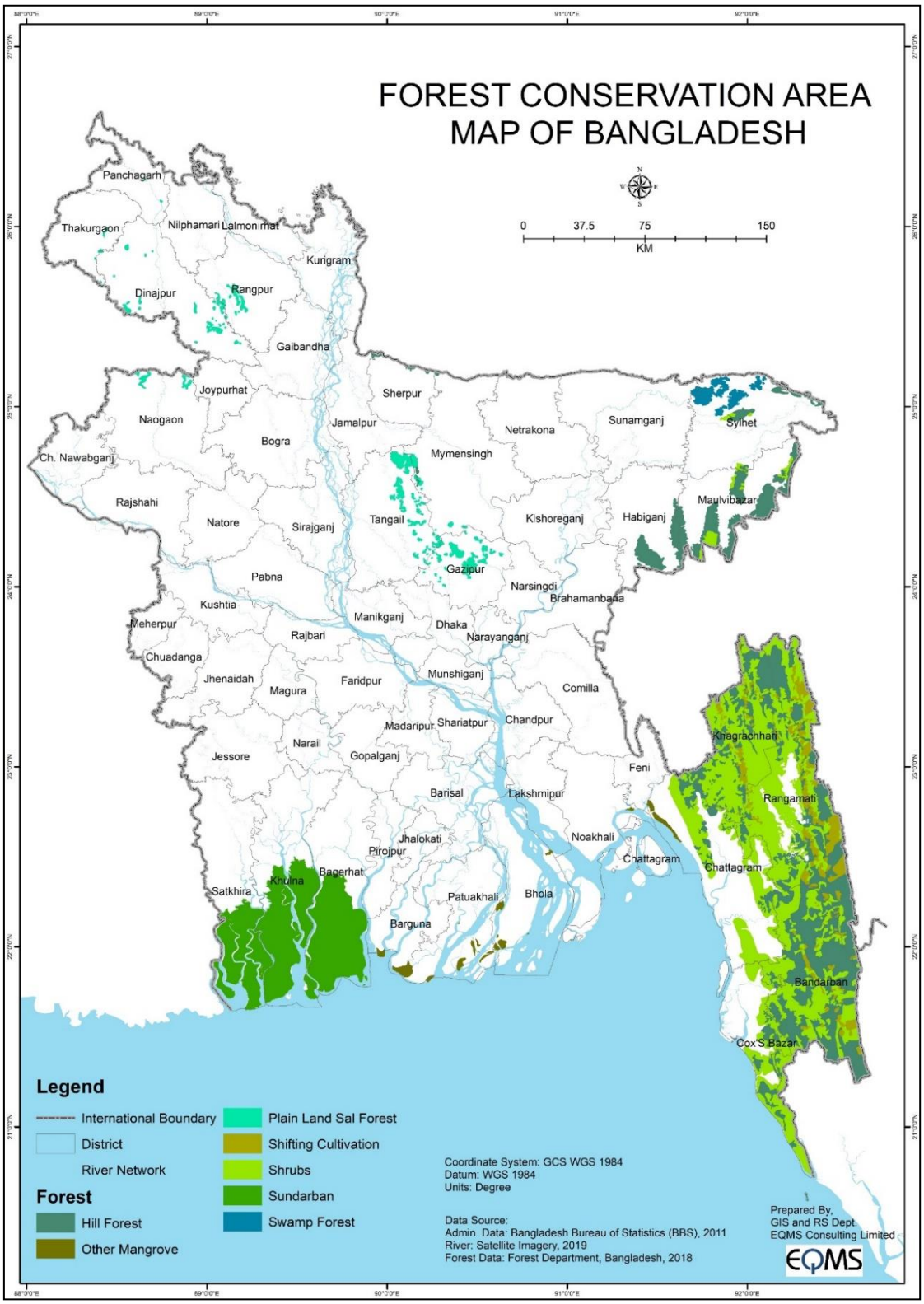


Source: Adopted from IUCN Bangladesh, 2015

Figure C.1-16 Distribution of Threatened Reptiles & Amphibians in Bangladesh

(4) Distribution of the Protected Areas, Sanctuaries and Sensitive Areas

The forest and tree resources inventory is being conducted by the Forest Department with the financial assistance of USAID and technical assistance of the United Nation's Food and Agriculture Organization (FAO) and Silva Carbon. This inventory provides a proper guideline to manage the country's tree and forest resources and to combat climate change at the national and international scale. In Bangladesh, the forest conservation areas are classified as Hill Forest, Sal Forest, Mangrove Forest, Shifting cultivation, and Swamp Forest. The forest conservation area is shown below.



Source: EQMS based on the information of BBS, 2011, Forest Department, 2018

Figure C.1-17 Forest Conservation Area Map of Bangladesh

(5) Vegetation and Forest Cover

A Country-wide forest and tree assessment was conducted in 2005 and 2007 while forest cover in the state forests and plantations was again mapped in 2013. On the basis of these two assessments, the status of forest and tree cover in the country is approximately as shown below.

Table C.1-10 Forest and Tree Cover in Bangladesh

Sl. No.	Category of Forest or Tree Cover	Area (Ha)	Remarks
1	Hill Forest	79,161	>10% Canopy Cover; all RF blocks not mapped
2	Sal Forest	17,495	>50% Sal trees
3	Mangrove Forest, Natural	390,550	
4	Bamboo	15,039	> 60% Bamboo
5	Plantations (Long Term and Short Term)	75,872	
6	Scattered Forest in CHT Mixed with Teak Plantations	116,971	
7	Plantations in USF (FD controlled)	17,347	
8	Plantations, Coastal	61,574	
9	Plantations, Rubber	9,217	
10	Plantations, Strip	62,329	
11	Cultivated land with >10% tree density	449,000	
12	Rural settlements with >10% tree cover*	1,197,000	
	Total	**2,491,555**	

Source: Bangladesh Forestry Master Plan 2017-2036

(6) Biodiversity Conservation Areas

According to sub-section (43) of section 2 of the Wildlife (Protection and Safety) Act, 2012 (Act No. 30 of 2012), Protected Area (PA) means all sanctuaries, national parks, community conservation areas, safari parks, eco-parks, botanical gardens declared by the Government under sections 13, 17, 18 and 19 of Chapter IV and special biodiversity conservation area established under section 22 of Chapter V and national heritage and kunjavana declared under section 23[12].

There are fifty-nine (59) PAs in total according to the Forest Department Website (February 3, 2021) in Bangladesh and forty-nine (49) of them are managed by the Bangladesh Forest Department. These PAs contain about 637,874.61 hectares (Terrestrial & Marine) and represents

[12] IUCN Bangladesh. 2015. Red List of Bangladesh Volume 1: Summary. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp. xvi+122.

a 4.32% area of the country[13]. The map of Bangladesh shows the location of the protected areas. There are different IUCN categories of Protected Areas in Bangladesh. The list of National parks, Marine Protected Area, Safari Park, Eco-Park, Botanical Garden, Aviary Park area are given in the tables below.

Table C.1-11 List of National Parks of Bangladesh

SN	National Parks	Location	IUCN Category	Area (ha.)	Gazette notification date
1	Bhawal National Park	Gazipur	IV	5,022.29	11-05-1982
2	Madhupur National Park	Tangail and Mymensingh	IV	8,436.13	24-02-1982
3	Ramsagar National Park	Dinajpur	IV	27.75	30-04-2001
4	Himchari National Park	Cox's Bazar	IV	1,729.00	15-02-1980
5	Lawachara National Park	Moulavibazar	II	1,250.00	07-07-1996
6	Kaptai National Park	Chittagong Hill Tracts	II	5,464.78	09-09-1999
7	Nijhum Dweep National Park	Noakhali	II	16,352.23	08-04-2001
8	Medhakachhapia National Park	Cox's Bazar	IV	395.92	04-04-2004
9	Satchari National Park	Habigonj	II	242.91	10-10-2005
10	Khadimnagar National Park	Sylhet	IV	678.80	13-04-2006
11	Baroiyadhala National Park	Chittagong	II	2,933.61	06-04-2010
12	Kuakata National Park	Patuakhali	II	1,613.00	24-10-2010
13	Nababgonj National Park	Dinajpur	IV	517.61	24-10-2010
14	Singra National Park	Dinajpur	IV	305.69	24-10-2010
15	Kadigarh National Park	Mymensingh	IV	344.13	24-10-2010
16	Altadighi National Park	Naogaon	IV	264.12	14-12-2011
17	Birgonj National Park	Dinajpur	IV	168.56	14-12-2011
18	Sheikh Jamal Inani National Park	Cox's Bazar		7,085.16	15-Apr-19

Source: Adopted from the Forest Department, 2021

Table C.1-12 List of Safari Parks of Bangladesh

Name	Location	Area (ha.)	Gazette notification date
Bangabandhu Sheikh Mujib Safari Park	Gazipur	1,493.93	2013
Bangabandhu Sheikh Mujib Safari Park	Cox's Bazar	600	1999

Source: Adopted from the Forest Department, 2021

[13] BFD, 2021. Protected Areas-Introduction. http://bforest.gov.bd/site/page/5430ce33-561e-44f6-9827-ea1ebaa2c00d/-. Retrieved on 26.10.2021

Table C.1-13 List of Eco Parks of Bangladesh

Name	Location	Area (ha.)	Gazette notification date
Madhabkundu Eco-Park	Moulavibazar	265.68	2001
Sitakunda Botanical Garden and Eco-Park	Chittagong	808	1998
Modhutila Eco-Park	Sherpur	100	1999
Banshkhali Eco-Park	Chittagong	1,200	2003
Kuakata Eco-Park	Patuakhali	5,661	2005
Tilagar Eco-Park	Sylhet	45.34	2006
Borshijora Eco-Park	Moulavibazar	326.07	2006
Jamuna Bridge Eco-Park	Jamuna River Bank, Pabna	50.02	2008
Pirojpur Rivervew Eco-Park	Pirojpur	2.54	2010
Char-muguria Eco-park	Madaripur	4.20	2015

Source: Adopted from the Forest Department, 2021

Table C.1-14 List of Botanical Gardens

Name	Location	Area (ha.)	Gazette notification date
National Botanical Garden	Dhaka	84.21	1961
Baldha Garden	Dhaka	1.37	1909

Source: Adopted from the Forest Department, 2021

(7) Wildlife Sanctuaries

Sanctuary means an area where capturing, killing, shooting or trapping of wildlife is prohibited and managed for the conservation of all natural resources such as vegetation, soil and water mainly for undisturbed breeding of wildlife and which is declared as such by notification in the official Gazette under section 13 of the Wildlife (Conservation and Security) Act, 2012. The sanctuaries declared according to the Wildlife (Conservation and Security) Act, 2012 are a wildlife sanctuary, bird sanctuary, elephant sanctuary, wetland dependent animal sanctuary or marine protected area.

The primary objective of the sanctuaries is conservation of the forest and habitat of wildlife. However, for wetlands declared a sanctuary, the objective refers to protect the occupational, traditional or the right of livelihood of the local community of the area such as fishermen, boatmen, etc.

Between 1981 and 2021, 24 wildlife sanctuaries were established in the country. Among them, three wildlife sanctuaries are located at the Sundarbans. The list of Wildlife Sanctuaries is given below the table and figure.

Table C.1-15 Wildlife Sanctuaries of Bangladesh

Sl. No.	Wildlife Sanctuaries	Location	IUCN category	Area (ha.)	Species in concern	Gazette notification date
1	Rema-Kalenga Wildlife Sanctuary	Hobigonj	II	1,795.54	Approx. 600 species of plants, 215 species of birds, and 29 species of mammals including White-Rumped Vulture, Black Giant Squirrel, Phayre's Leaf Monkey, Common Green Magpie, White-cheeked Partride, Bengal Slow Loris, Assamese Macaque, Northern Pig tailed Macaque, and Capped Langur, etc.	07-07-1996
2	Char Kukri-Mukri Wildlife Sanctuary	Bhola	IV	40.00	Fishing cat, Oriental small-clawed otter, Monitor lizard, Bengal monitor, etc.	19-12-1981
3	Sundarban (East) Wildlife Sanctuary	Bagerhat	Ib	122,920.90	Royal Bengal tigers, wild boar, (spotted deer), smooth-coated otter and macaque monkey, marine turtles' estuarine crocodile and the Indian python, Ganges River Dolphin and Irrawaddy Dolphin, White-Rumped Vulture, etc.	29-06-2017

Sl. No.	Wildlife Sanctuaries	Location	IUCN category	Area (ha.)	Species in concern	Gazette notification date
4	Sundarban (West) Wildlife Sanctuary	Satkhira	Ib	119,718.88	Royal Bengal tigers, wild boar, (spotted deer), smooth-coated otter and macaque monkey, marine turtles' estuarine crocodile and the Indian python, Ganges River Dolphin and Irrawaddy Dolphin, White-Rumped Vulture, etc.	29-06-2017
5	Sundarban (South) Wildlife Sanctuary	Khulna	Ib	75310.30	Royal Bengal tigers, wild boar, (spotted deer), smooth-coated otter and macaque monkey, marine turtles, estuarine crocodile and the Indian python, Ganges River Dolphin and Irrawaddy Dolphin, White-Rumped Vulture, etc.	29-06-2017
6	Pablakhali Wildlife Sanctuary	Chittagong Hill Tracts	II	42069.37	Asian elephant, Capped langur, Rhesus macaque, etc.	20-9-1983
7	Chunati Wildlife Sanctuary	Chittagong	IV	7763.97	Asian Elephants, muntjac deer, fishing cat, wild boar and Indian crested porcupine, etc.	18-3-1986
8	Fashiakhali Wildlife Sanctuary	Cox's Bazar	IV	1302.42	Asian Elephants, Northern Pig-tailed Macaque,	11-4-2007

Sl. No.	Wildlife Sanctuaries	Location	IUCN category	Area (ha.)	Species in concern	Gazette notification date
					Slow Loris, Jungle Cat, Fishing Cat, and White-crested Laughing Thrush, etc.	
9	Dudpukuria-Dhopachari Wildlife Sanctuary	Chittagong	IV	4716.57	Approx. 600 species of plants, 400 vertebrate species – 200 species of birds and 45 species of mammals including Asian Elephant, Bintorong, Western Hoolock Gibbon, Fishing Cat, Grey Peacock Pheasant, Oriental Pied Hornbill, King cobra, etc.	6-4-2010
10	Hajarikhil Wildlife Sanctuary	Chittagong	II	1177.53	Approx. 250 species of plants and 150 species of birds including Himalayan Serow, Capped Langur, Crab-eating Mongoose, Grey Peacock Pheasant, Oriental Pied Hornbill, etc.	6-4-2010
11	Sangu Wildlife Sanctuary	Bandarban	II	2331.98	Asian Elephants, barking deer, Asian black bear, monitor lizard, Bengal monitor, etc.	6-4-2010
12	Teknaf Wildlife Sanctuary	Cox's Bazar	IV	11,614.57	Approx. 13 species of amphibians, 56 species of reptiles, 260 species of	09-12-2009

Sl. No.	Wildlife Sanctuaries	Location	IUCN category	Area (ha.)	Species in concern	Gazette notification date
					birds and 55 species of mammals including Asian Elephant, Boilam, Great Slaty Woodpecker, Rhesus Macaque and Hog Badger, Blue Bearded Bee Eater, etc.	
13	Tengragiri Wildlife Sanctuary	Barguna	II	4,048.58	Fishing Cat, Smooth Coated Otter, Brown winged Kingfisher Estuarine Crocodile, White-Rumped Vulture, etc.	24-10-2010
14	Dudhmukhi Wildlife Sanctuary	Bagerhat	II	170.00	Ganges River Dolphin and Irrawaddy Dolphin, White-Rumped Vulture, etc.	29-01-2012
15	Chadpai Wildlife Sanctuary	Bagerhat	II	560.00	Ganges River Dolphin and Irrawaddy Dolphin, White-Rumped Vulture, etc.	29-01-2012
16	Dhangmari Wildlife Sanctuary	Bagerhat	II	340.00	Ganges River Dolphin and Irrawaddy Dolphin, White-Rumped Vulture	29-01-2012
17	Sonarchar Wildlife Sanctuary	Patuakhali	II	2,026.48	White-Rumped Vulture, etc.	24-12-2011
18	Nazirganj Wildlife (Dolphin) Sanctuary	Pabna	VI	146.00	Ganges River Dolphin	01-12-2013
19	Shilanda-Nagdemra Wildlife (Dolphin) Sanctuary	Pabna	VI	24.17	Ganges River Dolphin	01-12-2013
20	Nagarbari-Mohanganj Dolphine Sanctuary	Pabna	VI	408.11	Ganges River Dolphin	01-12-2013

Sl. No.	Wildlife Sanctuaries	Location	IUCN category	Area (ha.)	Species in concern	Gazette notification date
21	Pankhali Wildlife (Dolphin) Sanctuary	Khulna		404.00	Ganges River Dolphin and Irrawaddy Dolphin	04-03-2020
22	Shibsha Wildlife (Dolphin) Sanctuary	Khulna		2,155.00	Ganges River Dolphin and Irrawaddy Dolphin	04-03-2020
23	Vadra Wildlife (Dolphin) Sanctuary	Khulna		868.00	Ganges River Dolphin and Irrawaddy Dolphin	04-03-2020
24	Padma Setu Wildlife Sanctuary	Madaripur, Shariotpur, Munshiganj, Faridpur		1,772.605	112 species of birds, 25 species of mammals, 16 species of amphibians, 35 species of reptiles, 89 species of fishes and 331 species of flora including Ganges River Dolphin, Ganges softshell Turtle, Gangetic Gharial, Common Otter, Brown Fish Owl, River Lapwing, Hilsa, etc.	26-11-2020

Source: EQMS based on the information of BBS, 2011, Landsat 8 Imagery, 2019 and Forest Department, 2021

Figure C.1-18 Wild Sanctuary Areas of Bangladesh

(8) Ecologically Critical Area

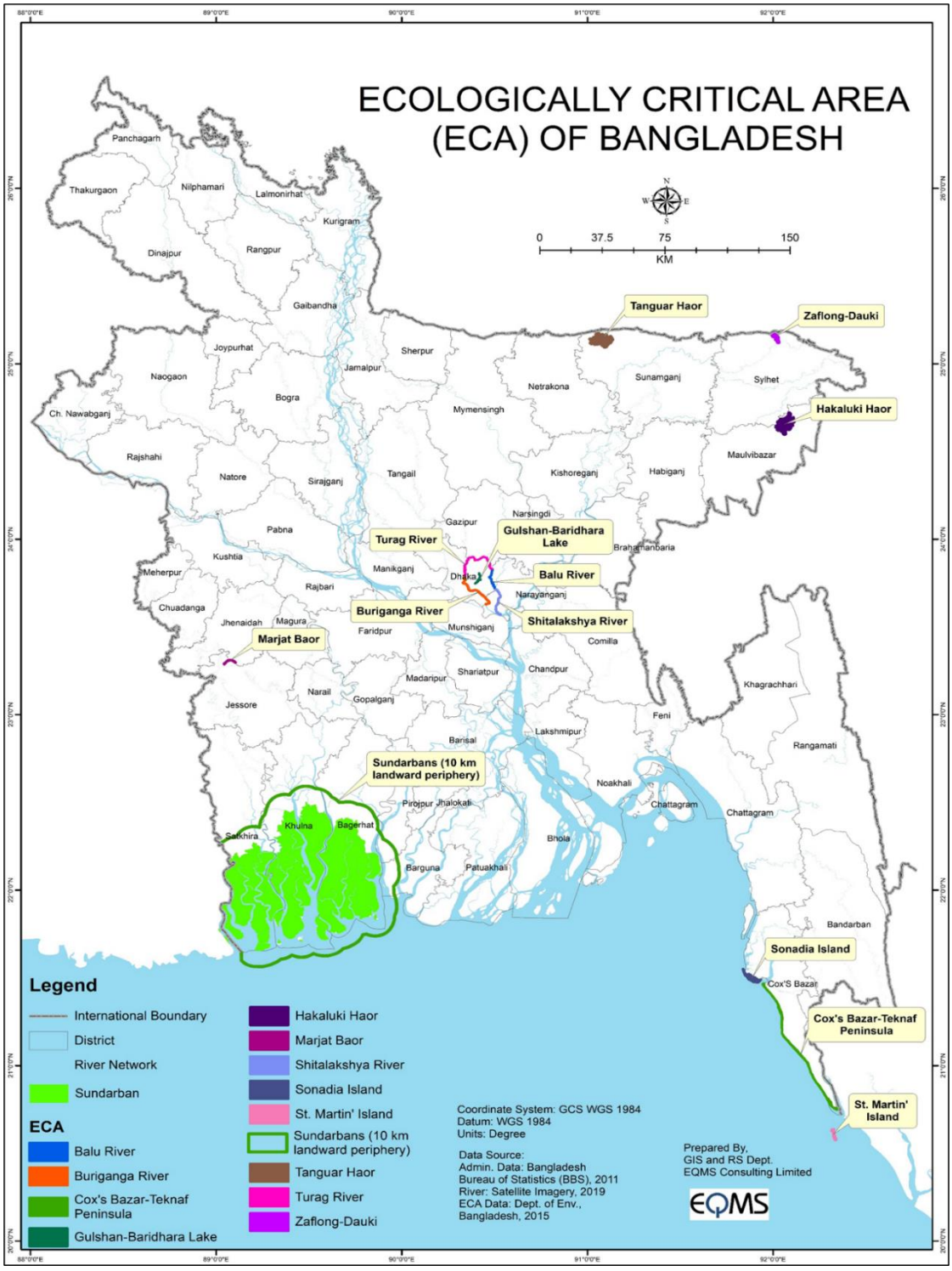
The Ecologically Critical Areas (ECA) are ecologically defined areas or ecosystems affected adversely by the changes brought through human activities. To improve the condition of ecosystems, the Government declared seven ECAs in 1999. During 2001−2009, five other ECAs were declared. These includes four rivers around Dhaka city emphasizing the impacts of rapid urbanization and industrialization around the capital. The latest ECA is a river including its shores in the north-eastern part of the country declared in early 2015. The table below represents the list of ECAs of Bangladesh including the type, location, area, and year of declaration.

Table C.1-16 List of Ecologically Critical Area (ECA) of Bangladesh

No.	Name of the ECA	Type of Ecosystem	Location	Areas (ha)	Year of Declaration
1	Cox's Bazar-Teknaf Peninsula	Coastal-Marine	Cox's Bazar	20,373	1999
2	Sundarbans (10 km landward periphery)	Coastal-Marine	Bagerhat, Khulna Barguna, Pirojpur and Satkhira	292,926	1999
3	St. Martin's Island	Marine Island with coral reefs	Teknaf upazila, Cox's Bazar	1,214	1999
4	Hakaluki Haor	Inland Freshwater Wetland	Sylhet and Moulvibazar	40,466	1999
5	Sonadia Island	Marine Island	Moheshkhali, Cox's Bazar	10,298	1999
6	Tanguar Haor	Inland Freshwater Wetland	Tahirpur, Sunamganj	9,727	1999
7	Marjat Baor	Oxbow Lake	Kaliganj upazila of Jhenaidah and Chaugacha upazila of Jessore	325	1999
8	Gulshan-Baridhara Lake	Urban Wetland	Dhaka city	101	2001
9	Buriganga	River	Around Dhaka	1,336	2009
10	Turag	River	Around Dhaka	1,184	2009
11	Sitalakhya	River	Around Dhaka	3,771	2009
12	Balu including Tongi canal	River	Around Dhaka	1,315	2009
13	Jaflong-Dawki	River	Jaflong, Sylhet	1,493	2015

Source: Department of Environment (2015)

The figure below shows the ECA map presenting the 13 declared Ecologically Critical Areas of Bangladesh.



Source: EQMS based on the information of BBS, 2011, Landsat 8 Imagery, 2019 and Department of Environment, 2015

Figure C.1-19 Ecological Critical Areas of Bangladesh

(9) Other Sensitive Coastal Areas

a. Vulture Zones

As a part of the vulture conservation, in 2014, the Government of Bangladesh declared two Vulture Safe Zones (VSZs) through gazette notification, with the two last known vulture colonies in the centers, covering a total of 47,380.44 km^2 in the Khulna and Sylhet regions (Table below). These are the first government-endorsed VSZs in the world. Bangladesh has also established its first Vulture Feeding Station in Rema-Kalenga Wildlife Sanctuary in Sylhet region[14].

Table C.1-17 Vulture Safe Zone -1

The name of the safe zone of the vulture	Districts	The total volume of Bangladesh's area of vulture's safe area	The total area of the core area of the Bangladesh region of vulture's safe area	Important areas for vultures or hotspots	Comments	The protected area identified for the vultures, and the area declared by the government, and its size
The safe areas of vulture under Sylhet, Dhaka (partial) and Chittagong division	Sylhet, Habiganj, Sunamganj, Moulvibazar, Netrokona, Kishoreganj, Gazipur, Mymensingh, Brahmanbaria, Narsingdi, Comilla and Khagrachari	19,663.18 square kilometers	7,459.182 square kilometers	Rama-Kalenga Wildlife Sanctuary	Reproduction and resting place of vulture	National Park (Lawachara, Satchari, Khadimnagar), Wildlife Sanctuary: (Rema-Kalenga) Eco-Park: (Madhabkunda, Tilagar, Barshijora) The total area is 4,603.98 hectares or 46.039 sq km
				Deorchhara and Kalachara, Madhabpur, Karimpur (Moulvibazar)	Reproduction and resting place of vulture	
				Nabiganj (Habiganj)	Reproduction and resting place of vulture	

Source: Forest Department, 2021

[14] IUCN Bangladesh 2016. Vultures and Vulture Safe Zones of Bangladesh. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, pp. x+184.

Table C.1-18 Vulture Safe Zone -2

The name of the safe zone of the vulture	Districts	The total volume of Bangladesh's area of vulture's safe area vulture's safe area	The total area of the core area of the Bangladesh region of vulture's safe area region of vulture's safe area	Important areas for vultures or hotspots	Comments	The protected area identified for the vultures, and the area declared by the government, and its size
The safe areas of vultures under Khunna, Barisal and Dhaka (partial) division	Faridpur, Magura, Jhenaidah, Madaripur, Jessore, Gopalganj (except Tungipara), Narail, Shariatpur, Barisal, Bagerhat, Khulna, Satkhira, Pirojpur (excluding Bhandaria), Jhalokati, Patuakhali and Barguna	27717.26 square kilometers	7846.258 square kilometers	Batiaghata (Khulna)	Reproduction and resting place of vulture	National Park (Kuakata), Wildlife Sanctuary: (Sundarbans East, Sundarban West, Sundarban South, Sonar Char, Tangragiri, Chandpai, Dukhmukhi, Dhangmari) The total area of 148457.56 hectares or 1485.57 sq km.
				Loudob (Dakop, Khulna)	Reproduction and resting place of vulture	
				Dumuria (Khulna)	Reproduction and resting place of vulture	

Source: Forest Department, 2021

b. Hilsha Sanctuaries

The government of Bangladesh has passed a number of acts, ordinances and rules to provide a framework for the exploitation, development, management and conservation of its fisheries sector and aquatic resources. The Bangladesh fisheries authority has also taken several measures to conserve and manage artisanal hilsa fishing. As a migratory fish, both inland and marine fishery legislation[15] is required for its management and conservation.

[15] Implemented by the Protection and Conservation of Fish Rules (1985)

Table C.1-19 Hilsha Fish Sanctuary Area

No	Hilsha Fish Sanctuary Area	Period
1	From Shatnol of Chandpur to Char Alexander of Laxmipur (100 k.m. stretch of lower Meghna River)	From March to April each year
2	Char llisha to Char Pial of Bhola district (90 k.m. stretch of Shahbazpur channel, a tributary of Meghna River)	
3	Bheduria of Bhola district to Char Rustam of Patuakhali (100 k.m. stretch of Tetulia River)	
4	Whole 40 k.m. stretch of Andhermanik River in Kalapara Upazila of Patuakhali	
5	20 k.m. stretch of Lower Padma River between Naria-Bhedorganj Upazila of Shariatpur in the north and Matlab Upazila of Chandpur and Bhedorganj Upazila of Shariatpur in the south	
6	Total Length of 82 km between three different river point of Barisal district. Three points are: 1. Total 13.70 km stretch of the Kalabadar River between Habinagar point, Barisal Sadar Upazila and Bamnar Char point, Mehendigonj Upazila of Barishal. 2. Total 8.81 km stretch of the Gajaria River between Bamnar Char point of Mehendigonj Upazila and Hizla Launch Ghat point, Hizla Upazila of Barishal 3. Total 59.51km stretch of the Meghna River between Hizla Launch Ghat point of Hizla Upazila and Dashkim-Paschim Jangalia point, Mehendigonj Upazila of Barishal	

Source: Ministry of Fisheries and Livestock (2011, 2018)

c. Ramsar Sites

The Convention on Wetlands, known as the Ramsar Convention, is an intergovernmental environmental treaty established in 1971 by UNESCO, which came into force in 1975. It provides support for national action and international cooperation regarding the conservation of wetlands, and wise sustainable use of their resources. The “Ramsar site” is a wetland site designated to be of international importance under the Ramsar Convention. Bangladesh currently has 2 sites designated as Wetlands of International Importance (Ramsar Sites) with a surface area of 611,200 hectares.

Table C.1-20 List of Ramsar Sites of Bangladesh

No.	Site Name	Area (ha)	Designation Dates
1.	Sundarbans Reserved Forest	601,700	21-05-1992
2.	Tanguar Haor	500	10-07-2000

Source: Ramsar Sites Information Services[16]

d. Coastal Area and Marine Fishing Zone and Fish Sanctuary

i. Marine Fishing Zone

Bangladesh is one of the most resourceful countries in the world with its wide range of marine aquatic bio-diversity. There are about 1093 marine aquatic organisms where 44.35% are finfish, 32.23% shellfish, 15.10% seaweed and only 8.32% are other organisms including shrimps. The details in the number of species and their percentages are shown in Table C. 1-21.

Table C.1-21 Number and Percentage of Marine Aquatic Organism

Group of the Organisms		No. of Species	%
1.	Finfish	486	44.35
2.	Sharks, Rays, Skates and Dolphin	21	1.92
3.	Shrimps	36	3.30
4.	Lobster	6	2.01
5.	Crabs	16	
6.	Sea Turtle	3	0.27
7.	Crocodiles	3	0.27
8.	Squid and Cuttle Fish	7	0.64
9.	Shellfish (Univalves and Bivalves)	350	32.23
10.	Seaweeds	165	15.10
Total		**1093**	**100**

Source: Kabir, 2006

Total production was estimated at 750,000 mt from inland capture fisheries, 850,000 mt from inland aquaculture, 95,000 mt from coastal aquaculture (on shore aquaculture; major species is shrimp and a few finfish) and 589,000 mt from marine fisheries.

Both inland and marine capture fisheries have declined by around 5% and 1% per annum.

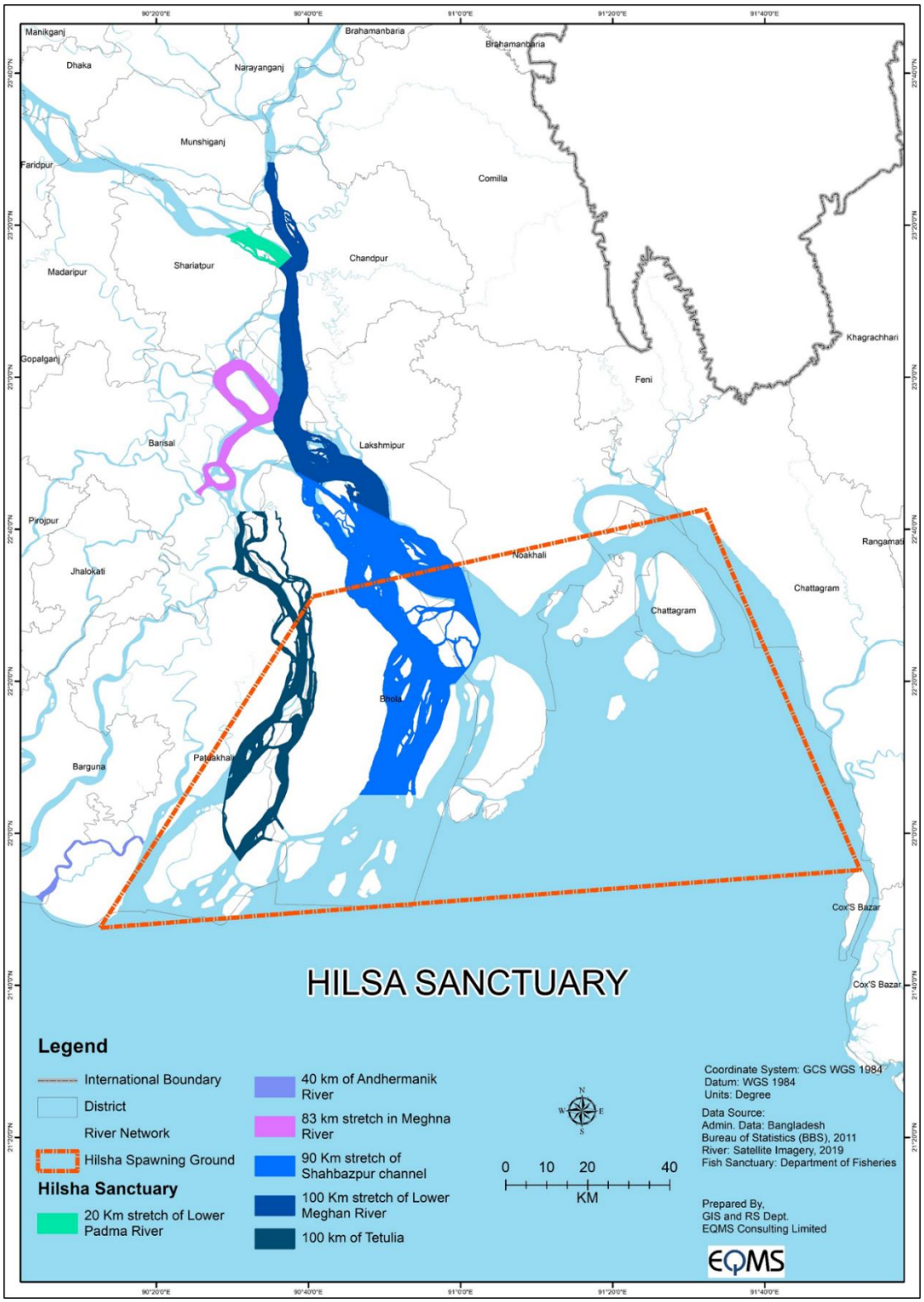
[16] https://www.ramsar.org/wetland/bangladesh

Current levels of marine fisheries production are only being maintained by significant increases in fishing efforts, which if not contained will contribute to greater reductions in production in the long term.

There are four fishing zones in the Bay of Bengal. Four different areas in the Middle ground and South patches have been declared 'Fish sanctuaries' by the Government in the Bay of Bengal-Bangladesh maritime area.

1) South patches, spans 3,400 km2 (towards km west of Cox's Bazar, 10-40 m depths)
2) South of south patches, spans 2,800 km2 (towards 5 km south west of Teknaf, 10- 100 m depths). These two fishing grounds (south patches and south of south patches) lie between 20°50′N to 21°40′N latitude and 91°00′E to 91°50′E longitude.
3) Middle ground, 4,600 km2 (towards 30 km south of Hatiya and Patuakhali, 10- 100 m depths). It lies between 20°50′N to 21°20′N latitude and 90°00′E to 91°00′E longitude.
4) Swatch of no ground, 3,800 km2 (towards 29 km south of Dubla Island, 10-100 m depths). This area lies between 21°00′N to 21°25′N latitude and 89°00′E to 90°00′E longitude.

The figure below shows the Hilsa Sanctuary area in accordance with the fishing zones.



Source: EQMS based on the information of BBS, 2011, Landsat 8 Imagery, 2019 and Department of Fisheries, GoB

Figure C.1-20 Hilsa Sanctuary of Bangladesh

ii. Fish Sanctuary

The four most important spawning grounds in the country are: Dhalerchar of Charfashion in Bhola (about 125 square kilometers); Monpura in Bhola (about 80km2); Moulavichar of Hatia in noakhali (about 120km2); and Kalirchar of Sandwip (about 194km2). Hilsa spawn throughout the year but the peak season is September and October. After hatching from free-floating eggs, the fry remains in their nursery grounds to feed and grow. A mature female hilsa can be between 30 and 55 centimeters long and lays 0.1 to 2 million eggs in freshwater. Hatching takes between about 23 to 26 hours at an average temperature of 23°C. The newly hatched larvae (about 2.3 millimeters long) make their way downstream to the sea through their freshwater nursery grounds, feeding and growing on the way. At this juvenile stage of their life cycle, a period of five or six months, they are known locally as Jatka. They are abundant between February and May in the foreshore.

Four sanctuaries were declared hilsa sanctuary areas in 2005 and the fifth in 2011. Recently, a 83km stripe in Meghna River (from Hizla to Mehendiganj) in the Barisal district was declared the sixth hilsa sanctuary of Bangladesh in 2018. According to Dept. of Forest (DOF), there are six main hilsa sanctuary grounds:

1) 100km stretch of the Meghna river from Shatnol, Chandpur District to Char Alexander, Lakshmipur District
2) 90km of Shahbajpur Channel, a tributary of the Meghna river, from Madanpur/Char Ilisha to Char Pial, Bhola District
3) 100km of the Tentulia river from Bheduria, Bhola District to Char rustom, Patuakhali District
4) 40km of the Andharmanik river route at Kalapara Upazila, Patuakhali District
5) 20km stretch of the Padma river's lower basin from narhira to Bhedarganj, Shariatpur District
6) 83km stripe in Meghna River (from Hizla to Mehendiganj) in Barisal district

iii. Marine Reserve/Protected Areas of Bangladesh

In 2000, the Government established a Marine Reserve extending 698 km^2 at Middle Ground and South Patches in the Bay of Bengal following the provision of clause 28 of Marine Fisheries Ordinance, 1983. Also, another one, "Nijhum Dwip Marine Reserve / MPA" was declared in 2019, through S.R.O. No. 211-Law/2019 dated 23rd June 2019 under the same provision.

The Government of Bangladesh has established the country's first marine protected area, "Swatch of No-Ground", of the Bay of Bengal, declared on the 27th of October 2014 under the

Bangladesh Wildlife (Conservation and Security) Act, 2012. The list of Marine Protected Areas[17] of Bangladesh is presented in Table C.1- and Figure C.1-22 (marine fishing zone) and C.1-23 (marine protected area).

Table C.1-22 Marine Reserve/Protected Areas of Bangladesh

No.	Name of Site	Location	Area (ha)	Declaration Date
a.	Marine Reserve	Middle Ground and South Patches of Bay of Bengal	69,800	2000
b.	Swatch of No-Ground Marine Protected Area	South Bay of Bengal	173,800	2014
c.	Nijhum Dwip Marine Reserve / MPA	Central Bay of Bengal	318,800	2019

Source: Department of Forest, GoB (31st January 2021) & World Fish Database

e. Migratory Bird Routes

Bangladesh is located in the path of two migratory bird flyways: The East Asian–Australasian Flyway (EAAFP) and Central Asian Flyway (CAF). The country comprises six Flyway Network Sites those are used by migratory birds as their wintering staging ground and migratory routes as shown in Table C.1- and Figure below presenting the bird area map.

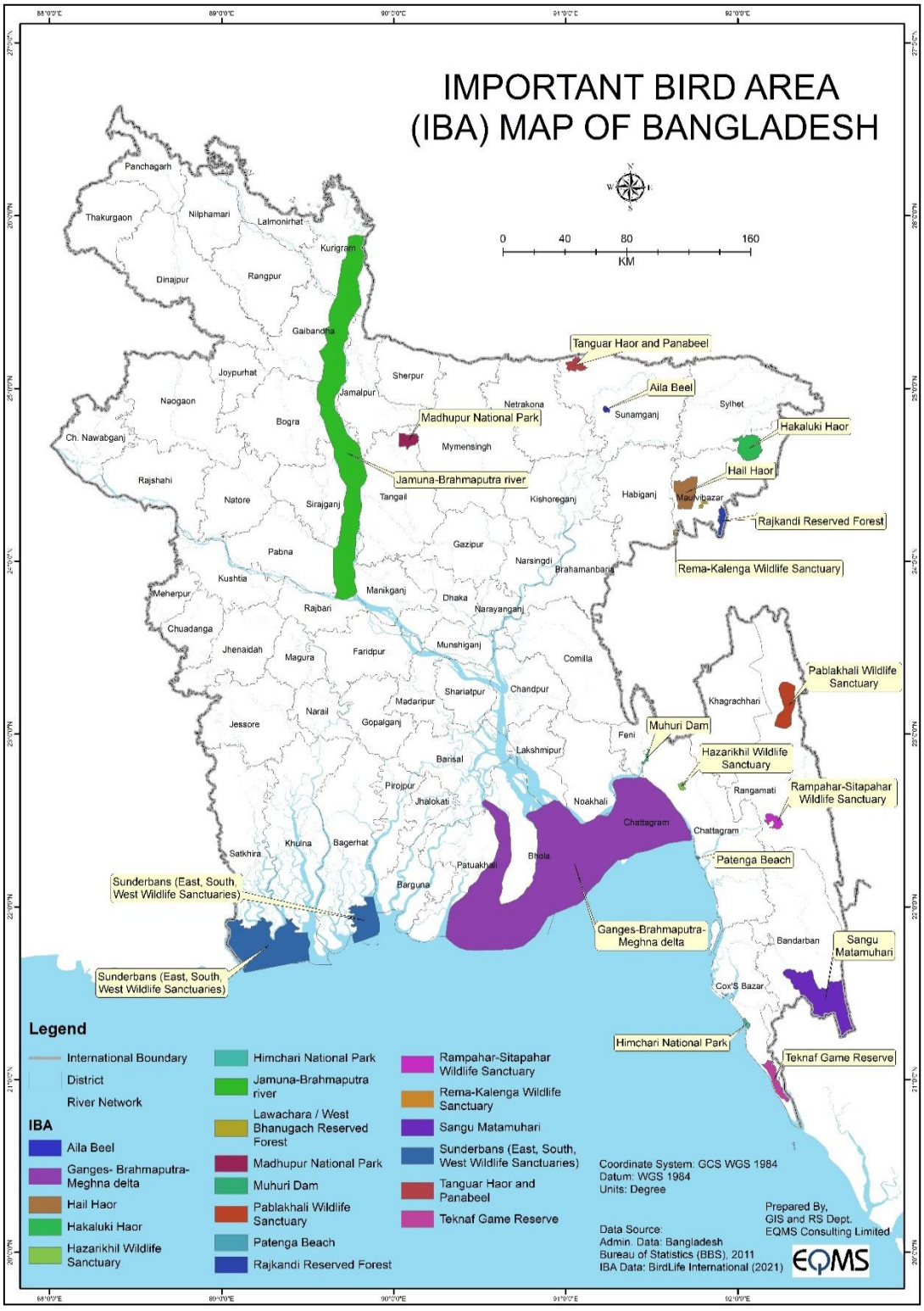
Table C.1-23 Migratory Flyway Sites of Bangladesh

No.	Site Name	Site Code	Area (ha)	Date of Joining
1	Nijhum Dweep National Park	EAAF102	16352.2	29 September, 2011
2	Sonadia	EAAF103	4924.0	29 September, 2011
3	Hakaluki Haor	EAAF104	18000.0	29 September, 2011
4	Tanguar Haor	EAAF105	9,727	29 September, 2011
5	Hail Haor	EAAF106	60000.0	25 March, 1996
6	Ganguirar Char	EAAF141	6,971	25 September, 2018

Source: EAAFP Official Website[18]

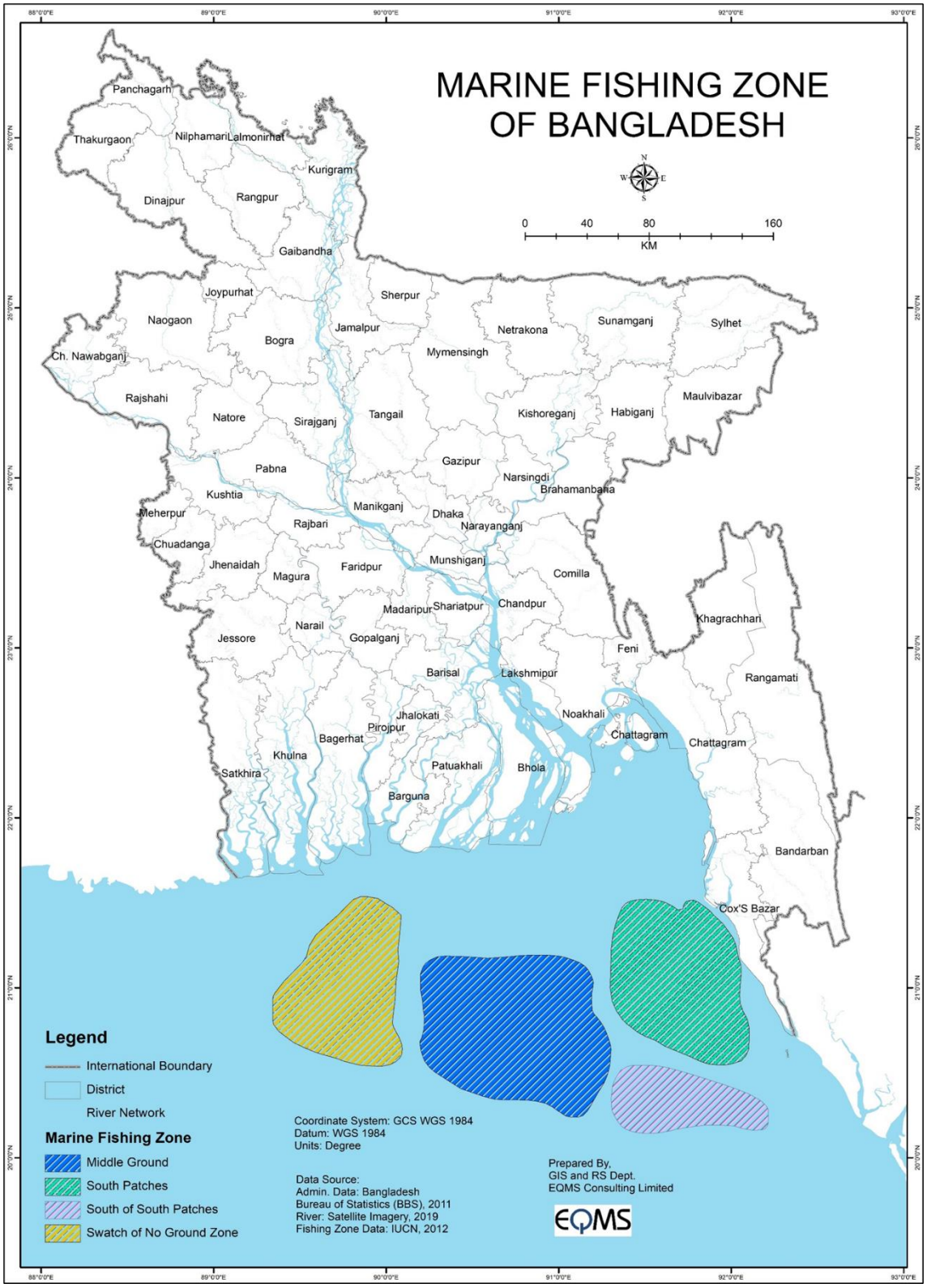
[17] https://mel.cgiar.org/projects/ecofish/287/the-declaration-of-marine-protected-area-mpa--to-generate-more-sustainable-fishing-and-livelihoods--while-protecting-the-marine-biodiversity-

[18] https://www.eaaflyway.net/bangladesh/



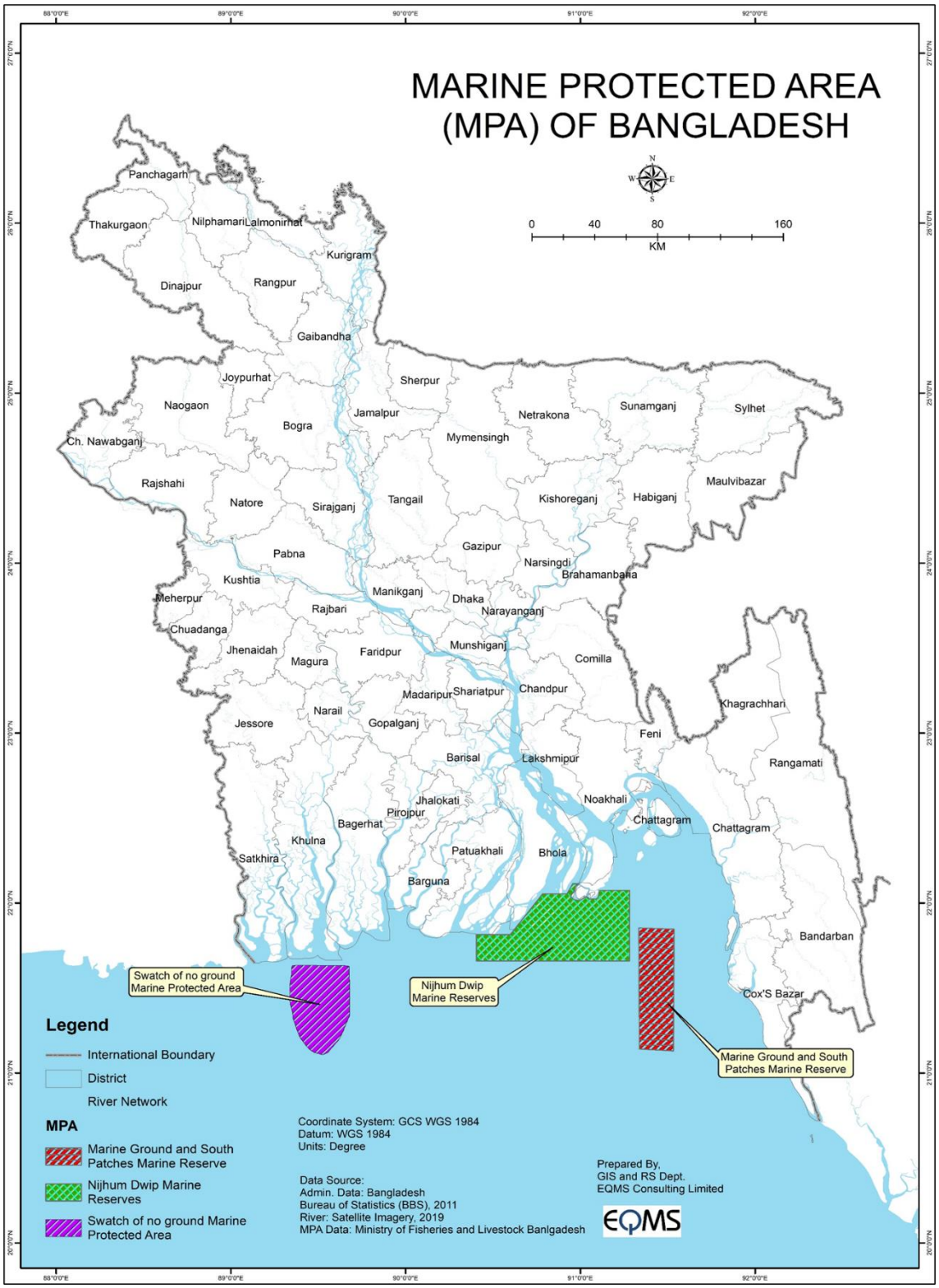
Source: EQMS based on the information of BBS, 2011, Landsat 8 Imagery, 2019 and BirdLife International, 2021

Figure C.1-21 Important Bird Area Map of Bangladesh



Source: EQMS based on the information of BBS, 2011, Landsat 8 Imagery, 2019 and IUCN, 2012

Figure C.1-22 Marine Fishing Zone of Bangladesh



Source: EQMS based on the information of BBS, 2011, Landsat 8 Imagery, 2019 and Ministry of Fisheries and Livestock Bangladesh

Figure C.1-23 Marine Protected Area of Bangladesh

C.1.11 Social Environment

(1) Population and GDP

Bangladesh has made remarkable progress in the last three decades towards achieving self-sufficiency in food grains, economic development, health and sanitation. At the beginning of the nineteenth century, the total population was 28.93 million in East Bengal, the region that became East Pakistan and eventually Bangladesh. After partitioned from India in 1947, the population of East Pakistan was 42.06 million according to the 1951 census; it was the 11th most densely populated country in the world. The first post-independence census, taken in 1974, reported a national population of 71.48 million. The 1981 census reported a population of 87.12 million and a 2.3 percent annual growth rate. The population of Bangladesh tripled within 80 years. In July 1988, the population, by then the eighth largest in the world, and the average annual growth rate was 2.6 percent (Bangladesh, Country Study). The recent population size is 144 million (Census, 2011).

According to Bangladesh Bureau of Statistics (BBS) data, Bangladesh's economy grew 3.51% in fiscal 2019-20, the lowest in three decades, as the Covid-19 pandemic is impacting all areas of the economy. The economic activities, however, began recovering gradually in the subsequent fiscal 2020-21 following the lifting of the more than two-month long countrywide shutdown, and the recovery efforts by people continued until the beginning of the second wave of coronavirus in March 2021. The table below shows the current national income and GDP of 2020-2021 (prov.).

Table C.1-24 Gross Domestic Product (GDP)

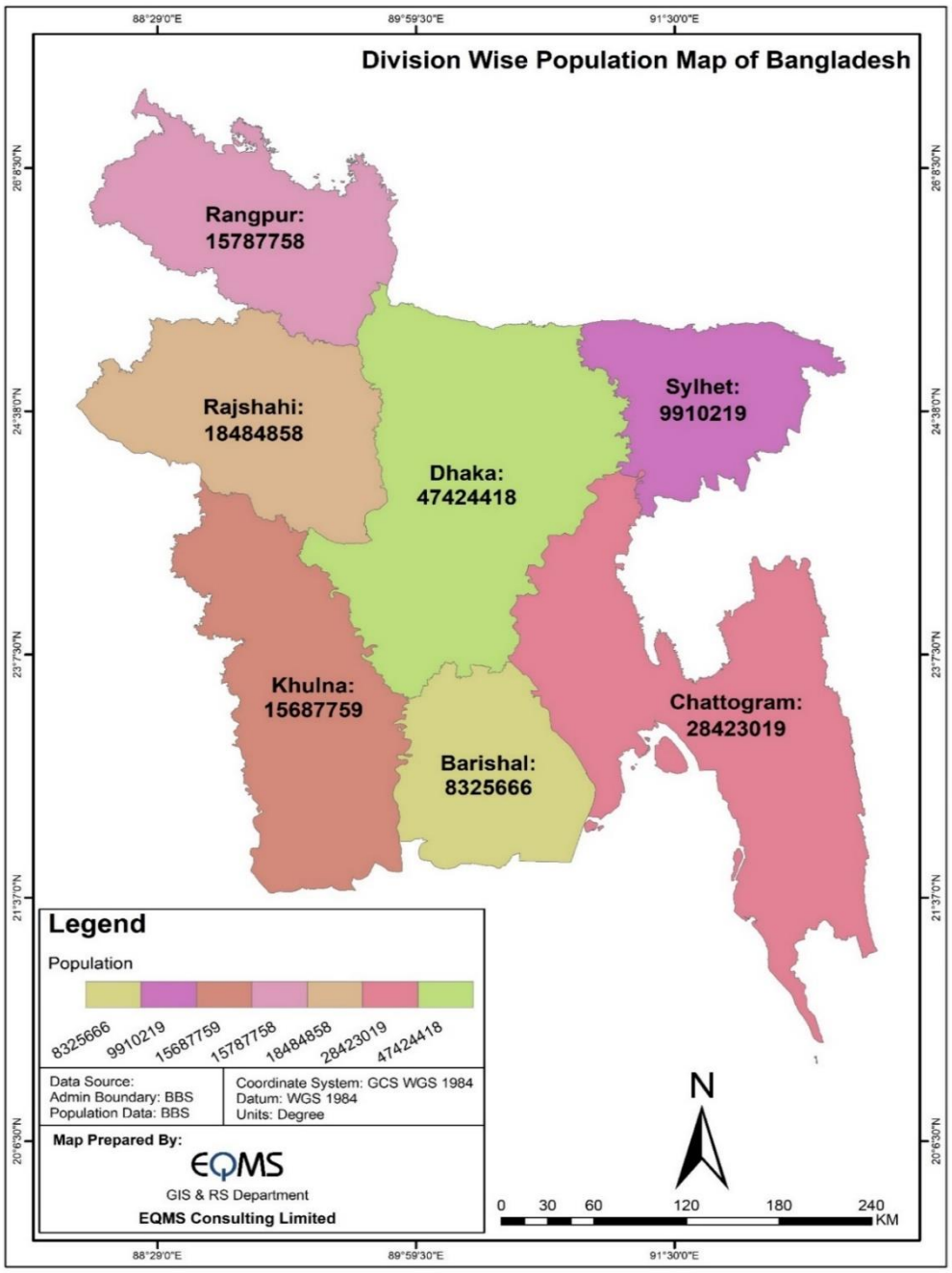
GDP at current price (In Cr. Tk.)	3,011,065
GDP at constant price (In Cr. Tk.)	1,207,246
GDP growth at constant price (%)	5.47%
Per capita national income (In USD)	2,227
Per capita GDP (In Tk.)	177,843
Per capita GDP (In USD)	2,097

Source: BBS (Bangladesh Bureau of Statistics), Bangladesh Economic Review, 2021

a. Population Distribution by Division

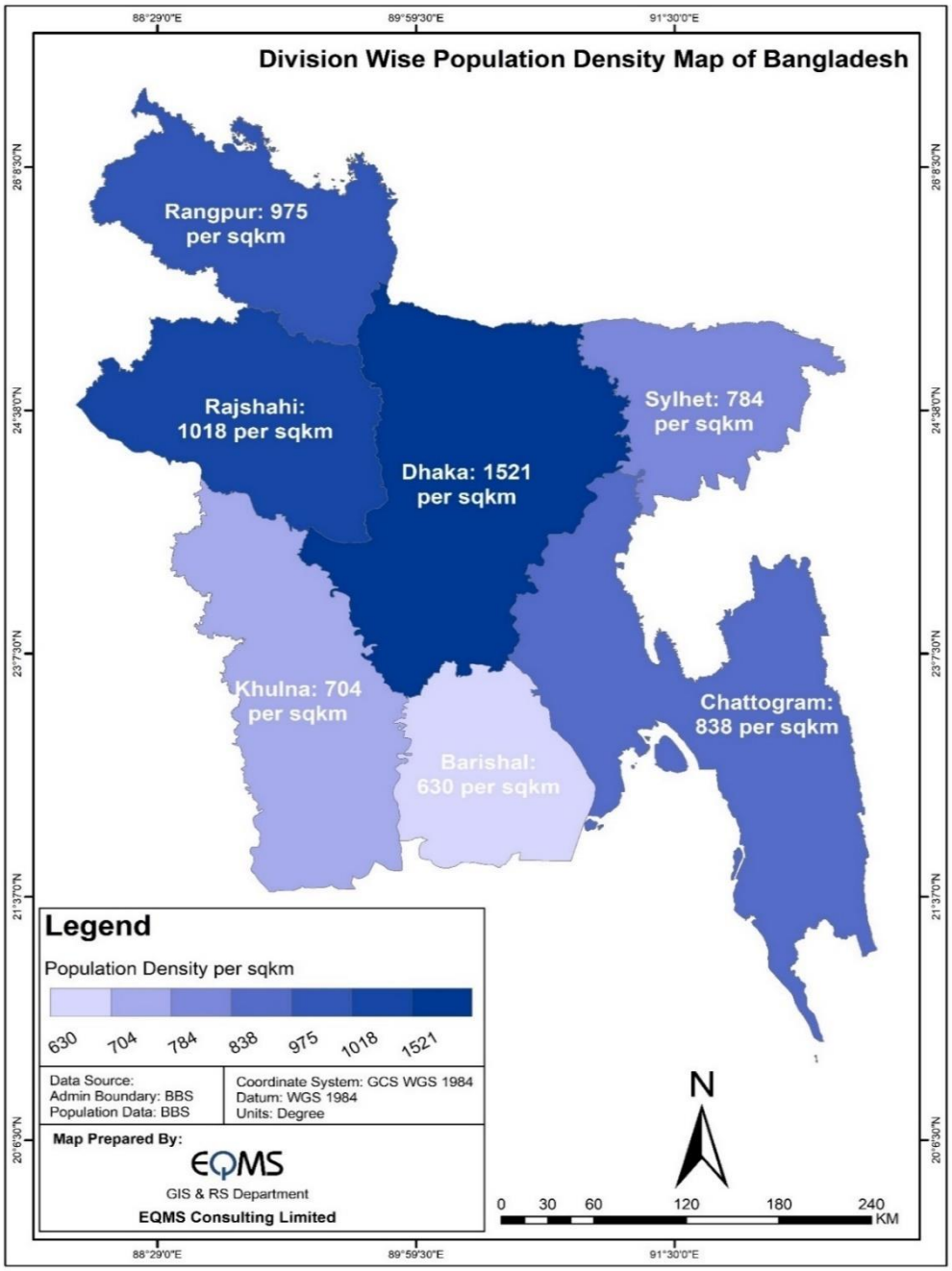
Bangladesh is ranked 8th in population among the countries and ranked 1st for having 1,252 people per square km, which is three times as dense as India. The following shows the population

density by divisional level, where the Dhaka division is highest for having 1,521 people per square km and the Rangpur division is the second highest having 975 population per square km while the Barishal division has the lowest density of 630 per square km.



Source: EQMS based on the information of Population Census 2011, BBS

Figure C.1-24 Division Wise Population Map of Bangladesh



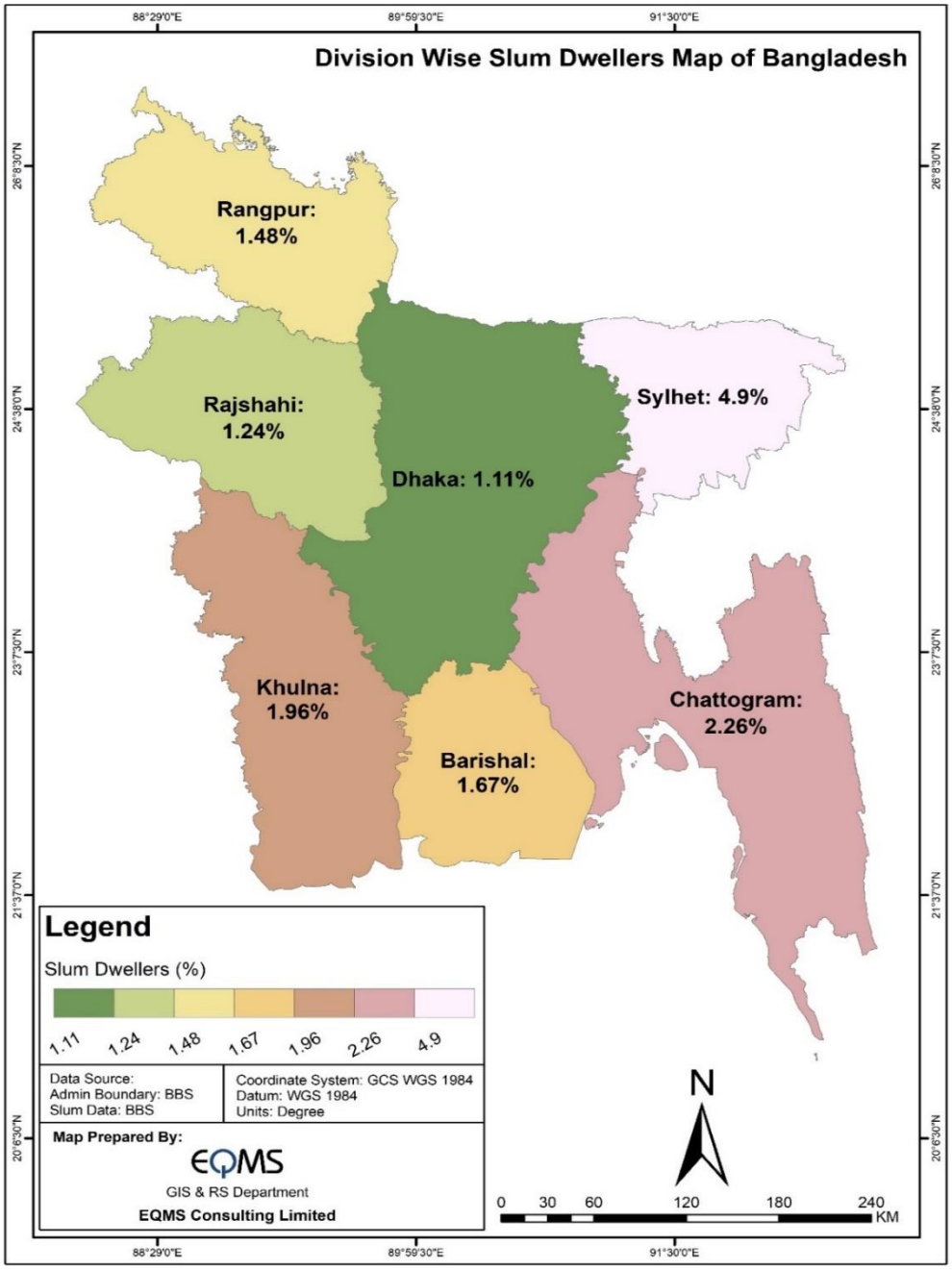
Source: Developed by EQMS based on the information of Population Census 2011, BBS

Figure C.1-25 Population Distribution Map by Density

b. Population Distribution by Slum Dwelling People

Bangladesh is a country of about 146.10 million people, which has 5.3 million slum dwellers. There are many factors behind the slums being in this country. The Sylhet division has the most,

4.9% of its total population, living as slum dwellers while Dhaka has 1.11%, the lowest. The following shows the distribution of slum dwellers at a divisional level.

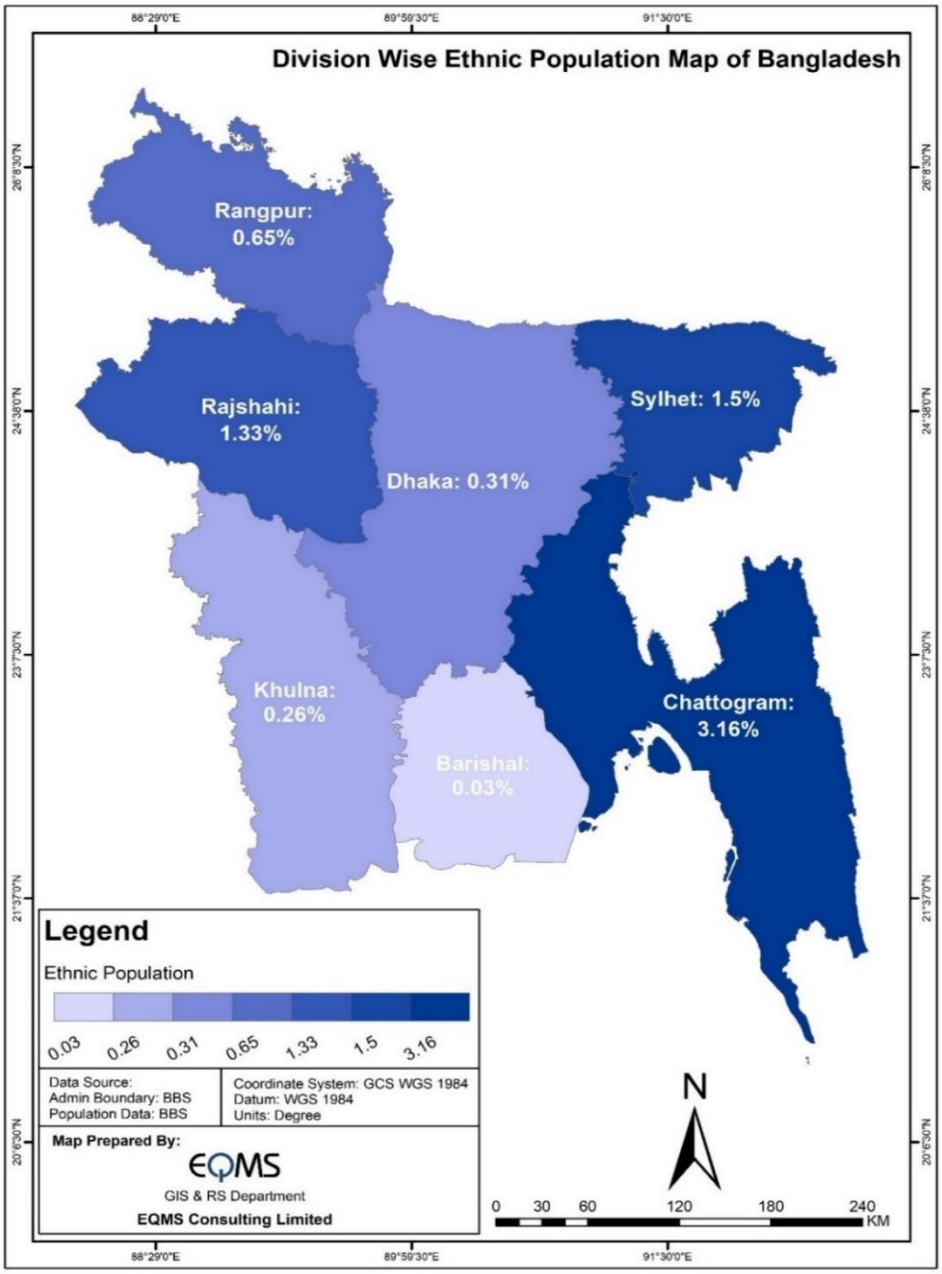


Source: EQMS based on the information of Population Census 2011, BBS

Figure C.1-26 Population (%) Distribution by Slum Dwelling at Divisional Level

c. Division-wise Population Distribution by Ethnic People

The indigenous people of Bangladesh refer to ethnic minorities in the Chittagong hill tracts (southeastern), Sylhet division (northeastern), Rajshahi division (west) and Mymensingh division (north central) areas of the country. The total population of indigenous ethnic minorities was estimated to be over 2 million in 2010. The following Figure shows the distribution of ethnic people at the divisional level.

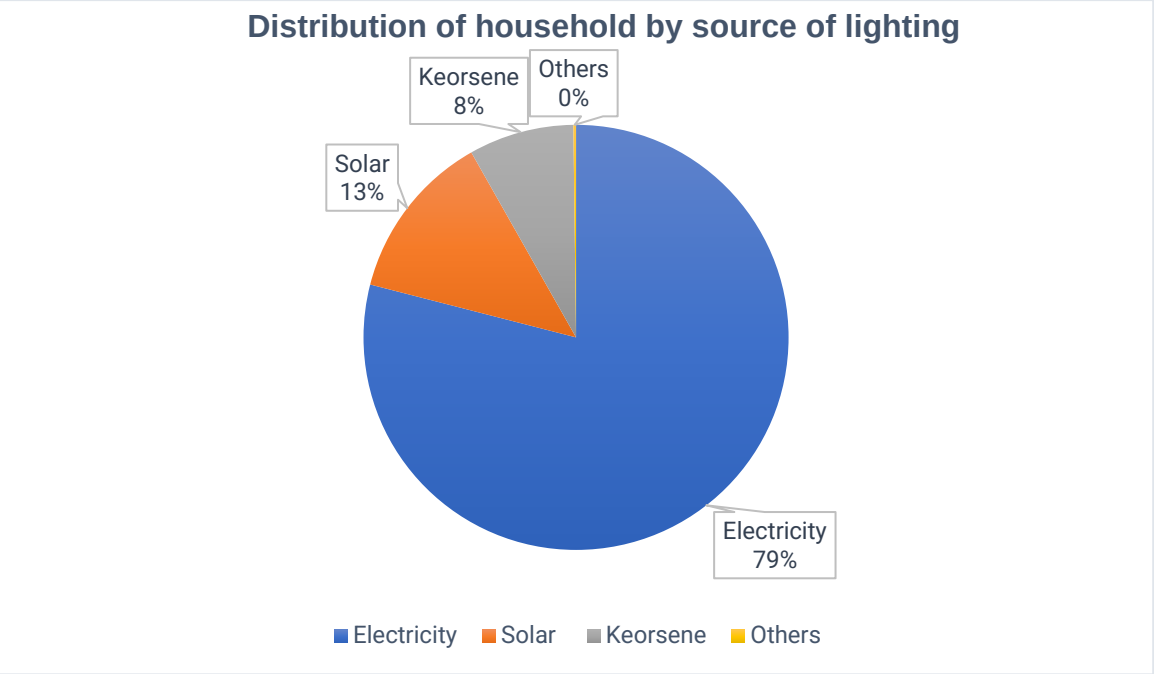


Source: EQMS based on the information of Population Census 2011, BBS

Figure C.1-27 Ethnic population (%) Distribution Division Wise

(2) Sources of Lighting

Distribution of households by sources of lighting is presented below. It shows that the use of electricity is increasing over the period. Access to electricity was 79.0% during the survey period between 2016 and 2017. There exists clear rural-urban variation in the access of electricity, as it was 72.4% for the rural areas and 94.9 for the urban areas. With the increased use of electricity as a source of lighting, the use of other sources such as kerosene is decreasing consequently.



Source: Labor force survey, Bangladesh, 2016-17, BBS

Figure C.1-28 Lighting Distribution of Household

(3) Type of Fuel Used for Cooking

Type of cooking fuel used by household is displayed below the table. The main fuel used for cooking is wood/firewood (41.3%), followed by dung / leaves / straw (38.7%) and natural gas/LP gas (19.6%). It is notable that the use of natural gas slightly increased in 2016-17 (19.6%) compared to 2015-16 (18.7%). There still exists a wide variation in the use of fuel between the urban and rural areas. In the urban area, 53.9% used natural gas for cooking compared to only 5.4% in the rural areas.

Table C.1-25 Type of fuel used for cooking by households

Fuel used for cooking	2016-2017		
	Rural	Urban	Total
Wood/Firewood	45.0	32.3	41.3
Dung/Leaves/Straw	49.5	12.8	38.7
Natural gas/ LP gas	5.4	53.9	19.6
Kerosene	0.0	0.1	0.0
Electricity	0.0	0.0	0.0
Bio-gas	0.0	0.5	0.2
Others	0.0	0.3	0.1
Total	**100.0**	**100.0**	**100.0**

Source: Labor force survey, Bangladesh, 2016-17, BBS

(4) Household by sources of drinking water

Sources of drinking water at the household level is presented below. Tube well was the dominant source of water both in rural (95.6%) and urban areas (86.7%).

Table C.1-26 Drinking Water Access by Area

Source of Drinking Water	2016-2017			
	Rural	Urban	City Corporation	Total
Tap Water	2.1	12.8	51.6	10.1
Tube Well	95.6	86.7	47.4	88.0
Well	0.6	0.1	0.0	0.5
Pond/River/Ditch/Canal	1.1	0.1	0.0	0.9
Others	0.5	0.3	0.9	0.5
Total	**100.0**	**100.0**	**100.0**	**100.0**

Source: Labor force survey, Bangladesh, 2016-17, BBS

(5) Access to Health Services

Bangladesh stands out as a country that has taken steps in healthcare. Public healthcare is operated by the Ministry of Health and Family Welfare, through its different Directorate Generals, Health Services, Family Planning, Drug Administration, Nursing and Midwifery, Health Economics Unit, etc.

Private healthcare encompasses for-profit private, not-for-profit private (mainly the NGOs), and informal providers (village doctors and a vast array of different unqualified providers). The public healthcare services are organized along four levels; community level healthcare (provided by the domiciliary health providers and community clinics); primary level healthcare (provided in Rural Health Centers, Union Subcenters, Union Family Welfare Centers, and Upazila Health Complexes); secondary level healthcare (provided in District Hospitals, General Hospitals, Chest Disease Clinics, Tuberculosis Clinics, and Leprosy Hospitals); and tertiary level healthcare (provided in Post Graduate Medical Institutes, Specialized Healthcare Centers, Medical College Hospitals, and Infectious Disease Hospitals).

Access to the nearest health care facilities from households is illustrated in Table C.1-7. Health care facilities providing institutions and their strengths are illustrated in the following table and primary health care facilities run by DGHS are presented in Table C.1-28.

Table C.1-27 Household Distance from the Nearest Health Facilities (%)

Health center	Distance of health					
	Within 1 km	1- 4 km	5-9 km	10-14 km	15-19 km	20+ km
District Hospital	4.48	4.48	4.48	4.48	4.48	4.48
Upazila Health Complex	9.01	13.53	30.94	25.20	12.93	8.39
Union health center	16.39	54.15	16.06	11.50	0.91	0.98
Community Clinic	13.18	24.22	20.57	27.15	13.35	1.53
Private hospital	7.60	9.90	18.25	25.92	18.73	19.60
Clinic	5.78	12.54	23.10	29.42	18.39	10.85
NGO clinic	5.89	8.13	24.60	32.53	14.96	13.89
Medical College & Hos.	3.55	7.89	17.08	23.50	21.08	26.89
Specialized hospital	0.90	1.86	3.07	7.27	12.91	74.00
Others	8.80	11.47	17.95	25.58	25.52	10.69

Source: Health and Morbidity Survey 2014

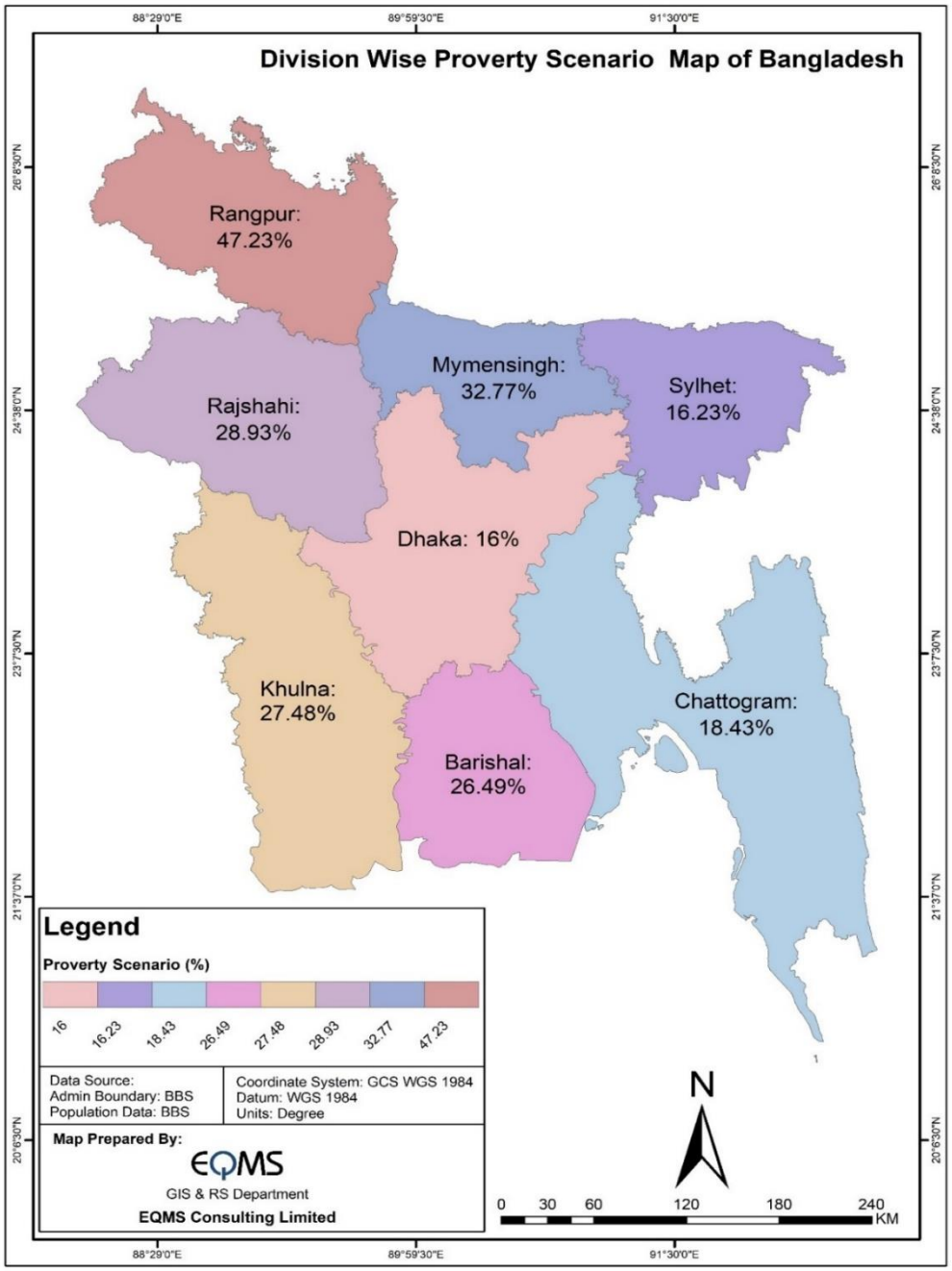
Table C.1-28 Health Service Facilities Strength

Health Services Provision	Number
Total no. of govt. hospitals under DGHS	739
No of non govt. hospitals and clinics (regd. By DGHS)	5,321
No. of beds under DGHS (functioning)	54,660
No. of beds in private sector Facilities (regd. by DGHS)	91,537
No. of regd. Physicians (MBBS & BDS)	111,413
Doctors working under DGHS per 10000 people	1.55
Doctors under DGHS	25,594
Registered diploma nurse	48,001
No. of registered dental surgeons	9,875

Source: DG of Health Service, Health Bulletin, 2019

(6) Poverty

Bangladesh has come a long way in a short time in its fight to end poverty. The country has halved poverty rates in a decade and a half, lifting more than 25 million people out of poverty. However, about 1 in 4 Bangladeshi still live in poverty, while almost half of those living in poverty live in extreme poverty and are unable to afford a basic food consumption basket. Poverty is estimated to be highest in Rampur and Mymensingh, and lowest in Dhaka and Sylhet. The figure shows the total percentage of the poverty ratio.



Source: EQMS based on the information of Population Census 2011, BBS

Figure C.1-29 Division Wise Poverty Scenario Map of Bangladesh

(7) Employed Population Aged 15 or Older, by Education Level

The largest proportion of the employed population in urban areas is 33.5% (5.7 million), completing a secondary education, while the largest proportion in rural areas account for 35.7% (15.7 million) without education. Table C.1- shows the employed population by their education

level and Table C.1-below shows the employed population by age and sex.

Table C.1-29 Employed Population by Education Level

Level of Education	Bangladesh		
	Male	Female	Total
None	12,584	9,792	19,376
Primary	11,194	4,505	15,699
Secondary	12,805	5,905	18,710
Higher secondary	2,836	801	3,637
Tertiary	2,581	627	3,209
Others	182	14	197
Total	**42,182**	**18,646**	**60,828**

Source: Labor force survey, Bangladesh, 2016-17, BBS

Table C.1-30 Employed Population Aged 15 or Older, by Age Group and Sex

Age group	Bangladesh		
	Male	Female	Total
15-19	2,869	1,035	3,904
20-24	3,775	2,009	5,783
25-29	5,373	2,892	8,265
30-34	5,481	2,962	8,443
25-39	5,713	3,017	8,730
40-44	4,461	2,043	6,504
45-49	4,280	1,921	6,201
50-54	3,289	1,227	4,516
55-59	2,793	853	3,646
60-64	1,985	397	2,382
65+	2,163	290	2,452
Total	**42,182**	**18,646**	**60,828**

Source: Labor force survey, Bangladesh, 2016-17, BBS

C.1.12 Education

The Government of Bangladesh places great importance on education and in this regard the Government has been trying to transform its huge population into human resources. Education for All (EFA) is the constitutional responsibility of the government. The constitution affirms

equal rights in education for all. The education system of Bangladesh is being managed and administered by two Ministries in association with the attached Departments and Directorates as well as a number of autonomous bodies governed by the Ministry of Primary and Mass Education (MOPME). Considering this, the government has emphasized providing education to the backward population and its female citizens.

The government is providing free education up to HSC (Class- 12) for the female along with stipend. It is expected that this will contribute to enhancing the enrollment rate of the female students, decreasing the rate of dropouts and enriching the country with an educated mass. The present education system of Bangladesh may be broadly divided into three major stages; primary, secondary and higher education.

Primary education is imparted basically by primary level institutions. Secondary education is imparted by junior secondary and higher secondary level institutions. Higher education is imparted by degree pass (3 years), degree honors (4 years), masters (1 & 2 years) and other higher-level institutions. Table C.1- shows the number of institutions and number of teachers available.

Table C.1-31 Number of Education Institutions and Teachers

Type of Institute	Number of Institutes	Teachers
Primary	129,258	721,801
Secondary	25,227	243,880
College	4,551	127,767
Madrashah	9,278	113,577
English Medium	145	7,705
Technical Education	7,052	53,684
Medical College & University	117	10,102
Dental College	35	327
Non-technical College & Institute	319	4,116
Education Institute for Professionals	216	3,060
University	148	30,730

Source: Bangladesh Education Statistics, 2019; BANBEIS

Literacy is one of the most fundamental elements of education and the government established an implementing agency named "Bureau of Non-Formal Education" in 1991. And literacy and education are the most important preconditions for social and economic development. As shown in the table below, the data of literacy shows that the urban literacy rate is higher than the rural.

Table C.1-32 Literacy Rate of Population

7 Years+		2018
National	Both Sex	73.2
	Male	75.2
	Female	71.2
Rural	Both Sex	67.6
	Male	69.6
	Female	65.5
Urban	Both Sex	80.1
	Male	82.0
	Female	78.2
15 Years+		**2018**
National	Both Sex	73.9
	Male	76.7
	Female	71.2
Rural	Both Sex	67.3
	Male	70.3
	Female	64.4
Urban	Both Sex	81.7
	Male	84.3
	Female	79.2

Source: MSVSB 2018, BBS

C.1.13 Public Health

The Government of Bangladesh has given the highest priority to achieve the goals of Millennium Development Goal (MDG) and to pursue a series of programs and policies to reduce infant and under 5 mortality, maternal mortality, and to ensure safe deliveries and so on. In order to provide the health services to the people properly, detailed information on the health and demographic situation of the country needs to be collected on a regular basis, particularly data on morbidity, impairment, maternal health, and injury/accidents.

(1) Mortality

The country's current mortality is shown in respective tables.

Table C.1-33 Infant Mortality Rate (per 1000 live birth)

Sex	2018
Both sex	22
Male	23
Female	21
Residence	2018
National	22
Urban	21
Rural	22

Source: MSVSB 2018, BBS

Table C.1-34 Maternal Mortality Rate (per 1000 live births)

	2018
National	1.69
Rural	1.93
Urban	1.32

Source: MSVSB 2018, BBS

(2) Morbidity

It is found that the highest percent (35. 71%) of the population facing morbidity in the Dhaka division while the lowest percent (4.47%) of the population having morbidity in the Barisal division. Table C.1- shows the morbidity proportion by divisional data.

Table C.1-35 Division Wise Morbidity Proportion

Division	**Male**	**Female**	**Total**
Barishal	4.90	5.05	4.47
Chittagong	16.18	15.18	19.01
Dhaka	35.17	34.98	35.71
Khulna	11.80	12.40	10.11
Rajsahi	14.89	14.61	15.67
Rangpur	11.41	12.13	9.35
Sylhet	5.65	5.64	5.68
Total	**100.0**	**100.0**	**100.0**

Source: Health and Morbidity Survey, 2014

Percentage of incidence and prevalence for all ages are shown: fever of unknown cause

(11.34%), ulcers (9.98%), arthritis (9.96%), hypertension (7.14%), and acute respiratory infection (6.62%).

Table C.1-36 Proportion and Prevalence of Morbidity by Disease

Selected diseases	Rank	Proportion (%)			Prevalence per 1000 pop.		
		Both Sex	Male	Female	Both Sex	Male	Female
Fever	1	8.66	10.05	7.29	19.54	22.32	16.7
Ulcer	2	7.62	7.02	8.21	17.18	15.58	18.82
Arthritis	3	7.61	6.35	8.85	17.16	14.10	20.29
High blood pressure	4	5.45	5.09	5.81	12.29	11.30	13.31
Acute respiratory infection	5	5.06	5.39	4.73	11.41	11.96	10.85
Diabetics	6	4.66	4.33	4.99	10.51	9.61	11.43
Diarrhea	7	4.02	4.33	3.71	9.06	9.61	8.50
Dysentery	8	3.86	4.28	3.44	8.7	9.49	7.88
Heart/Chest pain	9	2.92	2.89	2.96	6.59	6.40	6.78
Cataract	10	2.85	2.34	3.35	6.42	5.19	7.68
Conjunctive	11	2.37	2.1	2.63	5.33	4.66	6.03
Asthma	12	2.23	2.32	2.14	5.02	5.14	4.90
Skin disease	13	2.17	2.19	2.15	4.89	4.86	4.93
Typhoid	14	2.15	2.28	2.02	4.85	5.06	4.64
Migraine	15	1.97	2.06	1.89	4.45	4.56	4.33
Hepatitis	16	1.59	1.69	1.49	3.59	3.76	3.42
Paralysis	17	1.58	1.66	1.49	3.56	3.69	3.41
Ear infection	18	1.50	1.52	1.49	3.39	3.37	3.42
Urine tract infection	19	1.37	1.42	1.31	3.08	3.16	3.00
Malaria	20	1.27	1.31	1.24	2.87	2.91	2.84

Source: Health and Morbidity Survey, 2014

(3) Communicable and Non- communicable diseases

Proportion of morbidity from the selected communicable and non-communicable diseases by sex is shown in the table below. It shows that 39.21% of the population is suffering from communicable diseases showing a sharp difference between the male (42.58%) and female (36.04%) population. In case of non-communicable diseases, it is found that 60.79% of the population is suffering from non-communicable diseases, which indicates a sharp distinction

between the male (57.42%) and female (63.96%) population.

Table C.1-37 Communicable and Non- communicable Diseases

Selected diseases	Proportion (%)			Prevalence per 1000 pop.		
	Both Sex	Male	Female	Both Sex	Male	Female
Total	**100.00**	**100.00**	**100.00**	**70.34**	**67.52**	**73.21**
Communicable Disease						
Rabies	39.21	42.58	36.04	27.58	28.75	26.39
Chicken pox	0.52	0.58	0.47	0.37	0.39	0.34
Tuberculosis	2.44	2.40	2.48	1.72	1.62	1.81
Malaria	1.76	2.20	1.35	1.24	1.49	0.99
Measles	4.09	4.31	3.88	2.87	2.91	2.84
Diarrhea	2.03	2.44	1.65	1.43	1.65	1.21
Tetanus	12.88	14.24	11.61	9.06	9.61	8.50
Mumps	2.72	3.18	2.28	1.91	2.15	1.67
Whooping cough	1.33	1.23	1.42	0.93	0.83	1.04
Diphtheria	3.58	3.58	3.57	2.52	2.42	2.62
Typhoid	0.97	0.94	1.01	0.68	0.63	0.74
Non-communicable Disease						
Total	**60.79**	**57.42**	**63.96**	**42.76**	**38.77**	**46.82**
Arthritis	24.39	20.87	27.71	17.16	14.10	20.29
Diabetes	14.95	14.24	15.61	10.51	9.61	11.43
Cancer	1.01	1.13	0.91	0.71	0.76	0.66
Asthma	7.14	7.62	6.70	5.02	5.14	4.90
Heart/chest pain	9.37	9.48	9.27	6.59	6.40	6.78
Tumor	3.92	4.08	3.77	2.76	2.75	2.76

Source: Health and Morbidity Survey, 2014

C.1.14 Protected Cultural Heritages, Archeological Areas and Areas of Historical Significance

In 1968, the laws relating to the preservation and protection of antiquities, the Ancient Monuments Preservation Act, 1904 and the Antiquities (Export Control) Act, 1947 were repealed and a new Act entitled the Antiquities Act (1968) was enacted.

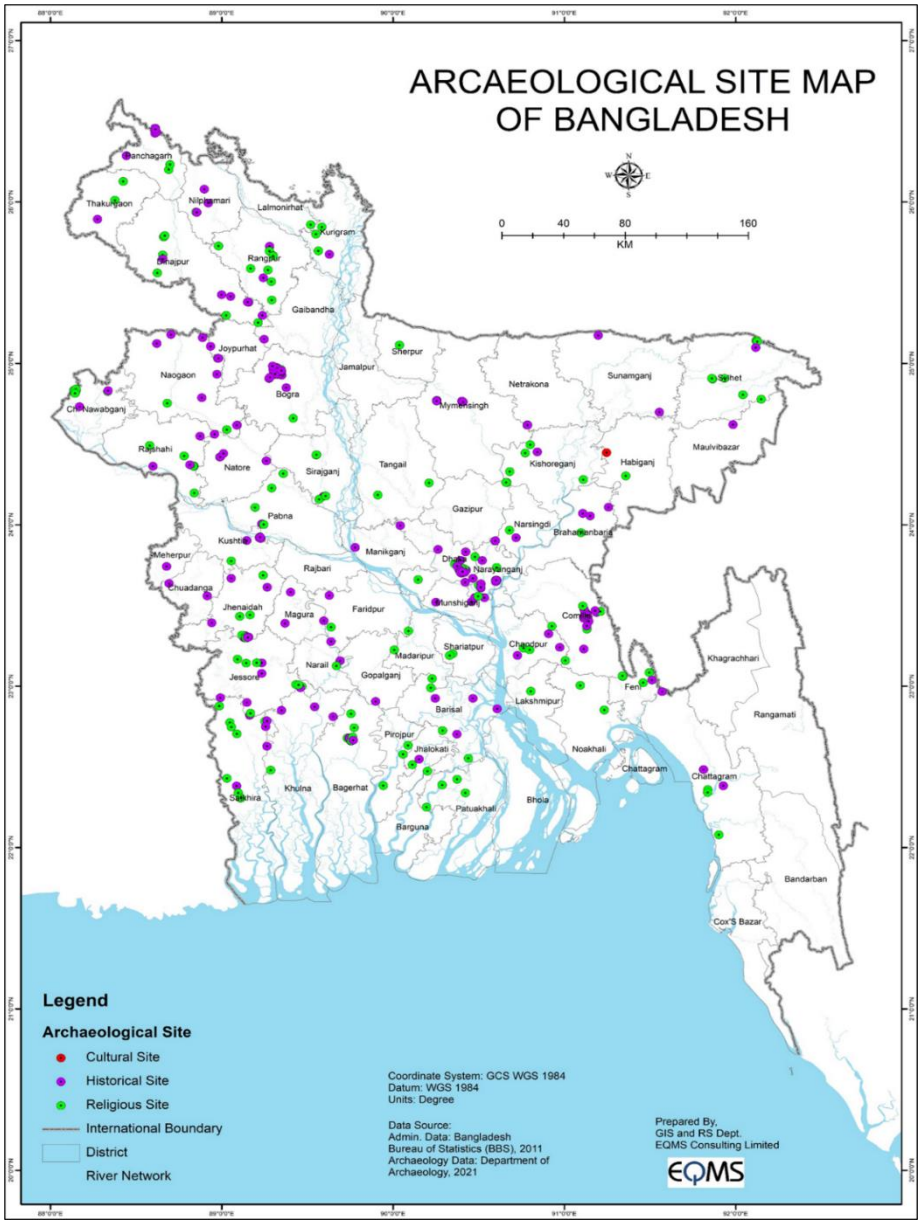
Until 2010, there were 397 protected sites, 14 site museums and 4 Libraries cum Museums. Of them, Panam City of Sonargaon itself possesses 49 individual heritage buildings which has been treated as a single site as per gazette notification.

Table C.1-38 Name of Cultural and Archeological Sites of Bangladesh

No.	Name of Location	Type of Site	District (Location)
	Sompur Bihar (Paharpur)	Protected Site	Naogaon
2	Khan Jahan Ali Mosque	Protected Site	Bagerhat
3	Jagaddal Bihar	Archeological	Naogaon
4	Kusumba Mosque	Archeological	Naogaon
5	Mohasthangar	Archeological	Bagura
6	Lokkhindor Med (Behula)	Archeological	Bagura
7	Nabaratna Temple	Archeological	Sirajganj
8	Dighapatia Royal Palace	Cultural	Natore
9	Bagha Mosque	Cultural	Rajshahi
10	Rath Temple	Cultural	Rajshahi
11	Boro Shib Temple	Cultural	Rajshahi
12	Dol Temple	Cultural	Rajshahi
13	Gubinda Temple	Cultural	Rajshahi
14	Puthia Royal Palace	Cultural	Rajshahi
15	Kansat Royal Palace	Cultural	Chapainabaganj
16	Choto Suna Mosque	Cultural	Chapainabaganj
17	Atia Mosque	Cultural	Tangail
18	Bhawal Royal Palace	Cultural	Gazipur
19	Temple of Poet Chndraboti	Cultural	Kishorganj
20	Kutub Mosque	Cultural	Kishorganj
21	Waribotessar	Cultural	Narsingdi
22	Hajiganj Fort	Cultural	Narayanganj
23	Panam City	Cultural	Narayanganj
24	Graveyard of Gia Uddin Azam	Cultural	Narayanganj
25	Sunakanda Fort	Cultural	Narayanganj
26	Murapara Royal Palace	Cultural	Narayanganj
27	Labag Fort	Cultural	Dhaka
28	Ahsan Manjil	Cultural	Dhaka
29	Hosni Dalan	Cultural	Dhaka
30	Armeninan Church	Cultural	Dhaka
31	Dhaka Gate	Cultural	Dhaka
32	Nimtoli Gate	Cultural	Dhaka
33	Rose Garden	Cultural	Dhaka

34	Palace of King Harischandra	Cultural	Dhaka
35	Idrakpur Fort	Cultural	Munshiganj
36	Balioati Royal Palace	Cultural	Monshiganj
37	Graveyard of Bangabandhu	Cultural	Gupalganj
38	Tajhat Royal Palace	Cultural	Rangpur
39	Kantajiu Temple	Cultural	Dinajpur
40	Sosi Lodge	Cultural	Mymensingh
41	Alexandar Castle	Cultural	Mymensingh
42	Aat Ani Royal Palace	Cultural	Mymensingh
43	Haripur Royal Palace	Cultural	Brahmanbaria
44	Salbon Bihar	Cultural	Cumilla
45	Itakhula Temple	Cultural	Cumilla
46	Condi Mura Temple	Cultural	Cumilla
47	Palace of Queen Maynamati	Cultural	Cumilla
48	War Cemetery Second World War	Cultural	Cumilla
49	Bojra Sahi Mosque	Cultural	Noakhali
50	Shrine of ShahJalal RH:	Cultural	Sylhet
51	Shrine of ShahParan RH:	Cultural	Sylhet
52	Sri Choitanna Temple	Cultural	Sylhet
53	Megalithic Tomb	Cultural	Sylhet
54	Hauli Royal Palace	Cultural	Sylhet
55	Bothingal Akhra	Cultural	Habiganj
56	Bibi Chini Mosque	Cultural	Barguna
57	Temple of Kauria Boro Dast Mitra	Cultural	Barihsal
58	Komlapur Mosque	Cultural	Barihsal
59	North Korapur Mia Bari Mosque	Cultural	Baishal
60	Tagor Lodge	Cultural	Kushtia
61	Shrine of Fakir Lalon	Cultural	Kushtia
62	Temple of Pnacharatna	Cultural	Jinedah
63	Palace of King Shitaram Ray	Cultural	Magura
64	11 Shib Temple	Cultural	Jessore
65	Teulia Mosque	Cultural	Shatkhira
66	Ayuddha Temple	Cultural	Bagerhat

Source: Department of Archaeology, Bangladesh



Source: EQMS based on the information of BBS, 2011, and Department of Archaeology, 2021

Figure C.1-30 Archaeological Site of Bangladesh

D. Legal Framework Relevant to Environmental and Social Considerations

D.1 Laws and Regulations pertaining to Environmental and Social Considerations

Bangladesh is recognized worldwide as one of the most vulnerable countries to the impacts of global warming and climate change. This is due to its unique geographic location, dominance of floodplains, low elevation from the sea, high population density, high levels of poverty, and

overwhelming dependence on nature, its resources, and services.

After gaining its independence in 1971, environmental issues in Bangladesh became seen as much more linked to broader development issues. There have been several key laws being enacted concerning about the deteriorating environmental condition in Bangladesh. In 1989, the government of Bangladesh established the Ministry of Environment and Forestry (MOEF) governing environmental and social dimensions of the development process. The government enacted the Water Pollution Control Act (1973), the Bangladesh Wildlife Preservation Act (1973), and Environmental Pollution Control Ordinance (1977), Environmental Conservation Act (1995) and Rules (1997), and Environment Court Act (2000).

Formal responsibilities for environment management are vested in MoEF, and many other institutions involve directly and indirectly. These include public and private sectors, and civil society organizations. At the highest level, the National Environment Council (NEC), established in 1993, headed by the Prime Minister, and the Executive Committee of the National Environment Council (ECNEC), headed by the Minister of Environment and Forest, are designed to provide guidance to the line Ministries on national environmental issues. Moreover, the Planning Commission of the Ministry of Planning has the authority to supervise and coordinate cross sectoral and inter-ministerial activities influencing the use of environment and natural resources. The following sections describe the respective laws and regulations.

D.1.1 Constitution of the Peoples Republic of Bangladesh (1972)

The Constitution of Bangladesh, officially the Constitution of the People's Republic of Bangladesh is the supreme law of Bangladesh. The document provides the framework that demarcates the Bangladeshi republic with a unitary, parliamentary democracy, that enshrines fundamental human rights and freedoms, an independent judiciary, democratic local government, and a national bureaucracy. In article No 18(A) of section “Fundamental Principles of State Policy” of the Constitution of Bangladesh (1972), it has been stated that, *The State shall endeavor to protect and improve the environment and to preserve and safeguard the natural resources, bio-diversity, wetlands, forests and wildlife for the present and future citizens*.

D.1.2 Environment Conservation Act (1995) and (subsequent amendments in 2000, 2002 and 2010)

The provisions of the Act authorize the Director General of Department of Environment (DoE) to undertake any activity that is deemed fit and necessary to conserve and enhance the quality of

environment and to control, prevent and mitigate pollution. The main highlights of the act are:

- Declaration of Ecologically Critical Areas (ECAs);
- Obtaining Environmental Clearance Certificate (ECC);
- Regulation with respect to vehicles emitting smoke harmful for the environment;
- Regulation of development activities from environmental perspective;
- Promulgation of standards for quality of air, water, noise, and soils for different areas and for different purposes;
- Promulgation of acceptable limits for discharging and emitting waste; and
- Formulation of environmental guidelines relating to control and mitigation of environmental pollution, conservation, and improvement of environment.

Before any new project can go ahead, as stipulated under the rules, the project promoter must obtain Environmental Clearance from the Director-General of Department of Environment (DoE). An appeal procedure does exist for those promoters who fail to obtain clearance. Failure to comply with any part of this act may result in punishment of a maximum of 3 years imprisonment or a maximum fine of Tk. 300,000 or both. The Department of Environment (DOE) executes the act under the leadership of the Director General (DG).

D.1.3 Environmental Conservation Rules (ECR, 1997) and subsequent amendments in 2002, 2003, 2005, 2007, 2008, 2010, 2017 and 2020

The Environment Conservation Rules (1997) are the first set of rules promulgated under the Environmental Conservation Act, 1995. These Rules provide for, inter alia, the following:

- The National Environmental Quality Standards (EQS) for ambient air, surface water, groundwater, drinking water, industrial effluents, emissions, noise and vehicular exhaust;
- Categorization of industries, development projects and other activities on the basis of actual (for existing industries/development projects/activities) and anticipated (for proposed industries/development projects/activities) pollution load;
- Procedure for obtaining environmental clearance;
- Requirements for undertaking IEE and EIA's as well as formulating EMP's according to categories of industries/development projects/activities; and
- Procedure for damage-claim by persons affected or likely to be affected due to polluting activities or activities causing hindrance to normal civic life.

D.1.4 The Acquisition and Requisition of Immovable Property Ordinance (1982)

This Ordinance has replaced the Land Acquisition Act of 1894 and the East Bengal (Emergency) Requisition of Property Act of 1948. The Ordinance governs acquisition and requisition by the government of immovable property for any public purpose or in public interest. It may be noted that contrary to the previous Acts (i.e. Act XIII of 1948), this Ordinance deals only with immovable property. The Ordinance has well-defined procedures regarding payment of compensation for an acquired piece of land. If, for example, the land is used for rice growing, then an amount equivalent to approximately 1.5 times the market value of a given variety of rice (e.g., paddy) that is currently being (or could be) produced annually is fixed as a yearly lease value. In case of outright purchase (carried out on a 99-year lease), the compensation-value of acquired land varies widely according to the locality, soil fertility, and access to transportation and related infrastructure factors. The current compensation and resettlement provisions are however inadequate both in terms of timing of payments and quantum. The procedures involved are cumbersome and time consuming and often causes hindrance to the smooth execution of the project. Legal provisions covering adequate compensation to the project affected persons, particularly disadvantaged groups such as women and squatters and such other vulnerable groups haven't been considered yet.

D.1.5 The Protection and Conservation of Fish Rules (1985)

Section 5 of the Rules requires that "*No person shall destroy or make any attempt to destroy any fish with explosives, gun, bow and arrow in inland waters or within coastal waters*". Section 6 of the Rules states: "*No person shall destroy or make any attempt to destroy any fish by poisoning of water or the depletion of fisheries by pollution, by trade effluents or otherwise in inland waters*". Therefore, the new bridge construction will need to be carried in such a manner that the activities do not cause damage to the inland waters or within coastal waters fisheries.

D.1.6 Biodiversity Act (2017)

The Act is to ensure conservation of biodiversity, the sustainable use of its components and fair and equitable sharing of benefits arising out of the utilization of genetic resources. The Act has enabled the government to form a "National Committee on Biodiversity" headed by the respective Minister/State Minister. The functions of the committee are to conserve biodiversity,

genetic biodiversity, identification of biodiversity-related important area, heritage, etc. The government is empowered to declare, in consultation with local communities and bodies and coordination with concerned ministries or departments, any place or area significant for its biological heritage as “Biodiversity Heritage Sites”. Prohibiting the taking of activities that may have an adverse effect on endangered animals or organisms, etc. No person shall take any such activity;(a) adversely affect or may have an effect on endangered species; (b) adversely affect or may affect the environmental characteristics of the endangered ecological community; or (c) In accordance with the Ramsar Convention, the wetland may adversely affect or affect the environment and environmental characteristics of the declared area.

D.1.7 Wildlife (Conservation and Security) Act (2012)

This Act is to provide for the conservation and safety of biodiversity, forest, and wildlife of the country by repealing the existing law relating to conservation and management of wildlife of Bangladesh. One of the important chapters in this act deals with the protection of wild animals and plants: 1) No person shall hunt any wild animal without a license or pick, uproot, destroy, or collect any plant (mentioned in Schedule IV), and 2) The Government may prohibit hunting of any specified or all wild animals in a specific forest area or throughout Bangladesh for a specific period. Determination of vulnerable, endangered and critically endangered species are vulnerable, endangered or critically endangered according to scientific data and internationally acceptable provisions or customs in consultation with the scientific committee. In addition, the following things have drawn attention in the act as follows:

- Prohibition is related to capturing, killing, shooting, or trapping wildlife. No person shall hunt any wild animal without a license;
- Determination of threatened flora and fauna;
- Prohibitions, entry, and declaration procedure of protected areas (sanctuary, national park, community conservation area, safari park, eco-park, botanical garden, wild animal breeding center, landscape zone or corridor, buffer zone, core zone, special biodiversity conservation area, national heritage, memorial tree, sacred tree, and kunjaban, etc.);
- No person, institution, or company shall establish or operate any industrial factory or brick-field within 2 (two) kilometers from the boundary of a sanctuary.

D.1.8 Bangladesh Labor Rules (2015)

The Bangladesh government introduced the Bangladesh Labor Rules 2015 on September 15, 2015 through a gazette. The following is the key rules as defined.

- Employment Policy/Service Rules: If any establishment wants to have its own Employment Policy/Service Rules, it must obtain approval from the Chief Inspector of Labor. All existing Employment Policy/Service Rules must be submitted to the Chief Inspector of Labor.
- Registration of Manpower Supply Agency: The Rules prescribe the process and forms for the registration of the Agency under the Labor Act.
- Establishment Organogram: Every owner of an establishment must prepare an organogram for the establishment and must obtain the approval of Chief Inspector of Labor for such organogram.
- Appointment Letter: Under the Labor Act, an appointment letter must be issued for hiring any labor. The Rules make it mandatory that the appointment letter must contain certain information such as salary, other financial benefits, applicable rules, etc.
- Various Register: The Rules prescribe certain forms for various registers such as service books, labor registers, leave registers, etc.
- Misconduct and punishment: The Rules prescribe the process for investigation of misconduct.
- Two Bonuses: The Rules makes it mandatory that any worker, who continuously works for a year, must receive two bonuses every year. Each bonus shall not be more than the basic salary.
- Provident Fund Elaborated: The Rules provide detailed guidelines regarding the provident fund. New additions include provisions related to selection of nominee, management of the fund, activities of the trust for managing the fund.
- Holiday: The Rules provide detailed provisions related to holidays. It also clarifies the provisions related to compensatory weekly holiday.
- Health and Fire Safely: The Rules provide a detailed guideline on health and fire safety.
- Wages: The Rules provide details on the provisions related to wages. Clarification is provided for the mechanism of calculating wages for fraction of months and deduction from wages.
- Prescription from filing a case in Labor Court: The Rules introduces some prescribed forms for filing cases in the Labor Court.
- Approval of Factory Plan and Any Extension: The Rules put an end to the Factory Rules and provide detailed guidelines on how approval of the factory plan and any extension thereof should be obtained.
- The safety measures like appliances of first aid, maintenance of safety record books, rooms for children, housing facilities, medical care, group insurance, etc. facility should be in the industry or any employment area;

- Building, wall, chimney, bridge, tunnel, road, gallery, stairway, ramp, floor, platform, staging or other structure, whether a permanent or temporary character, shall be constructed, situated or maintained in any factory in such a manner as to avoid risk of bodily injury (Rule 38) of factory rules 1979, etc.

D.1.9 Bangladesh Water Act (2013)

The Bangladesh Water Act 2013 (BWA) is a framework law to integrate and coordinate the water resources management of Bangladesh. The Water Act will establish a new, integrated approach to the protection, improvement and sustainable use of countries rivers, lakes, estuaries, coastal waters and groundwater. The BWA entails a coordinated and comprehensive water regime in respect of development, management, extraction, distribution, use, and protection and preservation of water resources in the country. The need for a comprehensive legal framework to face the growing challenges such as water rights, protection of water resources, water use, water services and management is widely acknowledged.

Key measures of the Water Act are:

- Right to water
- Adoption of National Water Policy and National Water Resources Plan
- Clearance Certificates
- Water Stressed Areas and Safe Yield
- Restricting abstraction, Protection Orders and Compliance Order
- Right to information and false information
- Water resource protection / pollution control and water quality standards.

D.2 Legal Framework for Environmental Impact Assessment

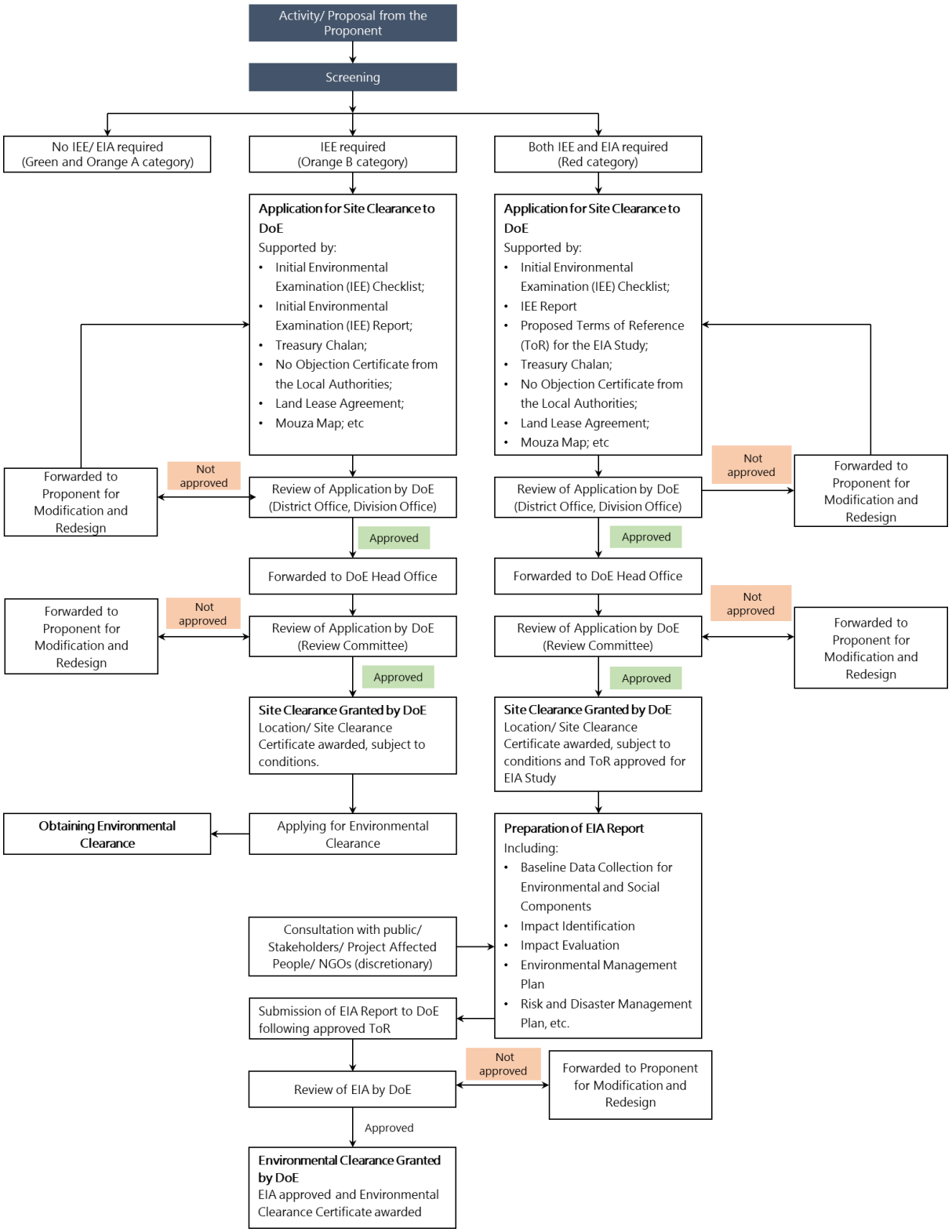
D.2.1 Environmental Clearance Procedure

It is mandatory to obtain Environmental Clearance for each and every type of industry and project as per the Bangladesh Environment Conservation Act, 1995 (Amended 2010). For the purpose of issuance of an Environmental Clearance Certificate, the industrial units and projects are, in consideration of their site and impact on the environment, classified into the following four categories:

- Green
- Orange-A
- Orange-B

- Red

Industries and projects included in the various categories as specified in Rule 7(2) of ECR (1997) is described in Schedule-1 (Environment Conservation Rules, 1997). Environmental Clearance for Green category industries and projects is provided through a comparatively simple procedure. In case of Orange-A, Orange-B and Red Category industries and projects, site clearance is mandatory at the beginning, then EIA approval and Environmental Clearance is issued. The environmental clearance procedure is presented below.



Source: Department of Environment

Figure D.2-1 Environmental Clearance Procedure of DoE

Table D.2-1 General Process Steps for Environmental Clearance

Step 1	Submit application with supporting documents
Step 2	Verification of application and supporting documents by DOE
Step 3	Inspection by the authorized officer after verification of all report and documents. [Then make decision about the clearance (Only Green and Orange-A)]
Step 4	Meeting of Environmental Clearance Committee (for Orange-B and Red Category) Decision
Step 5	Decision

Table D.2-2 Time Frame

No.	Category	Site Clearance	Environmental Clearance
1.	Green	N/A	15 Days
2.	Orange- A	30 Days	15 Days
3.	Orange- B	60 Days	30 Days
4.	Red	60 Days	30 Days

Documents required for different Categories of Industrial Units or Projects:

Green

- Application through prescribed form-3 under Environment Conservation Rules 1997
- Prescribed fees under schedule-13 under Environment Conservation Rules 1997 (Amended 2002)
- General information about the industrial unit or project;
- Exact description of the raw materials and the manufactured product; and
- No objection certificate (Prescribed Form) from the local authority;

If an application for an Environmental Clearance Certificate for an industrial unit or project of Green Category is made under Article 7(5) along with the relevant documents specified in Article7(6), then, within 15 days of the receipt of the application, the Certificate shall be issued or the application shall be rejected, provided with appropriate reasons for such rejection.

Orange-A

- Application through prescribed form-3 under Environment Conservation Rules 1997
- Prescribed fees under schedule-13 under Environment Conservation Rules 1997 (Amended 2002)

- General information about the industrial unit or project;
- Exact description of the raw materials and the manufactured product;
- No objection certificate (Prescribed Form) from the local authority;
- Process flow diagram;
- Layout Plan (showing location of Effluent Treatment Plant);
- Effluent discharge arrangement;
- Outlines of the plan for relocation, rehabilitation (if applicable);
- Other necessary information (if applicable);

If an application is made under Article 7(5) along with the relevant documents specified in Article 7(6), then in the case of an Orange- A Category industrial unit or project, within 30 days of the receipt of the application.

Orange-B

a. Application through prescribed form-3 under Environment Conservation Rules 1997
b. Prescribed fees under schedule-13 under Environment Conservation Rules 1997 (Amended 2002)
c. Report on the feasibility of the industrial unit or project (applicable only for proposed industrial unit or project);
d. Report on the Initial Environmental Examination of the industrial unit or project, and also the process flow diagram, layout plan (showing location of effluent treatment plant), design of the Plant of the unit or project (these are applicable only for a proposed industrial unit or project);
e. Report on the Environmental Management Plan (EMP) for the industrial unit or project, and also the process flow diagram, layout plan (showing location of effluent treatment plant), design of the effluent treatment plant and information about the effectiveness of the ETP of the unit or project, (these are applicable only for an existing industrial unit or project);
f. No objection certificate (Prescribed Form) from the local authority;
g. Emergency plan relating adverse environmental impact and plan for mitigation of the effect of pollution;
h. Outline of the relocation, rehabilitation plan (where applicable);
i. Other necessary information (where applicable).

If an application is made under Article 7(5) along with the relevant documents specified in Article 7(6), then Orange-B Category industrial unit or project, within 60 days of the receipt of the application, a Location Clearance Certificate shall be issued or the application shall be

rejected, provided with appropriate reasons for such rejection.

Red

- Application through prescribed form-3 under Environment Conservation Rules 1997
- Prescribed fees under schedule-13 under Environment Conservation Rules 1997 (Amended 2002)
- Report on the feasibility of the industrial unit or project (applicable only for proposed industrial unit or project);
- Report on the Initial Environmental Examination (IEE) relating to the industrial unit or project, and also the terms of reference (ToR) for the Environmental Impact Assessment (EIA) of the unit or the project and its Process Flow Diagram; or Environmental Impact Assessment (EIA) report prepared on the basis of ToR previously approved by the Department of Environment, along with the Layout Plan (showing location of Effluent Treatment Plant), process flow diagram, design and time schedule of the effluent treatment plant (these are applicable only for a proposed industrial unit or project);
- Report on the Environmental Management Plan (EMP) for the industrial unit or project, and also the process flow diagram, layout plan (showing location of effluent treatment plant), design and information about the effectiveness of the effluent treatment plant of the unit or project (these are applicable only for an existing industrial unit or project);
- No objection certificate (Prescribed Form) of the local authority:
- Emergency plan relating adverse environmental impact and plan for mitigation of the effect of pollution;
- Outline of relocation, rehabilitation plan (where applicable);
- Other necessary information (where applicable);

If an application is made under Article 7(5) along with the relevant documents specified in Article 7(6), then Red Category industrial unit or project, within 60 days of the receipt of the application, a Location Clearance Certificate shall be issued or the application shall be rejected mentioning appropriate reasons for such rejection.

D.2.2 Legal Framework Regarding Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) is a process of preliminary identification and consideration of the possible negative impacts into environment and human health caused by the implementation of any plan, program or other strategic document. The goals of SEA are: improving the plan or program in a way to minimize its potential negative environmental impact and to maximize positive impacts, and ensuring that possible negative impacts that cannot be

avoided are properly managed and offset during implementation of the plan or program.

In Bangladesh, the SEA is not a legal requirement but the policy level addresses organizational set-up and national environmental policy compliance for different sectors. The Bangladesh National Environmental Policy (2018) indicates performance of the Strategic Environmental Assessment (SEA) in different necessary applicable sectors as follows:

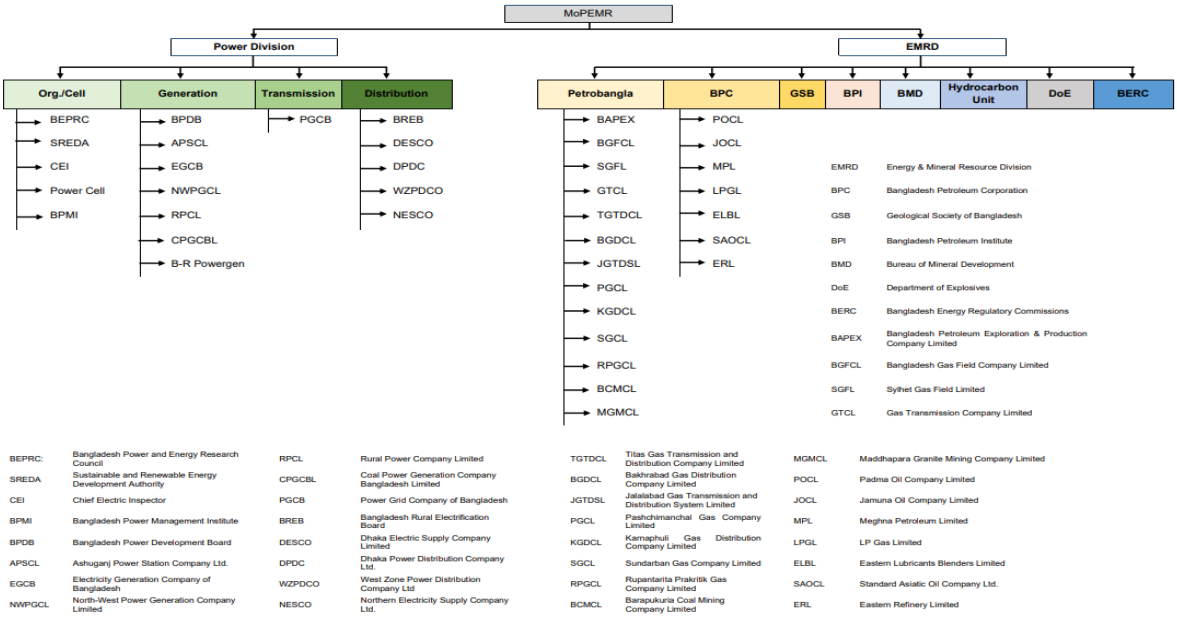
Table D.2-3 Statement about SEA in the National Environmental Policy 2018

Title	**Sub-section & page No. in NEP, 2018**	**Brief description**
2.0 Objectives of National Environmental policy *Page 4*	**2.0** Objectives	**2.12** Ensuring Environmental Impact Assessment and Strategic Environmental Assessment in all necessary sectors
Land Resources Management *Page 4-5*	**3.1** Land Resource Management	**3.1.5** To perform ecosystem and ecosystem-based land zoning and ecosystem based strategic environmental assessment
Implementation Plan/Activities: Accommodation, Housing and Urbanization *Page 35*	**3.7** Accommodation, Housing and Urbanization	**3.7.1** For any proposed housing and urban regional project and master plan implementing ensuring perform Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA).
Environmental Conservation Implementation Plan/Activities: Industrial Development *Page 44*	**3.15** Industrial Development	**3.15.4** To establish any industrial area Strategic Environmental Assessment (SEA). should be performed with land zoning and proper planning; ensure prohibiting industrial establishment in any residential area and shifting industries from residential area to industrial area.
5.0 Organizational Set-up (Institutional Framework) *Page 56*	**5.0** Organizational Set-up	**5.5** Relevant ministries/departments shall perform Strategic Environmental Assessment (SEA) on applicable policies, plans and programs.

Source: NEP, 2018

D.2.3 Organization in charge of preparing SEA for the Integrated Energy and Power Master Plan

Regarding the requirement of the Environmental Clearance Certificate, SEA is not mandatory as the procedure solely focuses on the requirement of the EIA. Considering the structure of the Power Division and Energy and Mineral Resources Division, they are the approval authorities but not the project executing bodies. When it comes to implementation of the EIA, different agencies under the PD and EMRD are responsible for its project development and execution such as power plant development, electricity transmission and distribution construction and operation, gas transmission and distribution pipeline construction and distribution, etc. Generally, a project director is selected and responsible for executing the project. PD and EMRD nominates the government officials to communicate with the DOE for further consultation. The table below presents an organigram of the Ministry.



Source: Ministry of Power, Energy and Mineral Resources

Figure D.2-2 Organigram of the Ministry of Power, Energy and Mineral Resources

E. List of Wildlife Species

Appendix A: List of Dominant Wildlife Species by their Habitats

SL No.	Scientific Name	Common Name	Local Name	Family	IUCN Bangladesh Status	IUCN Global Status	Habitat
j.	*Aonyx cinerea*	Oriental Small-clawed Otter	Dhaira Uud, Uud Biral,	Mustelidae	EN	VU	WH
k.	*Aplonis panayensis*	Asian Glossy Starling	Eshio Telshalik	Sturnidae	LC	LC	MEF
l.	*Arachnothera longirostra*	Little Spiderhunter	Cchoto Makormar	Nectarinidae	LC	LC	MEF
m.	*Arctictis binturong*	Binturong, Bear cat, Palawan	Geso Bhaluk, Gach	Viverridae	VU	VU	MEF
n.	*Ardea (Egretta) intermedia*	Intermediate Egret	Majhla Boga	Ardidae	LC	LC	WH
o.	*Ardea alba*	Great White Egret	Boro Boga	Ardidae	LC	LC	WH
p.	*Ardea cinerea*	Grey Heron	Dhupni Bok	Ardidae	LC	LC	WH
q.	*Ardea insignis*	White-bellied Heron	Dholapet Bok	Ardidae	RE	CR	WH
r.	*Ardea purpurea*	Purple Heron	Lalche Bok	Ardidae	LC	LC	WH
s.	*Ardeola bacchus*	Chinese Pond Heron	Cheena Kanibok	Ardidae	LC	LC	WH
t.	*Ardeola grayii*	Indian Pond Heron	Deshi Kanibok	Ardidae	LC	LC	WH
u.	*Bos gaurus*	Gaur	Bon Goru, Gour.	Bovidae	CR	VU	MEF
v.	*Bubulcus ibis*	Cattle Egret	Go Boga	Ardidae	LC	LC	WH
w.	*Butorides striata*	Green-backed (Striated) Heron	Khudey Bok	Ardidae	LC	LC	WH
x.	*Canis aureus*	Golden Jackal	Shial, Pati Shial	Canidae	LC	LC	SF

SL No.	Scientific Name	Common Name	Local Name	Family	IUCN Bangladesh Status	IUCN Global Status	Habitat
y.	*Capricornis sumatraensis*	Serow, Sumatran Serow,	Bon Chagol	Bovidae	EN	VU	MEF
z.	*Chloropsis hardwickii*	Orange-bellied Leafbird	Komlapet Horbola	Chloropsidae	LC	LC	MEF
aa.	*Cissa chinensis*	Green Magpie	Shobuj Taura	Corvidae	LC	LC	MEF
bb.	*Crocodylus porosus*	Salt-water Crocodile,	Lona-panir Kumir	Crocodylidae	EN	LC	MFS
cc.	*Egretta garzetta*	Little Egret	Cchoto Boga	Ardidae	LC	LC	WH
dd.	*Elephas maximus*	Asian Elephant	Hati, Hasti, Gaja	Elephantidae	CR	EN	MEF
ee.	*Felis chaus*	Jungle cat, Swamp cat,	Ban biral, Bon bilai,	Felidae	NT	LC	HF
ff.	*Gracula religiosa*	Hill Myna	Pati Moyna	Sturnidae	LC	LC	MEF
gg.	*Halcyon coromanda*	Ruddy Kingfisher	Lal Macchranga	Alcedinidae	LC	LC	MFS
hh.	*Heliopais personata*	Masked Finfoot	Kalamukh Perapakhi	Heliornithidae	EN	EN	MFS
ii.	*Herpestes auropunctatus*	Small Indian Mongoose	Chhoto Beji, Nakul	Herpestidae	LC	LC	SF
jj.	*Herpestes edwardsii*	Indian Grey Mongoose,	Boro Beji, Neul, Neule,	Herpestidae	LC	LC	SF
kk.	*Hoolock hoolock*	Hoolock Gibbon	Ulluk, Holou Bandar,	Hylobatidae	CR	EN	MEF
ll.	*Lophura leucomelanos*	Kalij Pheasant	Kala Mothura	Phasianidae	VU	LC	MEF
mm.	*Macaca arctoides*	Stump-tailed Macaque,	Choto-leji Banor	Cercopithecidae	DD	VU	MEF
nn.	*Macaca assamensis*	Assamese Macaque	Ashami Banor	Cercopithecidae	EN	NT	MEF
oo.	*Macaca leonina*	Pig-tailed Macaque	Ultaleji banor	Cercopithecidae	EN	VU	MEF
pp.	*Macaca mulatta*	Rhesus Macaque	Banor, Bandor	Cercopithecidae	VU	LC	SF
qq.	*Muntiacus muntjak*	Barking Deer, Indian	Maya Harin, Ruru	Cervidae	EN	LC	SF

SL No.	Scientific Name	Common Name	Local Name	Family	IUCN Bangladesh Status	IUCN Global Status	Habitat
		Muntjac	Harin				
rr.	*Nycticorax nycticorax*	Black-crowned Night Heron	Kalamatha Nishibok	Ardidae	LC	LC	WH
ss.	*Pachycephala grisola*	Mangrove Whistler	Nonabon Sheeshmar	Pachycephalidae	LC	LC	MFS
tt.	*Panthera tigris*	Tiger	Bagh	Felidae	CR	EN	MFS
uu.	*Phalacrocorax fuscicollis*	Indian Cormorant	Deshi Pankouri	Phalacrocoracidae	LC	LC	WH
vv.	*Phalacrocorax niger*	Little Cormorant	Cchoto Pankouri	Phalacrocoracidae	LC	LC	WH
ww.	*Pitta megarhyncha*	Mangrove Pitta	Pera Shumcha	Pittidae	LC	NT	MFS
xx.	*Platanista gangetica*	Ganges River Dolphin,	Shishu, Shushuk	Platanistidae	VU	EN	WH
yy.	*Polyplectron bicalcaratum*	Grey Peacock-Pheasant	Metey Kathmoyur	Phasianidae	VU	LC	MEF
zz.	*Ratufa bicolor*	Black Giant Squirrel,	Baro Kathbirali, Ram	Sciuridae	VU	NT	MEF
aaa.	*Semnopithecus entellus*	Northern Plains Sacred	Hanuman	Cercopithecidae	EN	LC	MEF
bbb.	*Semnopithecus entellus*	Northern Plains Sacred	Hanuman	Cercopithecidae	EN	LC	HF
ccc.	*Trachypithecus phayrei*	Spectacles langur	Chosmapora hanuman,	Cercopithecidae	CR	EN	HF
ddd.	*Trachypithecus pileatus*	Capped Langur	Mukhpora Hanuman	Cercopithecidae	EN	VU	MEF
eee.	*Tupaia glis*	Common Tree Shrew	Gecho Chhucho	Tupaiidae	NT	LC	MEF
fff.	*Varanus bengalensis*	Bengal Monitor	Gui Shap, Bangla Gui	Varanidae	NT	LC	WH

SL No.	Scientific Name	Common Name	Local Name	Family	IUCN Bangladesh Status	IUCN Global Status	Habitat
ggg.	*Varanus flavescens*	Yellow Monitor	Sona Gui, Haldey Gui	Varanidae	NT	LC	WH
hhh.	*Varanus salvator*	Ring Lizard, Water Monitor	Kalogui, Ramgodi	Varanidae	VU	LC	WH
iii.	*Viverra zibetha*	Large Indian Civet	Baghdas, Bham or	Viverridae	NT	NT	SF
jjj.	*Viverricula indica*	Small Indian Civet	Khatash, Gandho	Viverridae	NT	LC	SF

Habitats: Sal Forest = SF; Wetland Habitats = WH; Mixed-Evergreen Forest = MEF; Homestead Forest, Countryside Forest, Village Woodland or Village Groves and Crop fields = HF; Mangrove Forest and the Sundarbans = MFS

Source: IUCN Bangladesh 2015

Appendix B: List of Plants of Tropical Wet Evergreen Forest and Tropical Semi Evergreen Forest

Sl. No.	Scientific Name	Local name	Family
1.	*Albizia odoratissima* (Lf.) Benth.	Tatuya-	Fabaceae
2.	*Alstonia scholaris* (L.) R. Br.	Chattian	Apocynaceae
3.	*Anogeissus acuminata* (Roxb. ex DC.) Wall. ex	Shiuri	Combretaceae
4.	*Aphanamixis polystachya* (Wall.) R.Parker	Pitraj	Meliaceae
5.	*Artocarpus chama* Buch.-Ham.	Chapalish	Moraceae
6.	*Artocarpus lacucha* Buch.-Ham.	Bharta	Moraceae
7.	*Baccaurea ramiflora* Lour.	Lotkon	Euphorbiaceae
8.	*Bischofia javanica* Blume	Kanjal-	Euphorbiaceae
9.	*Bombax ceiba* L.	Shimul	Bombacaceae
10.	*Callicarpa arborea* Roxb.	Bormala	Verbenaceae
11.	*Cassia nodosa* Buch.-Hum. ex Roxb.	Bonsonalu	Fabaceae
12.	*Chukrasia tabularis* A. Juss.	Chakrashi	Meliaceae
13.	*Dillenia indica* L.	Chalta	Dilleniaceae
14.	*Dillenia pentagyna* Roxb.	Hargoja	Dilleniaceae
15.	*Diospyros blancoi* A. DC.	Gab	Ebenaceae
16.	*Dipterocarpus turbinatus* Gaertn.	Garjan	Dipterocarpace
17.	*Duabanga grandiflora* (Roxb. ex DC.) Walp.	Bandarhola	Lythraceae
18.	*Elaeocarpus tectorius* (Lour.) Poir.	Jalpai	Elaeocarpaceae
19.	*Erythrina variegata* L.	Mander	Fabaceae
20.	*Ficus auriculata* Lour.	Bara-	Moraceae
21.	*Ficus hispida* L.f.	Dumur	Moraceae
22.	*Ficus religiosa* L.	Aswath	Moraceae
23.	*Firmiana colorata* (Roxb.) R.Br.	Udal	Sterculiaceae
24.	*Garcinia cowa* Roxb. ex DC	Kao	Clusiaceae
25.	*Gmelina arborea* Roxb.	Gamar	Verbenaceae
26.	*Grewia nervosa* (Lour.) Panigrahi	Achargola	Tiliaceae
27.	*Haldina cordifolia* (Roxb.) Ridsdale	Haldu	Rubiaceae
28.	*Lagerstroemia speciosa* (L.) Pers.	Jarul	Lythraceae
29.	*Lannea coromandelica* (Houtt.) Merr.	Bhadi	Anacardiaceae
30.	*Macaranga denticulata* (Blume) Mull.Arg.	Bura	Euphorbiaceae
31.	*Neonauclea sessilifolia* (Roxb.) Merr.	Kom	Rubiaceae
32.	*Palaquium polyanthum* (Wall. ex G.Don) Baill.	Tali	Sapotaceae
33.	*Phyllanthus emblica* L.	Amloki	Euphorbiaceae
34.	*Protium serratum* (Wall. ex Colebr.) Engl.	Gutguttya	Burseraceae
35.	*Pterospermum acerifolium* (L.) Willd.	Moss	Sterculiaceae
36.	*Quercus gomeziana* A.Camus	Batna	Fagaceae
37.	*Schima wallichii* (DC) Korth	Kanak	Theaceae
38.	*Schleichera oleosa* (Lour.) Merr.	Kusum	Sapindaceae
39.	*Stereospermum colais* (Buch.-Ham. ex Dillwyn)	Dharmara	Bignoniaceae
40.	*Streblus asper* Lour.	Sheora	Moraceae

41.	*Swintonia floribunda* Griff.	Civit	Anacardiaceae
42.	*Syzygium fruticosum* DC.	Puti-jam	Myrtaceae
43.	*Terminalia bellirica* (Gaertn.) Roxb.	Bohera	Combretaceae
44.	*Terminalia catappa* L.	Kat-badam	Combretaceae
45.	*Tetrameles nudiflora* R. Br.	Chandul	Datiscaceae
46.	*Toona ciliata* M.Roem.	Toon	Meliaceae
47.	*Trewia nudiflora* L.	Pitali	Euphorbiaceae
48.	*Vitex glabrata* R.Br.	Goda	Verbenaceae
49.	*Walsura robusta* Roxb.	Bonlichu	Meliaceae
50.	*Zanthoxylum rhetsa* (Roxb.) DC.	Bajna	Rutaceae

Source: Chowdhury et. al. (2018)

Appendix C: List of Plants of Tropical Moist Deciduous Forest

Sl. No.	Scientific name	Local name	Family
1.	*Abroma augustum* (L.) L. f.	Ulotkombol	Sterculiaceae
2.	*Acacia auriculiformis* A. Cunn.	Akashmoni	Mimosaceae
3.	*Acacia mangium* Willd.	Mangium	Mimosaceae
4.	*Aegle marmelos* (L.) Corr.	Bel	Rutaceae
5.	*Albizia chinensis* (Osb.) Merr.	Chesra koroi	Mimosaceae
6.	*Albizia lebbeck* (L.) Benth. & Hook	Kala Koroi	Mimosaceae
7.	*Albizia richardiana* (Voigt.) King & Prain	Raj koroi	Mimosaceae
8.	*Albiziaprocera* (Roxb.) Benth.	Shil koroi	Mimosaceae
9.	*Alstonia scholaris* (L.) R. Br.	Chatian	Apocynaceae
10	*Annona squamosa* L.	Ata	Annonaceae
11	*Antidesma acuminatum* Wall. in Wight.	Chokoi	Euphorbiaceae
12	*Antidesma ghaesembilla* Gaertn.	Chokoi, Elena	Euphorbiaceae
13	*Antidesma spp.*	Moisa chokoi	Euphorbiaceae
14	*Aphanamixis polystachya* (Wall.) R.N. Parker.	Ptiraj	Mimosaceae
15	*Aporosa sp.*	Kharjon	Euphorbiaceae
16	*Aquilaria agallocha* Roxb.	Agar	Thymeliaceae
17	*Araucaria cunninghamii* Sw.	Christmas tree	Araucariaceae
18	*Ardisia colorata* Roxb.	Vet	Myrsinaceae
19	*Areca catechu* L.	Supari	Arecaceae
20	*Artocarpus chama* Hamilton	Chapalish, Chambal	Moraceae
21	*Artocarpus heterophyllus* Lamk.	Kanthal	Moraceae
22	*Artocarpus lacucha* Buch.-Ham.	Borta	Moraceae
23	*Averrhoa carambola* L.	Kamranga	Oxalidaceae
24	*Azadirachta indica* A. Juss.	Neem	Meliaceae
25	*Barringtonia acutangula* (L.) Gaertn.	Hijal	Lecythidaceae
26	*Bauhinia malabarica* Roxb.	Chokakola	Caesalpiniaceae
27	*Bischofiajavanica* Blume	Kanjal bhadi	Euphorbiace

Sl. No.	Scientific name	Local name	Family
			ae
28	*Bixa orellana* L.	Ranggula	Bixaceae
29	*Bombax ceiba* L.	Shimul	Bombacacea e
30	*Borassusflabellifer* L.	Tal	Arecaceae
31	*Bridelia tomentosa* Bl.	Sitki	Euphorbiace ae
32	*Butea monosperma* (Lamk.) Taub.	Polash	Fabaceae
33	*Careya arborea* Roxb.	Gadila, Kumbi	Lecythidacea e
34	*Cassia fistula* L.	Sonalu, Banor noli	Caesalpiniac eae
35	*CaUicarpa arborea* Roxb.	Bormala	Verbenaceae
36	*Chukrasia tabularis* A. Juss.	Chickrassi	Meliaceae
37	*Cinnamomum tamala* Nees & Eberm.	Tejpata	Lauraceae
38	*Citrus maxima* (Burm.) Merr.	Jambura	Rutaceae
39	*Citrus reticulata* Blanco	Komla	Rutaceae
40	*Cleistocalyx nervosum* (DC.) Kosterm.	Ludijam, Dephajam,	Myrtaceae
41	*Cocos nucifera* L.	Narikel	Arecaceae
42	*Cordia dichotoma* Forst. f.	Bolla gota, Bohal	Boraginacea e
43	*Croton tiglium* L.	Jamal gota	Euphorbiace ae
44	*Cryptocarya amygdalina* Nees.	Ojha	Lauraceae
45	*Delonix regia* Rafin.	Krisnachura	Caesalpiniac eae
46	*Derris robusta* (Roxb. ex DC.) Benth.	Katenga	Fabaceae
47	*Dillenia indica* L.	Chalta	Dilleniaceae
48	*Diospyros blancoi* A. DC.	Bilati gab	Ebenaceae
49	*Dipterocarpus alatus* Roxb. ex G. Don	Baitta garjan	Dipterocarpa ceae
50	*Dipterocarpus costatus* Gaertn.	Sada garjan	Dipterocarpa ceae
51	*Dipterocarpus turbinatus* Gaertn.	Telia garjan	Dipterocarpa ceae
52	*DiUenia scabreUa* Roxb. ex Wall.	Ajugi	Dilleniaceae

Sl. No.	Scientific name	Local name	Family
53	*Elaeis guineensis* Jacq.	Oil pulm	Arecaceae
54	*Elaeocarpus floribundus* Blume	Jalpai	Elaeocarpaceae
55	*Erythrina fusca* Lour.	Kanta mander	Fabaceae
56	*Erythrina variegata* L.	Mander	Fabaceae
57	*Eucalyptus camaldulensis* Dehnh.	Eucalyptus	Myrtaceae
58	*Eucalyptus citriodora* Hook.	Eucalyptus	Myrtaceae
59	*Ficus benghalensis* L.	Bot	Moraceae
60	*Ficus hispida* L. f.	Dumor, Kodora	Moraceae
61	*Ficus racemosa* L.	Jagya dumur	Moraceae
62	*Ficus religiosa* L.	Bot	Moraceae
63	*Ficus rumphii* Bl.	Bot	Moraceae
64	*Ficus virens* Ait.	Pakur	Moraceae
65	*Flacourtia jangomas* (Lour.) Raeusch.	Pheyala gola	Flacourtiaceae
66	*Garcinia cowa* Roxb. ex DC.	Cao	Clusiaceae
67	*Garuga pinnata* Roxb.	Sada Jiga	Burseraceae
68	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Gliricidia	Fabaceae
69	*Gmelina arborea* Roxb.	Gamar, Jogi	Verbenaceae
70	*Grevillea robusta* A. Cunn. ex R. Br.	Fern tree	Proteaceae
71	*Grewia asiatica* L.	Kapaia	Tiliaceae
72	*Grewia nervosa* (Lour.) Panigr.	Datoi	Tiliaceae
73	*Grewia serrulata* DC.	Khulla damor	Tiliaceae
74	*Haldina cordifolia* (Roxb.) Ridsdale	Kaika, haldu	Rubiaceae
75	*Hevea brasiliensis* (Willd. ex A. Juss.) Muell.-Arg.	Rubber	Euphorbiaceae
76	*Holarrhena antidysenterica (L.)* Wallich. ex Decne.	Kuruch	Apocynaceae
77	*Hopea odorata* Roxb.	Telsur	Dipterocarpaceae
78	*Hymenodictyon orixensis* (Roxb.) Mabberlly	Bhutum	Rubiaceae
79	*Lagerstroemia parviflora* Roxb.	Sidha	Lythraceae
80	*Lagerstroemia speciosa* (L.) Pers.	Jarul	Lythraceae
81	*Lannea coromandelica* (Houtt.) Merr.	Jiga	Burseraceae
82	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Harinagola	Sapindaceae
83	*Limonia acidissima* L.	Kodbel, Koethbel	Rutaceae
84	*Litchi chinensis* Sonn.	Litchi	Sapindaceae

Sl. No.	Scientific name	Local name	Family
85	*Litsea glutinosa* (Lour.) Robinson	Kharajora, Menda	Lauraceae
86	*Litsea monopetala* (Roxb.) Pers.	Kharajora	Lauraceae
87	*Madhuca longifolia* (Koenig) MacBride	Mahua	Sapotaceae
88	*Mallotusphilippensis* (Lamk.) Muell.-Arg.	Sinduri	Euphorbiaceae
89	*Mangifera indica* L.	Aam	Anacardiaceae
90	*Manilkara zapota* (L.) P van Royen	Sofeda	Sapotaceae
91	*Melia azedarach* L.	Ghoranim, Bokhain	Meliaceae
92	*Miliusa velutina* (Dunal) Hook. f. & Thom.	Gandhi gajari	Annonaceae
93	*Mimusops elengi* L.	Bakul	Sapotaceae
94	*Mitragynaparvifolia* (Roxb.) Korth.	Futikadam	Rubiaceae
95	*Moringa oleifera* Lamk.	Sajna	Moringaceae
96	*Murrayapaniculata* (L.) Jack	Kamini	Rutaceae
97	*Neolamarckia cadamba* (Roxb.) Bosser	Kadom	Rubiaceae
98	*Nyctanthes arbor-tristis* L.	Sheuli	Verbenaceae
99	*Oroxylum indicum* (L.) Kurz	Thona	Bignoniaceae
10	*Peltophorum pterocarpum* (DC.) K. Heyne	Halud krisnachura	Caesalpiniaceae
10	*Phoenix acaulis* Buch. -Ham. ex Roxb.	Khudi khejur	Arecaceae
10	*Phoenix sylvestris* Roxb.	Khejur	Arecaceae
10	*Phyllanthus emblica* L.	Amloki	Euphorbiaceae
10	*Plumeria rubra* L.	Kat-golap	Apocynaceae
10	*Polyalthia longifolia* (Sonn.) Thw.	Debdaru	Annonaceae
10	*Protium serratum* (Wallich ex Colebr.) Engl.	Neul, Neur	Burseraceae
10	*Psidium guajava* L.	Payara	Myrtaceae
10	*Pterospermum acerifolium* (L.) Willd.	Moos	Sterculiaceae
10	*Ricinus communis* L.	Varenda	Euphorbiaceae
11	*Samanea saman* (Jacq.) Merr.	Raintree	Mimosaceae
11	*Schleichera oleosa* (Lour.) Oken.	Joyna, Kusum	Sapindaceae
11	*Semecarpus anacardium* L.f.	Bheula, Bhela	Anacardiaceae

Sl. No.	Scientific name	Local name	Family
11	*Senna siamea* (Lamk.) Irwin & Barneby	Minjiri	Caesalpiniaceae
11	*Shorea robusta* Roxb. ex Gaertn. f.	Sal	Dipterocarpaceae
11	*Spondias pinnata* (L.f.) Kurz	Amla, Bon amra	Anacardiaceae
11	*Sterculia villosa* Roxb. ex Smith	Udal	Sterculiaceae
11	*Stereospermum colais* (Buch.-Ham. ex Dillw.) Mabberley	Dharmara	Bignoniaceae
11	*Streblus asper* Lour.	Sheora	Moraceae
11	*Suregada multiflora* (A. Juss.) Baill.	Suregada	Euphorbiaceae
12	*Swietenia mahagoni* Jacq.	Mahagoni	Meliaceae
12	*Syzygium cumini* (L.) Skeels	Kalojam	Myrtaceae
12	*Syzygium firmum* Thw.	Dhakijam	Myrtaceae
12	*Syzygium fruticosum* DC.	Putijam, Titijam	Myrtaceae
12	*Tamarindus indica* L.	Tentul	Caesalpiniaceae
12	*Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre	Pirilagota, Piralo	Rubiaceae
12	*Tectona grandis* L. f.	Shegun	Verbenaceae
12	*Terminalia afluna* (Roxb. ex DC.) Wight & Arn.	Arjun	Combretaceae
12	*Terminalia beUirica* (Gaertn.) Roxb.	Bohera	Combretaceae
12	*Terminalia chebula* Retz.	Haritaki	Combretaceae
13	*Toona ciliata* M. Roem.	Toon, Rongi	Meliaceae
13	*Trema orientalis* (L.) Blume	Jigni	Ulmaceae
13	*Vitex glabrata* R. Br.	Hakuni gach	Verbenaceae
13	*Vitexpedun cularis* Wallich. ex Schauer	Hakuni gach	Verbenaceae
13	*Wendlandia tinctoria* (Roxb.) DC.	Tulaload	Rubiaceae
13	*Wrightia arborea* (Dennst.) Mabb.	Dudh kuruch	Apocynaceae
13	*Xylia xylocarpa* (Roxb.) Taub. var. kerrii (Craib & Hutch.) Neilsen	Lohakath	Mimosaceae
13	*Zanthoxylum rhetsa* (Roxb.) DC.	Bajna	Rutaceae

Sl. No.	Scientific name	Local name	Family
13	*Ziziphus mauritiana* Lamk.	Boroi	Rhamnaceae
13	*Ziziphus rugosa* Lamk.	Anoi, Anai gota	Rhamnaceae

Source: Rahman et. al. (2019)

Appendix D: List of Plants of Mangrove Forest

Sl. No.	Scientific Name	Local name	Family
1.	*Acacia nilotica* Willd.	Babla	Leguminosae
2.	*Acalypha godseffiana* Linn.	Muktajhuri	Euphorbiaceae
3.	*Acalypha indica* Linn.	Muktajhuri	Euphorbiaceae
4.	*Acanthus ilicifolius* Linn.	Hargoza	Acanthaceae
5.	*Acrostichum aureum* Linn.	Hodo, Tiger fern	Polypodiaceae
6.	*Aegialitis rotundifolia* Roxb.	Dhalchaka	Plumbaginaceae
7.	*Aegiceras corniculatum* Bl.	Khalisha, khalshi	Myrsinaceae
8.	*Albizia lebbeck* Benth.	Kala koroy	Leguminosae
9.	*Albizia procera* Benth.	Sada koroy	Leguminosae
10.	*Albizia richardiana* King & Prain	Raj koroy	Leguminosae
11.	*Amaranthus spinosus* Linn.	Kantanote	Amaranthaceae
12.	*Amoora cucullata* Roxb.	Amur	Meliaceae
13.	*Avcennia officinalis* Linn.	Baen	Avicenniaceae
14.	*Avicennia alba* Bl.	Morcha baen	Avicenniaceae
15.	*Avicennia marina* Vierh.	Sada baen	Avicenniaceae
16.	*Barringtonia acutangula* Gaertl.	Hijal	Barringtoniaceae
17.	*Barringtonia racemosa* Spreng.	Kumba, kumbi	Barringtoniaceae
18.	*Boerhaavia diffusa* Linn.	Punarnava	Nyctaginaceae
19.	*Bouea hurmanica* Griff.	Muriam	Anacardiaceae
20.	*Bruguiera gymnorrhiza* Lamk.	Kankra	Rhizophoraceae
21.	*Bruguiera parviflora* W. & A.	Kankra	Rhizophoraceae
22.	*Bruguiera sexangula* Lam.	Kankra	Rhizophoraceae
23.	*Calophyllum inophyllum* Linn.	Puinal	Guttiferae
24.	*Casia fustula* Linn.	Sonalu	Leguminosae
25.	*Casuarina littorea* Linn.	Jhau	Casuarinaceae
26.	*Centala asiatica* Linn.	Thakuni	Unbellifera
27.	*Cerbera manghas* Gaertn.	Dagor	Apocynaceae
28.	*Ceriops decandra* Griff.	Goran	Rhizophoraceae
29.	*Ceriops tagal* Robins.	Moth goran	Rhizophoraceae
30.	*Cynometra ramiflora* Linn.	Shingra	Leguminosae
31.	*Diospyros peregrine* Gur.	Gub	Ebenaceae
32.	*Eugenia fruticosa* Roxb.	Ban jam	Myrtaceae
33.	*Eugenia lancaefoliaa* Roxb.	Pania jam	Myrtaceae
34.	*Eugenia operculata* Roxb.	Tepajam	Myrtaceae
35.	*Excoecaria agallocha* Linn.	Gewa	Euphorbiaceae
36.	*Excoecaria indica* Muell.	Batla, batul	Euphorbiaceae

Sl. No.	Scientific Name	Local name	Family
37.	*Ficus bengalensis* Linn.	Bot	Moraceae
38.	*Ficus hispida* L.F.	kakdumur	Moraceae
39.	*Ficus microcarpa* La.	Jir	Moraceae
40.	*Ficus racemosa* Linn.	Jogdumur	Moraceae
41.	*Heritiera fomes* Buch.-Ham.	Sundri	Sterculiaceae
42.	*Intsia bijuga* Kunt.	Bhaela, bharal	Leguminosae
43.	*Intsia retusa* Kunt.	Hinge	Leguminosae
44.	*Ipomoea quamoclit* Linn.	Tarulata	Convolvulaceae
45.	*Ixora arborea* Roxb.	Bon bakul	Rubiaceae
46.	*Kandelia candel* W. and A.	Gura, gurae, gural	Rhizophoraceae
47.	*Lagerastroemia speciosa* Linn.	Jarul	Lythraceae
48.	*Lannea coromandelica* Merr.	Jiga	Anacardiaceae
49.	*Lepisanthes rubiginosa* Lee.	Bon lichu	Sapindaceae
50.	*Lumnitzera racemosa* Willd.	Kirpa, kripa	Combretaceae
51.	*Magnifera indica* Linn.	Aam	Anacardiaceae
52.	*Mikania cordata* Roxb.	Asamlata	Compositae
53.	*Mikania scandens* CI.	Tara lata	Compositae
54.	*Nypa fruticans* Wurmb.	Golpata	Palmae
55.	*Operculina terpethum* Silva.Manso.	Dudh kalmi	Convolvulaceae
56.	*Pergularia daemia* Chiov.	Dudhialata	Asclepiadaceae
57.	*Petunga roxburghii* DC.	Narikili	Rubiaceae
58.	*Phoenix paludosa* Roxb.	Hantal	Palmae
59.	*Pongamia pinnata* Pierre.	Karanj, karanja	Leguminosae
60.	*Premna corymbosa* Linn.	Serpoli, setpoli	Verbenaceae
61.	*Rhizophora apiculata* Bl.	Jhana	Rhizophoraceae
62.	*Rhizophora mucronata* Lamk.	Garjan,	Rhizophoraceae
63.	*Salacia chinensis*	Choyt barai	Celastraceae
64.	*Sesbania sesban* Merr.	Katshola	Liguminosae
65.	*Smilax zeylanica* Linn.	Kumari lata	Liliaceae
66.	*Sonneratia apetala* Ham.	Keora	Sonneratiaceae
67.	*Sonneratia caseolaris* Engl.	Choyla	Sonneratiaceae
68.	*Stenochlaena palustris*	Deki lota	Blechnaceae
69.	*Syzygium cumini* Skeels.	Jam	Myrtaceae
70.	*Syzygium operculata* Roxb.	Butijam	Myrtaceae
71.	*Tamarindus indica* Linn.	Tentul	Leguminosae
72.	*Tamarix gallica* Linn.	Jhao, nonajhao	Tamaricaceae
73.	*Tinospora cordifolia* Miers.	Gulancha	Menispermaceae

Sl. No.	Scientific Name	Local name	Family
74.	*Trewia polycarpa* Benth.	Pithali	Euphorbiaceae
75.	*Typha elephantiana* Roxb.	Hogla	Typhaceae
76.	*Urena lobota* Linn.	Banokra	Malvaceae
77.	*Vangueria spinosa* Roxb.	Maina	Rubiaceae
78.	*Vitex negundo* Linn.	Nishanda	Verbenaceae
79.	*Vitis quadrangularis* Wall.	Harjora	Vitaceae
80.	*Vitis trifoliate* Linn.	Anal lata	Vitaceae
81.	*Xylocarpus granatum* Koen.	Dhundul	Meliaceae
82.	*Xylocarpus mekongensis* Pierre.	Passur	Meliaceae

Source: Siddiqui (2016)

Appendix E: List of Plants of Freshwater Swamp Forest

Sl. No.	Scientific Name	Local name	Family
1.	*Asparagus racemosus* L.	Satamuli	Liliaceae
2.	*Barringtonia aculangula (L.)* Gaertn.	Hijol	Lecythidaceae
3.	*Calamus viminalis* Willd.	Bet	Arecaceae
4.	*Crataeva nurvala* Buch.-Ham.	Borun	Capparaceae
5.	*Diplazium esculentum* (Retz.) Sw.	Dheki shak	Athyriaceae
6.	*Dopatrium junceum* Ham.	Binsowan	Scrophu la riaceae
7.	*Lagerstroemia speciosa* L.	Jarul	Lythraceae
8.	*Mikania cordata* (Burm. f.) Rob.	Assamlata	Asteraceae
9.	*Mucuna zygantea* DC.	Alkushi	Fabaceae
10.	*Phyllanthus dislicha*	Chitki	Phyllanthaceae
11.	*Pongamia pinnata* (L.) Merr.	Koroch	Apocynaceae
12.	*Pothos scandens* L.	Hatilata	Araceae
13.	*Schumannianthus dichotomus* (Roxb.) Gagnep.	Sitalpati	Marantaceae
14.	*Streblus asper* Lour.	Shaorah	Moraceae
15.	*Syzygium fruticosum* (Roxb.) DC.	Tit jam	Myrtaceae
16.	*Trewia polycarpa* Benth.	Pitali	Euphorbiaceae

Source: Hossain et. al. (2016)

Appendix G

Energy Data Management

Contents

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1. IEA's Classification Definition of Industrial Sector

The industrial sector is categorized into four sectors: Mining and quarrying, Construction, Manufacturing, and Industry not elsewhere specified. The manufacturing sector is further classified into 10 subsectors. Table G-1 shows the IEA's classification definition of the industrial sector.

Table G-1 IEA's Classification Definition of the Industrial Sector

Industry	Definition (Classification by ISIC Rev.4)	
Mining and quarrying	Mining of iron ores, uranium and thorium ores, other non-ferrous metal ores, Quarrying of stone, sand and clay, Mining of chemical and fertilizer minerals, Extraction of peat, salt, Other mining and quarrying n.e.c. (not elsewhere classified), Support activities for other mining and quarrying	
Construction	Construction of buildings, roads and railways, utility projects, other civil engineering projects, Demolition, Site preparation, Electrical installation, Plumbing, heat and air-conditioning installation, Other construction installation, Building completion and finishing, Other specialized construction activities	
Manufacturing	Iron and steel	Manufacture of basic iron and steel, Casting of iron and steel
	Chemical and petrochemical	Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms, Manufacture of pesticides and other agrochemical products, paints, varnishes and similar coatings, printing ink and mastics, soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations, other chemical products n.e.c., man-made fibers, pharmaceuticals, medicinal chemical and botanical products
	Non-ferrous metals	Manufacture of basic precious and other non-ferrous metals, Casting of non-ferrous metals
	Non-metallic minerals	Manufacture of glass and glass products, refractory products, clay building materials, other porcelain and ceramic products, cement, lime and plaster, articles of concrete, cement and plaster, other non-metallic mineral products n.e.c. Cutting, shaping and finishing of stone
	Transport equipment	Manufacture of motor vehicles, bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers, parts and accessories for motor vehicles, Building of ships and floating structures, pleasure and sporting boats, Manufacture of railway locomotives and rolling stock, air and spacecraft and related machinery, military fighting vehicles, motorcycles, bicycles and invalid carriages, other transport equipment n.e.c.
	Machinery	Manufacture of structural metal products, tanks, reservoirs and containers of metal, steam generators, except central heating hot water boilers, weapons and ammunition, Forging, pressing, stamping and roll-forming of metal; powder metallurgy, Treatment and coating of metals; machining, Manufacture of cutlery, hand tools and general hardware, other fabricated metal products n.e.c., electronic components and boards, computers and peripheral equipment, communication equipment, consumer electronics, measuring, testing, navigating and control equipment, watches and clocks, irradiation, electromedical

		and electrotherapeutic equipment, optical instruments and photographic equipment, magnetic and optical media, electric motors, generators, transformers and electricity distribution and control apparatus, batteries and accumulators, fiber optic cables, other electronic and electric wires and cables, wiring devices, electric lighting equipment, domestic appliances, other electrical equipment, engines and turbines, except aircraft, vehicle and cycle engines, fluid power equipment, other pumps, compressors, taps and valves, bearings, gears, gearing and driving elements, ovens, furnaces and furnace burners, lifting and handling equipment, office machinery and equipment (except computers and peripheral equipment), power-driven hand tools, other general-purpose machinery, agricultural and forestry machinery, metal-forming machinery and machine tools, machinery for metallurgy, machinery for mining, quarrying and construction, machinery for food, beverage and tobacco processing, machinery for textile, apparel and leather production, other special-purpose machinery
	Food and tobacco	Processing and preserving of meat, fish, crustaceans and mollusks, fruit and vegetables, Manufacture of vegetable and animal oils and fats, dairy products, Manufacture of grain mill products, starches and starch products, Manufacture of bakery products, sugar, cocoa, chocolate and sugar confectionery, macaroni, noodles, couscous and similar farinaceous products, prepared meals and dishes, other food products n.e.c., prepared animal feeds, Manufacture of distilling, rectifying and blending of spirits, wines, malt liquors and malt, soft drinks; production of mineral waters and other bottled waters, tobacco products
	Paper, pulp and printing	Manufacture of pulp, paper and paperboard, corrugated paper and paperboard and of containers of paper and paperboard, other articles of paper and paperboard, Printing, Service activities related to printing, Reproduction of recorded media
	Wood and wood products	Sawmilling and planning of wood, Manufacture of veneer sheets and wood-based panels, builders' carpentry and joinery, wooden containers, other products of wood; manufacture of articles of cork, straw and plaiting materials
	Textile and leather	Preparation and spinning of textile fibers, Weaving of textiles, Finishing of textiles, Manufacture of knitted and crocheted fabrics, made-up textile articles, except apparel, carpets and rugs, cordage, rope, twine and netting, other textiles n.e.c., wearing apparel, except fur apparel, articles of fur, knitted and crocheted apparel, Tanning and dressing of leather; dressing and dyeing of fur, Manufacture of luggage, handbags and the like, saddlery and harness, footwear
Industry not elsewhere specified	Manufacture of rubber tires and tubes; retreading and rebuilding of rubber tires, other rubber products, plastics products, furniture, jewelry and related articles, imitation jewelry and related articles, musical instruments, sports goods, games and toys, medical and dental instruments and supplies, other manufacturing n.e.c.	

Source: Prepared by World Energy Balances 2020 Edition Database Documentation, IEA and International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4

2. Data Template

Energy distribution companies are requested to submit energy data according to IEA's Classification. To request the data, a data template is prepared as shown in Table G-2 to 4.

Table G-2 Data Template of Power Distribution Companies

Name of Company:							
Customer Category wise Electricty Supply Data in Million kWh							
Category of customers		July	August	~	May	June	Total July-June
Residential							0
Commercial							0
Industrial							0
Irrigation/Agri Pumps							0
Street Lights							0
Construction							0
Battery Charging Stations							0
Education/Religious/Hospital							0
Others							0
Total		**0**	**0**	~	**0**	**0**	**0**
Electricity Supply Data in Million kWh in industry sectors							
Industry types	Subsector	July	August	~	May	June	Total July-June
Mining and quarrying							0
Construction							0
Manufacturing		0.00	0.00	~	0.00	0.00	0
	Iron and steel						0
	Chemical and petrochemical						0
	Non ferrous metals						0
	Non metallic minerals						0
	Transport equipment						0
	Machinery						0
	Food and tobacco						0
	Paper, pulp and printing						0
	Wood and wood products						0
	Textile and leather						0
Industry not elsewhere specified							0
Total		0	0	~	0	0	0

Table G-3 Data Template of Gas Distribution Companies

Name of Company:							
Customer Category wise Gas Supply Data in Cubic Meter							
Category of customers		July	August	~	May	June	Total July-June
Metered Domestic							0
Non-metered Domestic							0
Commercial							
Industrial							
C.N.G							
Captive							
Grid Connected Power Plant							
Fertilizer							0
Condensate							0
Total		**0**	**0**	~	**0**	**0**	**0**
Gas Supply Data in Cubic Meter in industry sectors							
Industry types	Subsector	July	August	~	May	June	Total July-June
Mining and quarrying							0
Construction							0
Manufacturing		0.00	0.00	~	0.00	0.00	0
	Iron and steel						0
	Chemical and petrochemical						0
	Non ferrous metals						0
	Non metallic minerals						0
	Transport equipment						0
	Machinery						0
	Food and tobacco						0
	Paper, pulp and printing						0
	Wood and wood products						0
	Textile and leather						0
Industry not elsewhere specified							0
Total		0	0	~	0	0	0

Table G-4 Data Template of Oil Distribution Companies

Name of Company:							
Customer Category wise SKO Supply Data in Metric Ton							
Category of customers		July	August	~	May	June	Total July-June
Residential							0
Transport							0
Industrial							0
Agriculture							0
Power generation							0
Others							0
Total		**0**	**0**	~	**0**	**0**	**0**
SKO Supply Data in Metric Ton in industry sectors							
Industry types	Subsector	July	August	~	May	June	Total July-June
Mining and quarrying							0
Construction							0
Manufacturing		0.00	0.00	~	0.00	0.00	0
	Iron and steel						0
	Chemical and petrochemical						0
	Non ferrous metals						0
	Non metallic minerals						0
	Transport equipment						0
	Machinery						0
	Food and tobacco						0
	Paper, pulp and printing						0
	Wood and wood products						0
	Textile and leather						0
Industry not elsewhere specified							0
Total		0	0	~	0	0	0

3. Survey on Data of Energy-intensive Industries

The purpose of this survey is to understand energy consumption of cement, paper and pulp, and bricks manufacturing industries and to verify data provided by energy supplying companies (energy consumption in industrial sub-sector) to get per-unit energy consumption of energy-intensive industries in Bangladesh.

We request 15 companies (five companies each for the cement industry, paper and pulp industry, and bricks manufacturing industry) to give us FY 2018-2019 data, which has no negative effects from COVID-19. We give an overview of the cement industry, paper and pulp industry, and bricks manufacturing industry in Bangladesh and analyze collected data.

1) Cement industry

There are 31 cement companies (including five foreign-affiliated companies) in Bangladesh at present[1]. The cement production capacity was 54 million ton/year, production was 32 million ton/year, and cement sales were 33 million ton/year in Bangladesh in 2018; 82% of total cement demand was covered by domestic production[2]. The operation rate of cement manufacturing facilities is about 60% since peak season of cement production takes place in dry season from November to April-May of the following year. The top 10 cement producing companies account for 81% of domestic cement sales. Bangladesh imports 90% of clinker, which is necessary for cement production, from Vietnam (the rest is imported from China, Thailand, and Malaysia). Clinker is domestically produced by only two companies in Bangladesh. Dhaka and Chittagong account for 75% of the total cement consumption.

Table G-5 shows collected data from five cement producing companies. We cannot calculate per-unit energy consumption exclusively for clinker production for company A because the company consumes gas both for kilns and their own generators. We need to check per-unit energy consumption for clinker of company B because the unit is about half that of Japanese cement companies. Electricity consumption for producing cement by smashing clinker of company C and E is about 80kWh/t-cement, which can be recognized as standard.

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1 List of All Top Cement Companies in Bangladesh,
https://bangladeshbusinessdir.com/cement-companies-in-bangladesh/
(Accessed on January 11, 2022)

2 The following data from “How many Cement plants are producing in Bangladesh 2020?”
DATIS EXPORT GROUP　2020-8-27, pp.4-16
https://datis-inc.com/blog/how-many-cement-plants-are-producing-in-bangladesh-2020/
(Accessed on January 11, 2022)

Table G-5 Collected Data from Cement Companies

Name of Factory	A	B	C	D	E
Plant Capacity (Annual) (ton)	140,000		876,000	730,000	438,000
Annual Cement Production: (ton)	11,925	1,057,000	144,000	90,000	280,000
Annual Clinker Production: (ton)	10,655	1,180,000	Do not produce		Do not produce
Annual Energy Consumption and Heat Value～Coal (ton)	0		Not Required		Not Required
Annual Energy Consumption and Heat Value～Gas: (m3)	6,655,179.28	42,718,426	Not Required	3,626,257	Not Required
Annual Electricity consumption from Grid (kWh)		602,621	11,520,000	21,885.22	21,330,000
Type of Kiln: Rotary Kiln (Wet Process)			Do not use		Do not use
Do you have own generator for production?	Yes. We have a captive power plant.	Not applicable	NO		NO
If yes, Capacity of Generator:	8,000.00 kW		Do not use	33,953.76 MW	Do not use
Frequency of usage:	Every day (ex. every day, once a week, during power outage only, etc.)		Do not use	Everyday	Do not use
Annual operation hours of captive generators:			Do not use		Do not use
Please mention average load factor of captive generators (%)			Do not use		Do not use
Other Comments			Factory only uses Electricity from National Grid. They also do not use any Kiln.	Uses no Kiln	Factory only uses Electricity from National Grid. They also do not use any Kiln.

Source: Cement companies

2) Paper and pulp industry

In Bangladesh, 70 private paper and pulp manufacturing companies out of 105 government-registered now operate and annual production capacity is 1.5 million ton/year[3]. Karnaphuli Paper Mills is the only national paper and pulp manufacturing company which is now in operation.

Table G-6 shows collected data from paper and pulp manufacturing companies. We have found that it is difficult to calculate per-unit energy consumption for paper and pulp manufacturing because many companies import pulp and bot chips as countermeasures for air pollution and deforestation.

[3] Bangladesh's paper industry holds huge export potential, 2021-12-8, https://thefinancialexpress.com.bd/trade/bangladeshs-paper-industry-holds-huge-export-potential-1638932197 (Accessed on January 11, 2022)

Table G-6 Collected Data from Paper and Pulp Companies

Name of Factory	A	B	C	D	E
Annual Plant Capacity (ton)	600,000	100,000	21,600	842,000	828,000
Annual Pulp Production (ton)	N/A	X		95,566	Nil
Annual Paper Production (ton)	421,308	Paper & Tissues	21,600	78,600	75,594
Annual Energy Consumption～Coal (ton)	N/A	X			N/A
Annual Energy Consumption～Gas (m3)	N/A		2,635,669.74	4,947,774	4,755,000
Heat ValueGas (kcal/m3)			8,455.55		
Heat ValueGas (KJ/m3)			35,378		
Fuel Oil	N/A	X		70,763kl	73,126 (Diesel)kl
Others	N/A	X			N/A
Annual Electricity consumption from Grid (kWh)	38,697,140			18,981,512	18,334,753
Do you have own generator for production?	N/A			Uses the own powerplant of the Meghna Group of Industries (MGI)	Uses own power plant of Meghna Group
Capacity of Generator (kW)		32,000	10,301,020		

Source: Paper and pulp manufacturing companies

3) Brick producing industry

There are 7,200 brick kilns in Bangladesh in 2019 and 23 billion pieces of brick were produced domestically[4]. All produced bricks are used in Bangladesh and brick factories consume 3.65 million ton of coal, emit 15.67 million tons of CO2 and consume 3.35 billion cubic feet of clay annually[5].

Table G-7 shows collected data from brick producing companies. Every five companies consume about 0.14kg of coal to produce one piece of brick. This is a reasonable figure because Bangladesh consumes 3.65 million ton of coal (0.158kg/piece of brick) in total.

Table G-7 Collected Data from Brick Companies

Name of Factory	A	B	C	D	E
Plant Capacity (Annual) (pieces)	2,000,000	1,900,000	2,000,000	2,200,000	1,800,000
Annual Production: Bricks (pieces)	2,000,000	1,900,000	2,000,000	2,200,000	1,800,000
Annual Energy Consumption～Coal (ton)	275	266	280	300	252
Type of Kiln	Zigzag	Zigzag	Zigzag	Zigzag	Zigzag

Source: Each brick producing company

[4] FACT SHEET, Brick sector in Bangladesh. ICIMOD https://lib.icimod.org/record/34681/files/icimodBrickBangladesh.pdf?type=primary (Accessed on January 11, 2022)

[5] Ibid.

Appendix H

Legal Framework for LNG Import

Appendix H considers preparation of appropriate legal framework for import of LNG in light of the FERC regulations and practices in the USA.

Contents

Task 1 1

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This report sets out the findings of the following tasks undertaken by the Master Plan TWG-4.

Task 1: Analysis of existing laws and regulations in Bangladesh with regard to LNG import and subsequent distributions of re-gasified LNG.

Task 2: Propose an action plan toward recommended modifications to applicable laws and regulations in Bangladesh in consideration of increased volumes of LNG import and subsequent distributions of re-gasified LNG.

Task 3: Propose an action plan toward enhancement of legal and commercial capabilities of Bangladesh in negotiating LNG import from international market.

Task 1

1.1. Summary of Findings

We have recommended in our previous assignment with JICA that Bangladesh modify energy laws and regulations modeling after US laws and regulations, which have been formulated and enacted through our long history and experience of natural gas productions and distributions in the US as well as import and export of LNG to and from the US. To encourage investors from foreign countries into the Bangladesh energy, gas and LNG sector, it is critical that Bangladesh maintain laws and regulations applicable to LNG import and subsequent re-gasified gas distributions that match or even exceed international standards in all aspects including safety, environmental and operational perspectives. The Bangladesh Energy Regulatory Commission ("BERC") was established by the Bangladesh Energy Regulatory Commission Act of 2003 while the Federal Energy Regulatory Commission ("FERC") in the US was established by the Department of Energy Organization Act of 1977. Although both organizations have similar names and appear to play similar roles in administering the energy regulatory framework of each country, FERC obviously has profound experience over its 45-year history under an ever-changing environment of the energy and gas industry in the US and global market. BERC certainly would benefit by looking at FERC's experience and how FERC took administrative initiatives in resolving complicated issues at critical moments of energy, gas and power industry in the US.

Many of the existing laws and regulations in Bangladesh do not have formal English translations. In order to make a meaningful analysis of existing laws and regulations in Bangladesh, it is imperative that the study team reviews an English translation of subject laws and regulations. Accordingly, the study team worked with a local English translation firm and obtained translations of the following laws and regulations that appear relevant to LNG import and subsequent distribution of gas into the domestic market. These translations are not formal translations by the government of Bangladesh, however they provide us with a sufficient basis in understanding the substance of these laws and regulations. Please note however, the following list of laws and regulations may not represent an entire set of laws and regulations applicable to LNG

and gas industry. These laws and regulations are selected for purposes of analysis based on the information available on the BERC website as well as written inquiries into Bangladesh counterparts in TWG-4.

1.2. Existing Laws and Regulations

Under Bangladesh Energy Regulatory Commission (BERC):

- Bangladesh Energy Regulatory Commission Act, Act No. 13, 2003
- Bangladesh Energy Regulatory Commission (Amendment) Act, Act No. 3, 2005
- Bangladesh Energy Regulatory Commission (Amendment) Act, Act No. 6, 2010
- Bangladesh Energy Regulatory Commission (Amendment) Act, Act No. 25, 2020
- Bangladesh Energy Regulatory Commission License Regulations, Act No. 177, 2006
- Bangladesh Gas Act, 2010
- BERC Electricity Generation Tariff Regulations, 2008
- BERC Natural Gas Transmission Tariff Regulations, 2010
- BERC Natural Gas Distribution Tariff Regulations, 2010
- BERC Dispute Resolution Regulations, 2021

Under Energy and Mineral Resources Division (EMRD):

- CNG Rules, 2005
- Gas Development Fund Policy, 2012
- Gas Distribution Rules (Domestic), 2014
- Gas Sales Rules (Commercial, Industry, Seasonal, Captive Power, CNG & Tea-Estate), 2014
- LNG Infrastructure Formation, Importing & Distribution in Private Sector Policy, 2019
- Natural Gas Allocation Policy, 2019

1.3. Analysis of Existing Laws and Regulations

As described above, existing laws and regulations are categorized into two sets of laws and regulations, one pertinent to BERC, and another pertinent to EMRD.

1.3.1. BERC Act and its Amendments (above 1.2.1.- 1.2.4)

These are the laws that established BERC in 2003 and supplemental amendments to the 2003 Act. These laws clearly set out objectives of establishing BERC and appear to sufficiently provide for functions and roles of BERC in administering energy regulatory issues. FERC in the U.S. was created by similar establishing law and its administrative authority comes from various other relevant laws. To analyze the substance and sufficiency of establishing laws of BERC, the study team has created a comparison chart below summarizing the provisions of establishing laws of BERC and FERC (without taking into consideration amendments to the BERC Act).

Section Number/Title	
BERC BERC Act of 2003	**FERC** Department of Energy Organization Act USC Title 42 Ch.84 Subchapter IV
Chapter 2 – Establishment of the Commission 4. Establishment of the Commission 5. Office of the Commission, etc. 6. Constitution of the Commission, etc. 7. Qualifications and Disqualifications of Members, etc. 8. Tenure of office, resignation, etc. of the Chairman and Members 9. Actions and proceedings not to be void due to the vacancy in the position of Member 10. Status, pay and allowances, etc. of the Members 11. Removal of Member 12. Commission's meeting 13. Appointment of Secretary, officers and staff, etc. of the Commission 14. Committee 15. Appointment of employee to the Commission on deputation 16. Employment outside Commission	**§7171 Appointment of Administration** (a) Federal Energy Regulatory Commission; establishment (b) Composition; term of office; conflict of interest; expiration of terms (c) Duties and responsibilities of Chairman (d) Supervision and direction of members, employees, or other personnel of Commission (e) Designation of Acting Chairman; quorum; seal (f) Rules (g) Power of Commission (h) Principal office of Commission (i) Commission deemed agency; attorney for Commission (j) Annual authorization and appropriation request (k) Addressing insufficient compensation of employees and other personnel of the Commission
Chapter 3 – Financial matters of the Commission 17. Funds of the Commission 18. Authority to receive loan 19. Annual budget and statement 20. Accounting and audit 21. Report	**§7172 Jurisdiction of Commission** (a) Transfer of functions from Federal Power Commission (b) Repealed. (c) Consideration of proposals made by Secretary to amend regulations issued under section 753 of title 15; exception (d) Matters involving agency determinations to be made on record after agency hearing (e) Matters assigned by Secretary after public notice and matters referred under section 7174 of this title (f) Limitation

	(g) Final agency action (h) Rules, regulations, and statements of policy
Chapter 4 – Functions, Powers and Proceedings of the Commission 22. Functions of the Commission 23. Investigation power	**§7173 Initiation of rulemaking procedures before Commission** (a) Proposal of rules, regulations, and statements of policy of general applicability by Secretary and Commission (b) Consideration and final action on proposals of Secretary (c) Utilization of rulemaking procedures for establishment of rates and charges under Federal Power Act and Natural Gas Act (d) Submission of written questions by interested persons
Chapter 5 – Relationship between the Government and the Commission 24. Powers of the Government of the Energy Sector 25. Emergency power to control energy use 26. Settlement of Disputes	**7174 Referral of other rulemaking proceedings to Commission** (a) Notification of Commission of proposed action; public comment (b) Recommendations of Commission; publication (c) Options of Secretary; final agency action
Chapter 6 – License 27. License 28. Issuance of license by the Commission 29. Exemption from the requirement of license 30. Renewal, revision and cancellation of license 31. General duties and powers of the licensee 32. Restrictions to the licensee 33. Annual accounts of licensee	**§7175 The right of Secretary to intervene in Commission Proceedings**
Chapter 7 – Tariff 34. Tariff	**§7176 Reorganization**
Chapter 8 – Commission's power to issue order and implement its decision 35. Interim or Final Order 36. Emergency Provision 37. Implementation of Interim and Final Order	**§7177 Access to information**
Chapter 9 – Flow of Information 38. Information regarding quality of work	**§7178 Federal Energy Regulatory Commission fees and annual charges**

39. Restrictions on publishing information	(a) In general (b) Basis for assessments (c) Estimates (d) Time of payment (e) Adjustments (f) Use of funds (g) Waiver
Chapter 10 – Arbitration – Settlement and Appeal 40. Arbitration – Settlement by the Commission 41. Appeal against the decision of Inspector	
Chapter 11 – Offence and Penalty 42. Penalty 43. Penalty and fine for violation of Order 44. Penalty for stealing energy 45. Penalty for obstruction of the construction during the installation or repair of electric line or gas pipeline, etc. 46. Offence by a Company 47. Cognizance of offence for trial 48. Not to hamper proceeding under any other Act 49. Jurisdiction of cognizing Court 50. Jurisdiction of trial Court 51. Filing of compliant and procedure of investigation 52. Application of Code of Criminal Procedure 53. Assistance to the public prosecutor by the Officer of the Commission	
Chapter 12 – Receipt of Compliant of Consumer and disposal 54. Receipt of Compliant of Consumer and their disposal	
Chapter 13 – Miscellaneous 55. Finality of the Commission's order 56. Collection of fee, fine and charges 57. Expenditure of fine, penalty and charges 58. Power to make rules 59. Power to make regulations	

60. Delegation of powers 61. Public servant 62. Indemnity in case of work done in good faith 63. Proceedings regarded as judicial proceedings. 64. Appointment of Special or Metropolitan Magistrate 65. Publication of Authentic English Text	
Chapter 13 – Transition Provision 66. Provisions for issuance of license during transitional period	

As you can see above, the BERC Act is more extensive and descriptive about its roles and functions compared to the FERC establishing laws. While we observe good attempts by the Bangladesh legislative body trying to achieve completeness of the provisions of the Act in creating BERC, a notable difference between the BERC Act and FERC establishing laws would be the emphasis placed on the rulemaking powers of each organization. In administering energy regulatory issues in the U.S., it is critical that FERC have broad and independent powers to promulgate and enforce its own rules delegated by applicable underlying laws. FERC has the flexibility to determine how it will operate within its authority specifically delegated by these laws. Most relevant laws to FERC's actual authority with regard to natural gas come from the Natural Gas Act, Natural Gas Policy Act, and Energy Policy Act of 2005. The rulemaking powers are the core of the FERC's administrative function to carry out its roles in a prompt and effective manner. This is why FERC establishing laws provide for its rulemaking powers at the outset of the laws.

On the contrary, BERC's rulemaking powers are incorporated as item 58 in the section of Miscellaneous toward the end of the Act. This does not necessarily mean BERC's rulemaking powers are considered unimportant, however, we haven't identified the rulemaking powers of BERC specifically delegated by relevant laws as we see in the US in Natural Gas Act, etc. We will further examine this issue at the section of BERC Regulations and FERC Regulations below.

1.3.2. Mission Statements of BERC and FERC

Before analyzing administrative functions and practices of BERC and FERC, it would be beneficial to review organizational objectives of BERC and FERC. The charts below summarize vision, mission and guidelines, and roles of BERC and FREC.

Vision

BERC	FERC
To create an enabling environment, efficient,	Economically Efficient, Safe, Reliable, and

well-managed and sustainable energy sector in Bangladesh for providing energy at just & reasonable cost, and protection of consumers interest & satisfaction through fair practices.	Secure Energy for Consumers. Assist consumers in obtaining economically efficient, safe, reliable, and secure energy services at a reasonable cost through appropriate regulatory and market means, and collaborative efforts.

Mission and Guidelines

BERC	FERC
Promote equal opportunities for public and private investments and to develop competitive market	***Organizational Excellence:*** The Commission strives to use its resources efficiently and effectively to achieve its strategic priorities
Transparency in energy sector management, cost rationalization & tariff determination	***Due Process and Transparency:*** Paramount in all of its proceedings is the Commission's determination to be open and fair to all participants
Enforcement of fiscal discipline in the energy sector	***Regulatory Certainty:*** In each of the thousands of orders, opinions, and reports issued by the Commission each year, the Commission strives to provide regulatory certainty through consistent approaches and actions
Introduction of performance and incentive-based regulation	***Stakeholder Involvement:*** The Commission conducts regular outreach to ensure that interested parties have an appropriate opportunity to contribute to the performance of the Commission's responsibilities
Introduction of uniform operational standards and help ensure quality of supply	***Timeliness:*** The Commission's goal is to reach an appropriate resolution of each proceeding in an expeditious manner

Roles

BERC	FERC
Issue, cancel, amend and determine conditions of licenses, exemption of licenses and determine the conditions to be followed by such exempted persons	Regulates the transmission and wholesale sales of electricity in interstate commerce
Help ensure efficient use, quality services,	Reviews certain mergers and acquisitions

determine tariff and safety enhancement of electricity generation and transmission, marketing, supply, storage and distribution of energy	and corporate transactions by electricity companies
Approve schemes on the basis of overall program of the licensee and take decision taking into consideration the load forecast and financial status	Regulates the transmission and sale of natural gas for resale in interstate commerce
Extend co-operation and advice to the Government, if necessary, regarding electricity generation, transmission, marketing, supply, distribution and storage of energy	Regulates the transportation of oil by pipeline in interstate commerce
Encourage to create a congenial atmosphere to promote competition amongst the licensees	Approves the siting and abandonment of interstate natural gas pipelines and storage facilities
Ensure control of environmental standard of energy under existing laws	Reviews the siting application for electric transmission projects under limited circumstances
Ensure appropriate remedy for consumer disputes, dishonest business practices or monopoly	Assess the safe operation and reliability of proposed and operating LNG terminals
Resolve disputes between licensees and between licensees and consumers, and refer to arbitration if necessary	Licenses and inspects private, municipal, and state hydroelectric projects
Develop uniform methodology of accounting for all licensees to help ensure performance rating on a fair platform	Protects the reliability of the high voltage interstate transmission system through mandatory reliability standards
Frame codes and standards and make enforcement of those compulsory to ensure quality of services	Enforces FERC regulatory requirements through imposition of civil penalties and other means
Determine efficiency and standard of the machinery & appliances using energy and ensure through energy audit the verification, monitoring, analysis of the energy data and economic use and enhancement of efficiency on use of energy	Oversees environmental matters related to natural gas and hydroelectricity projects and other matters
Perform any incidental functions if considered appropriate by the Commission	Administers accounting and financial reporting regulations and conduct of

for fulfilling objectives of the Act	regulated companies

As you can see above, both BERC and FERC set out clear mission statements in their vision, mission and guidelines, and roles. BERC's mission statements published on its website are clear and comprehensive, and successfully illustrate "who BERC is" and "what BERC does".

1.3.3. BERC Regulations (above 1.2.5 – 1.2.10) and FERC Regulations

These are the representative regulations published on the website of BERC. While these regulations appear to address issues presented to BERC, we believe that BERC regulations could be issued more frequently and broadly in a proactive manner to address issues that come under the jurisdiction of BERC. In the U.S., FERC oversees industry sectors of electric, natural gas, LNG, hydropower and oil. To promote its objective, FERC has issued various regulations, which are comprehensively published and updated every year on its website. BERC regulations appear to have similar administrative objections as we see in FERC regulations however, we see that the number and volume of BERC regulations issued to date are far less than those of FERC's. To highlight the difference, we describe below the list of the regulations issued by BERC and FERC.

BERC Regulations

No.	Title	Publish Date
1	BERC Fund Regulation, 2004	2005-02-17
2	BERC Budget, Accounts and Reporting Regulation, 2004	2005-02-17
3	Bangladesh Energy Regulatory Commission License Regulations, 2006	2006-09-07
4	BERC (Electricity Generation Tariff) Regulations, 2008	2008-04-08
5	BERC Employee Service Regulations, 2008	2008-04-08
6	BERC (Natural Gas Distribution Tariff) Regulations, 2010	2011-01-13
7	BERC (Natural Gas Distribution Tariff) Regulations, 2010	2011-01-13
8	BERC (Power Transmission Tariff) Regulations, 2016	2016-06-07
9	BERC Power Distribution (Retail) Tariff Regulations, 2016	2016-06-07
10	হালনাগাদকৃত স্বশাসিত প্রতিষ্ঠানের জন্য একইরুপ চাকরি প্রবিধানমালা প্রণয়ন এবং চাকরি প্রবিধানমালা জারির বিষয়ে জনপ্রশাসন মন্ত্রণালয়ের নির্দেশনা। (২৮ ডিসেম্বর ২০১৬)	2016-12-26
11	Bangladesh Energy Regulatory Commission Dispute Settlement (Cancel) Regulations, 2021	2021-06-17
12	বাংলাদেশ এনার্জি রেগুলেটরী কমিশন বিরোধ নিষ্পত্তি প্রবিধানমালা. ২০২১	2021-06-17

FERC Regulations

Title 18	Conservation of Power and Water Resources	Part / Section
Chapter I	Federal Energy Regulatory Commission, Department of	1 – 399
Subchapter A	General Rules	1 – 3c
Subchapter B	Regulations Under the Federal Power Act	4 – 50
Subchapter C	Accounts, Federal Power Act	101 – 125
Subchapter D	Approved Forms, Federal Power Act and Public Utility Regulatory Policies Act of 1978	131 – 149
Subchapter E	Regulations Under Natural Gas Act	152 – 158
Subchapter F	Accounts, Natural Gas Act	201 – 225
Subchapter G	Approved Forms, Natural Gas Act	250 – 260
Subchapter H	Procedures Governing Determinations for Tax Credit	270
Part 270	Determination Procedures	270.101 – 270.506
Subchapter I	Other Regulations Under the Natural Gas Policy Act of 1978 and Related Authorities	280 – 286
Subchapter J	Regulations Under the Powerplant and Industrial Fuel Use	287
Part 287	Rules Generally Applicable to Powerplant and Industrial	287.101
Subchapter K	Regulations Under the Public Utility Regulatory Policies	290 – 294
Subchapter L	Regulations for Federal Power Marketing Administrations	300 – 301
Subchapters M-O [Reserved]		
Subchapter P	Regulations Under the Interstate Commerce Act	340 – 349
Subchapter Q	Accounts Under the Interstate Commerce Act	351
Subchapter R	Approved Forms, Interstate Commerce Act	356 – 357
Subchapter S	Standards of Conduct for Transmission Providers	358
Part 358	Standards of Conduct	358.1 – 358.8
Subchapter T [Reserved]		
Subchapter U	Regulations Under the Public Utility Holding Company Act of 2005, Federal Power Act and Natural Gas Act	366 – 369
Subchapter W	Revised General Rules	375 – 382
Subchapter X	Procedural Rules	385 – 399

As you can see above, FERC has issued more regulations than BERC covering broad areas of gas and power industries including accounting and tax issues. FERC has a long history of administering energy industry in the U.S. and dealt with various fundamental changes in energy industry in domestic and global market. This may be the reason why FERC has issued more regulations than BERC to date. However, it is not appropriate to conclude that FERC regulations have been used more effectively than BERC regulations just by looking at the number of regulations issued by each organization. To analyze actual substance and depth of regulations issued by BERC and FERC in the same designated area of industry with a more narrowed-down scope of comparison, we took an example in natural gas related regulations issued by BERC and FERC respectively and compared them. This analysis would allow us to determine whether or not BERC regulations have been issued effectively, as they relate to the natural gas industry in Bangladesh, as we see in the practice of FERC regulations in natural gas industry in the U.S.

1.3.4. Natural Gas Regulations of BERC and FERC

FERC regulations with regard to natural gas

CFR Title 18 Chapter I sets out following Subchapters with regard to natural gas.

- Subchapter E: Regulations under Natural Gas Act
- Subchapter F: Accounts, Natural Gas Act
- Subchapter G: Approved Forms, Natural Gas Act
- Subchapter I: Natural Gas Policy Act 1978 and related authorities

The following is the list of sections included in each of Subchapter E, F, G and I.

Subchapter E:

Part 152 provides for exemption from the Natural Gas Act for the sale of natural gas. Part 153 provides for regulations broadly encompassing the issues regarding construction, operation, modification to natural gas import and export facilities. Part 154 sets out rate schedules and tariffs. Part 156 cover Orders Under Section 7(a) of the Natural Gas Act, Part 157 covers Applications for Public Convenience and Necessity and for Orders Permitting and Approving Abandonment Under the Natural Gas Act. Part 158 provides for accounting and auditing issues.

Subchapter E	Regulations Under Natural Gas Act	152 – 158
Part 152	Application for Exemption from the Provisions of the Natural Gas Act Pursuant to Section 1(c) Thereof and Issuance of Blanket Certificates Authorizing Certain Sales for Resale	152.1 – 152.5
§ 152.1	Exemption applications and blanket certificates.	
§ 152.2	Form of application; service.	
§ 152.3	Contents of application.	
§ 152.4	Certificate from State Commission.	
§ 152.5	Applicability of exemption.	
Part 153	Applications for Authorization to Construct, Operate, or Modify Facilities Used for the Export or Import of Natural Gas	153.1 – 153.23
Subpart A	General Provisions	153.1 – 153.3
Subpart B	Application Under Section 3	153.4 – 153.13
Subpart C	Application for a Presidential Permit	153.15 – 153.17
Subpart D	Paper Media and Other Requirements	153.20 – 153.23
Part 154	Rate Schedules and Tariffs	154.1 – 154.603
Subpart A	General Provisions and Conditions	154.1 – 154.8
Subpart B	Form and Composition of Tariff	154.101 – 154.112
Subpart C	Procedures for Changing Tariffs	154.201 – 154.210
Subpart D	Material To Be Filed With Changes	154.301 – 154.315
Subpart E	Limited Rate Changes	154.400 – 154.403
Subpart F	Refunds and Reports	154.501 – 154.502
Subpart G	Other Tariff Changes	154.600 – 154.603
Part 156	Applications for Orders Under Section 7(a) of the Natural Gas Act	156.1 – 156.11
Part 157	Applications for Certificates of Public Convenience and Necessity and for Orders Permitting and Approving Abandonment Under Section 7 of the Natural Gas Act	157.1 – 157.218
Part 158	Accounts, Records, Memoranda and Disposition of Contested Audit Findings and Proposed Remedies	158.1 – 158.12

Subchapter F:

Part 201 sets out natural gas accounting provisions and Part 202 sets out accounting recording keeping issues.

Subchapter F	Accounts, Natural Gas Act	201 – 225
Part 201	Uniform System of Accounts Prescribed for Natural Gas Companies Subject to the Provisions of the Natural Gas Act	
	Income Accounts 400 Operating Revenues.	
	Retained Earnings Accounts 433 Balance Transferred from Income.	
	Operating Revenue Accounts 480 Residential Sales.	
	Operation and Maintenance Expense Accounts 700 Operation Supervision and Engineering.	
Part 204 [Reserved]		
Part 225	Preservation of Records of Natural Gas Companies	225.1 – 225.3
§ 225.1	Promulgation.	
§ 225.2	General instructions.	
§ 225.3	Schedule of records and periods of retention.	

Subchapter G:

This Subchapter sets out required forms under the Natural Gas Act. Part 260 provides for forms for Statements and Reports to FERC.

Subchapter G		Approved Forms, Natural Gas Act	250 – 260
		Forms	250.1 – 250.16
	§ § 250.1-250.5 [Reserved]		
	§ 250.6	Form of application to be filled by distributor under section 7(a), seeking gas service of not more than 2,000 Mcf per day (3d year of operation) for a single community.	
	§ § 250.7-250.15 [Reserved]		
	§ 250.16	Format of compliance plan for transportation services and affiliate Transactions.	
Part 260		Statements and Reports (Schedules)	260.1 – 260.401
	§ 260.1	FERC Form No. 2, Annual report for Major natural gas companies.	
	§ 260.2	FERC Form No. 2-A, Annual report for Nonmajor natural gas companies.	
	§ § 260.4-260.7 [Reserved]		
	§ 260.8	System flow diagrams: Format No. FERC 567.	
	§ 260.9	Reports by natural gas pipeline companies on service interruptions and damage to facilities.	
	§ § 260.11-260.15 [Reserved]		
	§ 260.200	Original cost statement of utility property.	
	§ 260.300	FERC Form No.3-Q, Quarterly financial report of electric utilities, licensees, and natural gas companies.	
	§ 260.400	Cash management programs.	
	§ 260.401	FERC Form No. 552, Annual Report of Natural Gas Transactions.	

Subchapter I:

This subchapter sets out regulations under the Natural Gas Policy Act 1978 and related authorities.

Other Regulations Under the Natural Gas Policy Act of 1978 and Related Authorities		280 – 286
Part 280	General Provisions Applicable to Subchapter I	280.101
§ 280.101	Definitions.	
Part 281	Natural Gas Curtailment Under the Natural Gas Policy Act of 1978	281.201 – 281.305
Subpart A [Reserved]		
Subpart B	Permanent Curtailment Rule	281.201 – 281.215
Subpart C	Alternative Fuel Determination	281.301 – 281.305
Appendix A to Part 281	Comparison of Selected Fuel Price Data, FPC Form No. 423 Versus Monthly Energy Review, 1976 - January 1980	
Part 284	Certain Sales and Transportation of Natural Gas Under the Natural Gas Policy Act of 1978 and Related Authorities	284.1 – 284.505
Part 286	Accounts, Records, Memoranda and Disposition of Contested Audit Findings and Proposed Remedies	286.101 – 286.109
§ 286.101	Application for stay.	
§ 286.102	Application for rehearing.	
Disposition of Contested Audit Findings and Proposed Remedies		286.103 – 286.109
§ 286.103	Notice to audited person.	
§ 286.104	Response to notification.	
§ 286.105	Shortened procedure.	
§ 286.106	Form and style.	
§ 286.107	Verification.	
§ 286.108	Determination.	
§ 286.109	Assignment for oral hearing.	

BERC regulations with regard to natural gas

According to BERC regulations published on its website, the following regulations appear to be relevant to natural gas.

- BERC Fund Regulation, 2004
- BERC Budgets, Accounts and Reporting Regulation, 2004
- Bangladesh Energy Regulatory Commission License Regulations, 2006
- BERC Employee Service Regulations, 2008
- BERC (Natural Gas Distribution) Tariff Regulations, 2010
- Bangladesh Energy Regulatory Commission Dispute Settlement (Cancel) Regulations, 2021

Comparison and Analysis of natural gas regulations issued by BERC and FERC:

As discussed above, FERC regulations address broad issues spanning across the sale of natural gas, construction and operation of natural gas facilities, export and import of natural gas and natural gas accounting and auditing, as well as providing various forms for reporting to FERC. These regulations appear to cover most, if not all, of the issues pertaining to the natural gas business that comes under the federal jurisdiction and provide clear and comprehensive guidelines to industry participants how FERC would regulate them and how industry participants should report to FERC when necessary.

On the contrary, BERC regulations appear to be primarily focused on natural gas accounting and tariff issues. Other than regulations pertaining to accounting and tariff issues, we were not able to identify regulations that describe substantive issues relevant to natural gas operations and commercial issues as we find in FERC regulations. This is probably because of the factual background that the gas industry in Bangladesh has been dominated by Petrobangla and therefore necessity for regulating private corporations for the sale of gas, construction and operation of natural gas facilities has been limited or virtually non-existent in Bangladesh. Going into the future, however, we are in a view that participation of foreign investors in the natural gas sector in Bangladesh is key to help support the development of the natural gas industry in Bangladesh as well as to securing constant supply of natural gas into the domestic market. Type of foreign investment in the natural gas sector may come in various forms such as in the construction of LNG receiving terminals, building gas distribution pipeline network, organizing secondary transportation system by trucks and coastal vessels, and gas emission controls including carbon capture and sequestration ("CCS"). For prospective foreign investors, it is critical that their investment is protected under the laws of Bangladesh and treated fairly under the administrative regulations and orders by BERC applicable to them. In this regard, BERC is expected to set out comprehensive and predictable administrative guidelines that are published on its website in English and accessible to any foreign investors or stakeholders.

1.3.5. PHMSA Regulations

In the US, natural gas pipeline safety issues are regulated by a separate agency called the Pipeline and Hazardous Materials Safety Administration "PHMSA" under the Department of Transportation.

Subtitle B	Other Regulations Relating to Transportation	100 – 1699
Chapter I	Pipeline and Hazardous Materials Safety Administration, Department of Transportation	100 – 199
Subchapter D	Pipeline Safety	186 – 199
Parts 186-189 [Reserved]		
Part 190	Pipeline Safety Enforcement and Regulatory Procedures	190.1 – 190.411
Part 191	Transportation of Natural and Other Gas by Pipeline; Annual, Incident, and Other Reporting	191.1 – 191.29
Part 192	Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards	192.1 – 192.1015
Part 193	Liquefied Natural Gas Facilities: Federal Safety Standards	193.2001 – 193.2917
Part 194	Response Plans for Onshore Oil Pipelines	194.1 – 194.121
Subpart A	General	194.1 – 194.7
Subpart B	Response Plans	194.101 – 194.121
Appendix A to Part 194	Guidelines for the Preparation of Response Plans	
Appendix B to Part 194	High Volume Areas	
Part 195	Transportation of Hazardous Liquids by Pipeline	195.0 – 195.591
Part 196	Protection of Underground Pipelines from Excavation Activity	196.1 – 196.211
Subpart A	General	196.1 – 196.3
Subpart B	Damage Prevention Requirements	196.101 – 196.111
Subpart C	Administrative Enforcement Process	196.201 – 196.211
Part 197 [Reserved]		
Part 198	Regulations for Grants to Aid State Pipeline Safety Programs	198.1 – 198.63
Subpart A	General	198.1 – 198.3
Subpart B	Grant Allocation	198.11 – 198.13
Subpart C	Adoption of One-Call Damage Prevention Program	198.31 – 198.39
Subpart D	State Damage Prevention Enforcement Programs	198.51 – 198.63
Part 199	Drug and Alcohol Testing	199.1 – 199.245
Subpart A	General	199.1 – 199.9
Subpart B	Drug Testing	199.100 – 199.119
Subpart C	Alcohol Misuse Prevention Program	199.200 – 199.245

Bangladesh pipeline regulations:

We tried to locate Bangladesh pipeline regulations similar to the PHMSA regulations, however, we were not able locate relevant regulations on the BERC website or any other Bangladesh governmental website. Regardless of if the pipeline regulations come under BERC jurisdiction or any other governmental institution, it is important that pipeline safety issues are addressed appropriately by a competent overseeing governmental institution. We note that future potential transportation of hydrogen by pipelines, in addition to existing pipeline transportation of natural gas, LNG and hazardous chemicals, would require enhanced pipeline safety regulations.

1.3.6. BERC Rules and FERC Orders

Within the authority bestowed on by applicable laws and regulations, FERC routinely issues its orders to resolve various issues presented before it. Timely and effective issuance of orders is a key administrative function of FERC to implement its administrative objectives. The table attached below is the recent list of FERC orders with regard to natural gas. As you can see, FERC orders have addressed a broad range of natural gas related issues spanning from facilities construction and permit issues to pipeline tariffs and rate issues. In comparison, we have researched the BERC website and found a section of Tariff Orders. It appears that the term "order" is given a limited reference to the "Tariff Order" by BERC. Instead BERC lists its rules together with laws and regulations. Accordingly, we assume that BERC rules play similar roles as FERC orders, however there are only 12 rules listed on the BERC website. On the contrary, FERC has issued many more orders in recent years as we see below and yet these orders are only representative orders in the natural gas industry alone. Because there is no English translation of BERC rules on its website, we are not certain whether or not these are all the rules issued by BERC to date or only recent representative rules of critical importance, and also what specific areas of energy, i.e. natural gas, LNG, oil, power or otherwise and what substantive issues these rules have discussed. Assuming BERC rules have similar objectives and functions as FERC orders, issuance of 12 rules does not appear to be sufficient to address all the issues that would come under BERC jurisdiction, especially at the time recently commenced LNG import and regasification could have added new aspects and complications to BERC's oversight functions.

In the U.S., FERC orders are issued to make detailed analysis, arguments and directives to resolve the broad issues presented before FERC, serving as a core authoritative function of FERC in discharging its administrative roles as a gate keeper of energy regulatory issues. FERC orders are also "quasi-judicial" in that they are precedential - FERC is required to abide by the precedent set in its prior orders, explain why that precedent does not apply, or explain why they are changing policy. A FERC order may be remanded by federal court if it does not adhere to any applicable precedent. Because available information is limited, we are not certain BERC rules have similar quasi-judicial functions as we see in the U.S. Precedential nature of BERC rules would need to be established and expressly set out so that BERC rulings are predictable and stable for all participants or stakeholders alike in the energy industry in Bangladesh.

As we discussed above in the section of BERC regulations, it is critical that BERC rules are issued timely including substantive analysis and discussions to convincingly resolve whole issues presented before BERC to the maximum extent it can do so under its administrative authority. By doing so BERC can set out comprehensive and predictable administrative guidelines, which would certainly provide assurance to foreign investors in the Bangladesh energy sector and encourage their investment. In this regard, BERC is expected to publish its rules in English on its website in a timely fashion so that these rules are comprehensively and conveniently available to foreign investors or stakeholders alike.

FERC orders with regard to natural gas

Below is the list of recent representative orders issued by FERC with regard to natural gas.

Order No.	Date	Title
PL20-3-000	April 21, 2022	Actions Regarding the Commission's Policy on Price Index Formation and Transparency, and Indices referenced in Natural Gas and Electric Tariffs
IN19-4-000	January 20, 2022	Order to Show Cause and Notice of Proposed Penalty concerning Rover Pipeline, LLC
IN12-17-000	July 15, 2021	FERC Establishes Administrative Hearing for Total Gas Proceeding
CP20-487-000	March 19, 2021	Order grants the requested certificate and abandonment authorizations for Northern Natural Gas Company
CP16-9-012	February 18, 2021	Order establishing a briefing schedule to address issues related to the operation of the Atlantic Bridge Project.
RM96-1-042	February 18, 2021	FERC Proposes to Amend its Standards for Business Practices of Interstate Natural Gas Pipelines (NOPR)
CP17-178-000	May 21, 2020	Order Granting Authorization Under Section 3 of The Natural Gas Act to Alaska Gasoline Development Corporation (AGDC).
RM18-11-001 and RP18-415-001	April 18, 2019	Order on Interstate and Intrastate Natural Gas Pipelines; Rate Changes Relating to Federal Income Tax Rate - Order No. 849-A (American Forest & Paper Association)
CP17-20-000, CP17-21-000 CP17-21-001 CP18-7-000	April 18, 2019	Order Granting Authorizations under Sections 3 and 7 of the Natural Gas Act to Port Arthur LNG, LLC and PALNG Common Facilities Company, LLC
CP17-117-000, CP17-118-000	April 18, 2019	Order Granting Authorizations under Sections 3 and 7 of the Natural Gas Act to Driftwood LNG project
RP19-439 and RP19-417 et al.	March 20, 2019	Order on form 501-G, Section 5 of the Nat Gas Act (Stagecoach Pipeline & Storage Company LLC)
RP19-266-000 and RP19-267-000	December 20, 2018	Order on Rate Reduction Filing and FERC Form No. 501-G (Southeast Supply Header, LLC)
Order No. 587-Y (RM96-1-041)	November 15, 2018	Standards for Business Practices of Interstate Natural Gas Pipelines (Final Rule)
RP19-65-000,	November 15, 2018	Order on Rate Reduction Filing and FERC Form No.

Order No.	Date	Title
RP19-66-000		501-G (Millennium Pipeline Company, L.L.C.)
RP19-71-000	November 15, 2018	Order on Rate Reduction Filing and FERC Form No. 501-G (North Baja Pipeline, LLC)
ER19-60-000	November 15, 2018	Order on Rate Reduction Filing and FERC Form No. 501-G (Vector Pipeline L.P.)
RP19-55-000, RP19-76-000	November 15, 2018	Order Approving Settlement on Rate Reduction Filing and FERC Form No. 501-G (Kern River Gas Transmission Company.)
Order No. 849 (RM18-11-000, RP18-415-000)	July 19, 2018	Interstate and Intrastate Natural Gas Pipelines; Rate Changes Relating to Federal Income Tax Rate (Final Rule)
Order No. 587-X (RM96-1-039)	March 17, 2016 (effective April 22, 2016)	Standards for Business Practices of Interstate Natural Gas Pipelines (Order Granting Rehearing)

As we discussed above, FERC orders are issued frequently and address substantive issues in its rulings. For example, if you look at the order below with regard to the authorization of the Driftwood LNG export project and the pipeline project associated therewith, you will see how FERC analyzed relevant issues in a thorough and complete manner and eventually reached the conclusion to issue the authorization.

CP17-117-000/CP17-118-000 April 18, 2019

Order Granting Authorizations under Sections 3 and 7 of the Natural Gas Act to Driftwood LNG project and associated pipeline project

Driftwood LNG Project

The Driftwood LNG project consists of the following major components:

five liquefaction plants, three LNG storage tanks, marine facilities, and associated infrastructure and support facilities. Each of the liquefaction plants, which will liquefy the natural gas delivered to the facility, will consist of: one gas pre-treatment unit, one condensate stabilization unit, and four heavy hydrocarbon removal and liquefaction units. LNG produced by the five plants will be stored in the three on-site, aboveground storage tanks. Each full-containment storage tank will have a net capacity of approximately 235,000 cubic meters (m^3).

Driftwood Pipeline Project

In conjunction with the Driftwood LNG project, Driftwood Pipeline proposes to construct and operate a new interstate natural gas transmission system, consisting of a new 96- mile-long mainline pipeline, a new 3.4-mile-long lateral pipeline, 15 new meter stations, and three new

compressor stations, to provide up to 3,954,000 dekatherms per day (Dth/d) of firm natural gas transmission service. Natural gas transported on the Driftwood Pipeline will be delivered to the Driftwood LNG Project for liquefaction and export. The pipeline will interconnect with 14 interstate pipelines along its route.

Summary of the Discussions

Order CP17-117-000/CP17-118-000 consists of 88 pages with an extensive and complete analysis of issues that come under the jurisdiction of FERC. We will not describe detailed analysis and discussions by FERC in this memo as they may not exactly fit the business circumstances in Bangladesh. Instead, in order to provide some idea on the depth and breadth of FERC's analysis at a very high level, we will list the section titles of key discussion items below:

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CP17-117-000/CP17-118-000 Section Titles

1) Certificate Policy Statement
2) Blanket Certificates
3) Rates
    a. Initial Rates
    b. Negotiated Rates
    c. Three Year Filing Requirement
4) Tariff
    a. Price Index
    b. Force Majeure
    c. Monthly Balancing
    d. Pre-Granted Abandonment and Right of First Refusal
    e. North American Energy Standard Board (NAESB) Standards
5) Revised Tariff Record
    a. Nominations, Confirmations and Scheduling and Incidental Purchases and Sales
    b. Discounting
6) Accounting
7) Environmental Analysis
    a. Geology
    b. Soils
    c. Water Resources
    d. Fisheries and Aquatic Resources
    e. Wetlands
    f. Vegetation
    g. Wildlife Resources

h. Threatened and Endangered Species
i. Land Use, Reclamation, and Visual Resources
j. Socio Economics
k. Cultural Resources
l. Air Quality and Noise
m. Greenhouse Gas Emissions
n. Reliability and Safety
o. Cumulative Impacts
p. Alternatives
q. Comments Received After Issuance of the Final EIS
r. Environmental Analysis Conclusion

8) Conclusion

++++++++++

As you can see above, authorization of an LNG export terminal and interstate natural gas pipeline associated thereto require rigorous analysis of a whole suite of issues such as environmental, marketing, engineering, rates and tariff, accounting and bookkeeping, business practice standards, etc. Multiple governmental agencies that have jurisdictional authority over these issues are involved in the review process and FERC is the lead agency to organize reviews by these independent agencies. We will discuss this issue separately and recommend BERC to take a coordination role with other governmental agencies or divisions of Bangladesh in reviewing proposed LNG import terminals and connecting gas pipeline network in Bangladesh.

1.3.7. Organization of BERC and FERC

FERC

Overview

FERC consists of five Commissioners, led by a Chairman, as well as numerous offices with separate, defined functions dedicated to assisting FERC satisfy its statutory and regulatory responsibilities. FERC has approximately 1,500 full time employees, and requested from the U.S. Congress a fiscal year 2023 operating budget of $508,400,000 to cover its operations for the year. By law, FERC must recover 100% of its approved operating budget from Congress, through the imposition of annual charges and filing fees, and deposits this amount to the U.S. Treasury, resulting in a net appropriation of $0 per year.

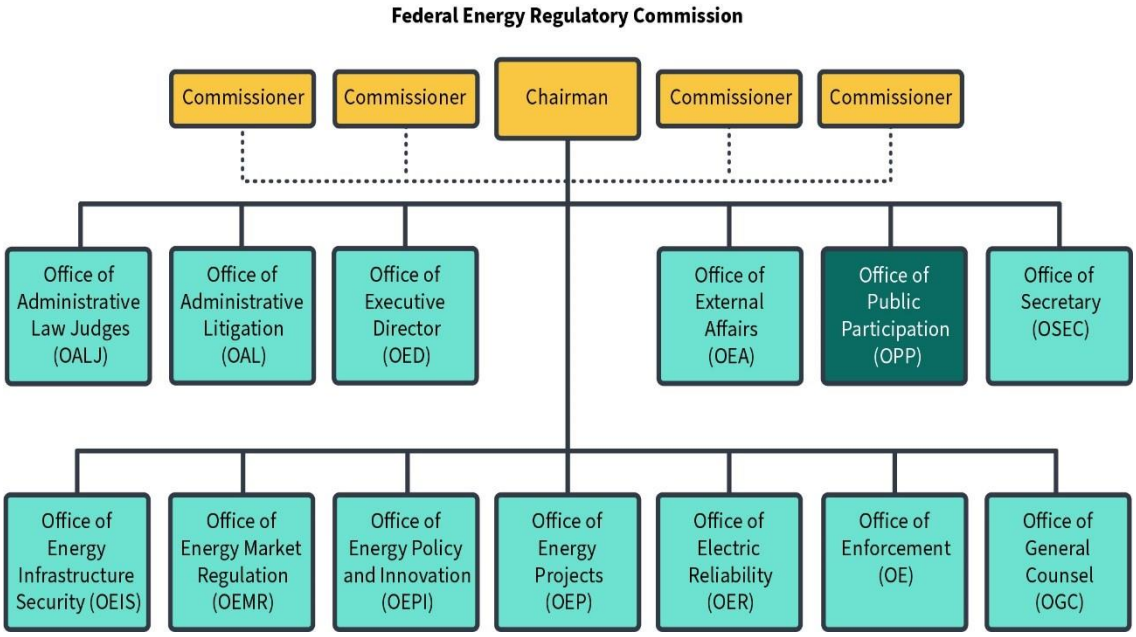
Commissioners

As noted above, FERC consists of five Commissioners, led by a Chairman. All Commissioners are nominated by the President, and must be approved by the Senate. By law, the Commission must be bipartisan - no more than three sitting Commissioners may be from the same political party. Commissioners serve staggered five-year terms, and at the end of their term may be re-

nominated by the President to serve an additional term. There is no limit to the number of terms a Commissioner may serve. The President has the discretion to name the Chairman of the Commission. While each Commissioner has one vote, the Chairman has the authority to "set the agenda" of items the Commission will consider and vote on, and otherwise may establish Commission policy.

Offices

To assist the Commission in carrying out its statutory and regulatory responsibilities, FERC relies on several offices. At present, FERC has a total of 13 different offices, each with a dedicated role and responsibility. Below is an organizational chart of the various FERC Offices.



Many of these offices serve legal or executive functions, and several are dedicated to FERC's oversight of the interstate state transmission and wholesale sale of electricity. With regards to FERC's oversight of natural gas and LNG, there are three offices in particular that assist the Commission:

- Office of the General Counsel: FERC's Office of the General Counsel (OGC) provides legal counsel to the Commissioners and other offices, and ensures FERC's activities comply with applicable laws and regulations. OGC takes a lead role in preparing orders authorizing interstate natural gas pipelines and LNG terminals.
- Office of Energy Projects: the Office of Energy Projects ("OEP") consists of a team of engineers and various environmental scientists that assess the environmental and safety impacts of constructing and operating interstate natural gas pipelines, LNG terminals, and hydropower infrastructure.

- OEMR: The Office of Energy Market Regulation reviews and approves the proposed rates for interstate transportation of natural gas.

Review, Approval Process for Natural Gas Infrastructure and LNG Terminal Applications

Under the NGA, FERC has the authority to approve the siting, construction and operation of interstate natural gas transportation facilities and LNG terminals. For LNG, it is important to note that FERC only has the authority to approve the construction and operation of the terminal itself - the U.S. Department of Energy, not FERC, has the authority to approve the export of LNG itself.

The FERC Order

In authorizing the construction of interstate natural gas pipelines and LNG terminals, FERC acts through issuing "orders." An order of the Commission constitutes the approval of the Commission to undertake the activity the developer wishes, i.e. the construction of an interstate natural gas pipeline, or an LNG terminal. In order to be approved, a majority of the Commission must vote in favor of the proposed project. In addition, FERC has delegated authority to the heads of its offices to approve certain classes of more minor construction and other requests, to improve the efficiency of the Commission and the natural gas industry.

FERC orders carry precedential weight - FERC is expected to rule on similar issues and proposals similarly, or FERC must explain why they are choosing not to do so. If a party disagrees with a FERC order, they may seek "rehearing" of the order from FERC, in which the party requests FERC revise its ruling based on one or more perceived errors. After seeking rehearing of a FERC order, the party may appeal the order directly to a U.S. Federal Court of Appeals.

FERC Order Process

There is a fairly standardized process by which FERC considers and authorizes the construction and operation of LNG Terminals.

- Pre-Filing Review: Developers of LNG terminals must first use FERC's "pre-filing" process prior to filing a formal application. The pre-filing process is an opportunity for the developer to submit information regarding the environmental impacts of its proposed projects, and allows the developer to work more openly with FERC Staff and interested stakeholders to address and ideally resolve concerns regarding the environmental impacts of the proposed project, prior to filing the application. This enables a more streamlined and efficient review of the proposed project.

- Application Filed: After the pre-filing process has been completed, the developer files a formal application with FERC, seeking authorization to construct and operate the project. FERC will then issue a public notice of the application, and provide a period of time for interested parties to file comments on the application, and/or "intervene" in the proceeding, and become a formal party to the proceeding. Only intervenors may seek rehearing and/or

appeal a FERC order.

- Environmental Review: The National Environmental Policy Act ("NEPA") requires federal agencies such as FERC to consider the environmental impacts of its actions, including authorizing the construction and operation of an LNG terminal. For such a project, FERC Staff, led by OEP, will prepare an "Environmental Impact Statement" in which considers the impacts of the terminal on a wide range of environmental resources. In preparing the Environmental Impact Statement, FERC Staff will consider comments from the public, information submitted by the applicant (including measures intended to reduce environmental impacts) as well as comments of other federal agencies. The NEPA review process is typically the longest portion of FERC's review of an application to construct an LNG Terminal, and it can often take over two years.

Order Preparation and Issuance

Once the environmental review is completed, FERC will prepare an order in which it decides whether or not to authorize the project, which FERC almost always has. The order will address the environmental and other impacts regarding construction and operation of the project, as well as any comments or opposition to the project that have been raised.

BERC

The BERC organization is not published in English on its website. It is not clear from the organogram in Bengali if BERC has a sufficient number of staff members and divisions to oversee and administer all necessary regulatory work under BERC jurisdiction. As we can see above, the FERC organization is extensive with a number of staff members and divisions to deal with a broad range of issues that come under FERC jurisdiction. This is because FERC is designated by law exclusive authority to oversee and administer entire energy regulatory matters. According to our interviews, BERC does not appear to have such broad authority as we see in FERC. This is understandable given that the roles and functions of governmental agencies are different in Bangladesh and in the US. The other factor is that BERC's role may not have been as extensive as FERC's because energy business in Bangladesh has been primarily carried out by governmental organizations or governmental owned companies. In these circumstances, BERC's role may have been limited to support these governmental organizations rather than to oversee their activities. Going into the future, however, as we anticipate dynamic changes in energy business and industry in Bangladesh through potential privatization of governmental energy companies and/or opening up of government monopolized businesses to private companies, it would be necessary to regulate activities of private companies that engage in energy business in Bangladesh. BERC's role is expected to be broader and extensive.

1.3.8. EMRD Rules and Policy Statements

In Chapter 4 of the Bangladesh Energy Regulatory Commission Act, BERC has broad functions

and power in administering and regulating the energy sector in Bangladesh. At the same time, we recognize that EMRD has separately set out various polices and rules regarding LNG and the gas sector as we listed in above 1.2.11 through 1.2.11 as follows:

- CNG Rules, 2005
- Gas Development Fund Policy, 2012
- Gas Distribution Rules (Domestic), 2014
- Gas Sales Rules (Commercial, Industry, Seasonal, Captive Power, CNG& Tea-Estate), 2014
- LNG Infrastructure Formation, Importing & Distribution in Private Sector Policy, 2019
- Natural Gas Allocation Policy, 2019

In our review of above policies and rules, it appears that EMRD is responsible for policy matters as well as some regulatory matters, for which EMRD issued directives in the name of its rules. If the purpose of these rules was to regulate operational matters rather than to set out high level policy matters, these rules may be issued by BERC instead of EMRD. In the U.S., the Department of Energy ("DOE") sets out high level policies and directives while the implementation of operational level issues are undertaken by FERC, an agency under DOE, by the designation of underlying laws. The US and Bangladesh have different governmental organizations and accordingly roles of EMRD and DOE are different. Even so, it would be helpful for industry participants if the roles of EMRD and BERC are more clearly distinguished, and ideally if all regulatory matters are delegated to BERC. This will make it easier for industry participants and stakeholders alike to make necessary inquiries about energy administrative matters. Communications with BERC would be systematically available through its administrative hearing process and public comment period while communications with EMRD, which is the governmental body itself, may not be warranted by similar process.

2. Task 2

2.1 Summary of Recommendations

This Report is not intended to draft proposed languages to modify applicable laws and regulations in Bangladesh. Rather it is intended to recommend how applicable laws and regulations may be restructured or modified from a high-level point of view and how BERC may enhance its roles as an energy policy regulator in Bangladesh as well as intended to provide preliminary findings of existing power, gas and LNG laws and regulations in Bangladesh. Currently, we have not fully completed analysis of these laws and regulations in comparison with US laws and FERC regulations. Accordingly, we have yet to propose a concrete action plan

toward recommended modifications to these laws and regulations. However, at the very high level, we would like to recommend that the following issues be considered in enhancing power, gas and LNG regulatory framework in Bangladesh. Some of these issues may have been already addressed under current regulatory framework in Bangladesh, however, due to a lack of English translation and organized publication of laws and regulations in archive accessible by public at large, it is difficult to determine the depth and breadth of existing regulatory framework of energy laws and regulations in Bangladesh. To encourage investment in the energy industry by the private sector, in particular by foreign investors, visibility and predictability of the legal framework of energy laws and regulations is critically important. As energy industry sees participation by private investors, we anticipate increased number of regulatory issues will be presented before BERC as we see in the case of FERC in the U.S. BERC's role would become ever more important and its administrative functions need to be enhanced. BERC, as an independent agency, is expected to play a key role in overseeing the overall energy regulatory framework in Bangladesh.

- BERC organizational issues (Organization, Staffing)
- Alignment of BERC Regulations in line with underlying applicable laws
- Clarification of the roles of BERC and EMRD
- BERC's role in reviewing proposed LNG terminals, gas pipelines in coordination with other governmental divisions and agencies
- Pipeline safety issues
- Training of BERC staff (introduction of FERC practice)
- Deregulations – Open Access to Gas Pipelines

2.2. Detailed Recommendations

2.2.1. BERC organizational issues (Organization, Staffing)

As we discussed in the section of 1.3.7, BERC organization and staffing is not currently designed to deal with issues that may arise as the energy industry anticipates significant participation by private corporations including foreign corporations. We recommend that BERC study FERC organizations and staffing and determine the extent on how BERC can add staff and create new divisions to deal with issues associated with potential participation by private corporations. The necessity to enhance BERC organization may not be solely driven by the participation of private corporations. It would also be driven by the changes in the nature of energy industry and its business. New sources of energy such as renewables, hydrogen, etc. would require additional regulatory overseeing roles and functions to BERC.

2.2.2. Alignment of BERC Regulations in line with underlying applicable laws

FERC regulations are set out in CFR Title 18 Chapter 1 in reference to several underlying laws.

FERC is authorized to establish regulations in order to carry out its administrative functions pursuant to the underlying laws. These underlying laws and corresponding FERC regulations in subchapters are set out as follows:

1) Federal Power Act (Subchapter B, C, D)
2) Public Utility Regulatory Policies Act of 1978 (Subchapter D, K)
3) Natural Gas Act (Subchapter E, F, G)
4) Natural Gas Policy Act of 1978 (Subchapter I)
5) Powerplant and Industrial Fuel Use Act of 1978 (Subchapter J)
6) Interstate Commerce Act (Subchapter P, Q, R)
7) Public Utility Holding Company Act of 2005 (Subchapter U)

On the contrary, BERC regulations do not appear to be organized in line with corresponding underlying laws as we see in FERC regulations. According to the BERC website, the following laws appear to be relevant to BERC regulations, however there is no comprehensive explanation on how each of BERC regulations corresponds to these underlying laws. It would be easier for foreign investors in the energy sector to understand applicable BERC regulations if the regulations are referenced and organized in line with applicable underlying laws.

1) Bangladesh Energy Regulatory Commission Act 2003, and amendment
2) Petroleum Act, 2016
3) Bangladesh Petroleum Corporation Act, 2016
4) Bangladesh Energy and Power Research Act, 2015
5) Electricity and Energy Rapid Supply Increase (Special) Act, 2010 and amendment
6) Bangladesh Gas Act, 2010
7) Public Procurement Act, 1913 and amendment
8) Electricity Act, 1910
9) Public Demand Recovery Act, 1913
10) The Explosive Substance Act, 1908

2.2.3. Clarification of the roles of BERC and EMRD

As we have discussed in Section 1.3.8, it is recommended that EMRD is solely responsible for high level policy matters and BERC is responsible for all regulatory matters so that any inquires or requests regarding regulatory matters may be directed to BERC. For industry participants and

stakeholders, communications with ERMD is not readily available. On the contrary, communications with BERC would be systematically available through its administrative hearing process and public comment process, whereby industry participants and stakeholders are provided fair and reasonable opportunities to state their views and opinions before BERC. This would serve to promote interest in the energy industry overall by encouraging investors, in particular foreign investors who wish to see predictability and transparency of energy regulatory matters in Bangladesh before making their investment.

2.2.4. BERC's role in reviewing proposed LNG terminals, gas pipelines in coordination with other governmental divisions and agencies

As we discussed in Section 1.3.6, LNG terminal approval in the US requires rigorous analysis by various agencies and governmental bodies involved, which are led and coordinated by FERC. Below is a brief summary of the review and approval process in the U.S.

National Environmental Policy Act ("NEPA")

Under NEPA, federal and state agencies must review and analyze the project effects of major federal actions that could significantly affect the environment (i.e., the 'NEPA" review) 42 U.S.C. Section 4321 et. seq. While the primary purpose of NEPA is to prevent damage to the environment during the NEPA review, FERC also analyzes engineering plans and safety systems, such as fire suppression and alarm systems.

The NEPA Review

For all federal authorizations reviewing natural gas pipeline certificates and storage facilities including terminals, FERC is the "lead agency" and must coordinate with other agencies with statutory jurisdiction or special expertise on an associated environmental impact, i.e., "coordinating agencies". Below is the list of the NEPA review process.

Resource Report 1: General Project Description
Resource Report 2: Water Use and Quality
Resource Report 3: Fish, Wild Life, and Vegetation
Resource Report 4: Cultural Resources
Resource Report 5: Socioeconomics
Resource Report 6: Geological Resources
Resource Report 7: Soils
Resource Report 8: Land Use, Recreation and Aesthetics
Resource Report 9: Air and Noise Quality
Resource Report 10: Alternatives
Resource Report 11: Reliability and Safety
Resource Report 12: PCB Contamination
Resource Report 13: Engineering and Design Materials

LNG Terminal Review and Approval

There is a rigorous set of review coordinates by FERC including the NEPA review above. Coordinating agencies include:

- The U.S. Coastal Guard and Corps
- Department of Transportation (PHMSA)
- Deparment of Energy
- Environmental Protection Agency
- The National Oceanic and Atmospheric Administration ("NOAA")
- Bureau of Land Management, Fish and Wildlife Service ("USFWS")

We interviewed BERC, Petrobanla and EMDR with regard to the LNG terminal approval process in Bangladesh and understand there is a similar coordination system between governmental bodies for the approval of LNG receiving terminal. However, unlike in the US, such approval process does not appear to be openly published in Bangladesh. It would be beneficial to serve the public interest and stakeholders alike if such approval process and standards for approval is published on the governmental website.

2.2.5. Pipeline safety issues

As we discussed in Section 1.3.5, in the US a separate governmental organization PHMSA oversees gas and chemical pipeline issues. It does not appear that Bangladesh has a similar governmental agency to PHMSA. It is recommended that the government of Bangladesh study if a separate organization to BERC needs to be created to oversee the pipeline issue as Bangladesh expands gas pipeline networks including ones dedicated to hydrogen transportation. Alternative BERC could enhance its divisions and staffing dedicated to overseeing pipeline issues.

2.2.6. Training of BERC staff (introduction of FERC practice)

Timely and effective issuance of regulations and use of legally enforceable orders is key to ensure achievement of BERC's administrative objectives as well as to provide predictability and comfort to foreign investors with regard to BERC's regulatory practices, and provide foreign investors with regulatory certainty. However, it is difficult to research timeliness, effectiveness and practicality of BERC regulations through publicly available data or from BERC website. This issue needs to be verified at the time of interviews with BERC. To the extent we can observe from the BERC website, the depth and breadth of BERC's regulatory practices appear limited compared to those of FERC's. In this regard, it would be beneficial for the staff of BERC to visit the US and learn FERC regulatory practices from the sources that have direct knowledge about it. The K&L Gates Washington DC office has lawyers who have deep knowledge and experience with FERC regulatory practices. The K&L Gates Washington D.C. office has lawyers that have

experience both practicing in front of FERC, and as former FERC attorneys. We are willing to provide educational sessions to BERC representatives about FERC regulatory practices and any other issues that are beneficial to BERC.

We would be happy to tailor the training to any particular areas the BERC representatives would like to discuss. Potential items could include:

- FERC's enabling statutes, particularly the Federal Power Act, Natural Gas Act, and Natural Gas Policy Act;
- FERC's process for issuing new regulations;
- The role FERC plays in regulating the U.S. natural gas and LNG industries;
- The environmental review process; and
- FERC's handling of natural gas and LNG infrastructure applications

2.2.7. Deregulations – Open Access to Gas Pipelines

In Bangladesh, gas pipeline management and transportation is exclusively handled by the Gas Transportation Company Limited (GTCL). Given the current structure of natural gas business in Bangladesh, which is handled by governmental companies, i.e., Petrobangla and RPGCL, it is understandable that GTCL is dedicated to serve the interest of Petrobangla and RPGCL for their gas transportation requirements. However, as we expect dynamic development of the economy and energy industry in Bangladesh, it is imperative that gas business, including its transportation by pipelines be opened up to private investors. In this regard, open access to gas pipelines need to be promoted. We raised this question with GTCL, who recognized the potential needs for the open access, however, their view was that initiatives of the Bangladesh government to fully open up the gas business to private companies needed to take place as a precedent to open access to gas pipelines. Obviously open access is an energy policy that matters, which needs to be promoted by EMDR.

2.2.8. Enhancement of legal skills of Petrobangla/RPGCL in securing constant supply of LNG with competitive prices (in consideration of Russian gas supply disruption and its prolonged effect in global natural gas/LNG market)

The Global LNG market is going through dramatic changes in the last couple of years. Further, due to the Russian invasion to Ukraine, the global gas market has recently been experiencing significant supply shortages. LNG is expected to fill pipeline gas supply disruptions from Russia to European nations. Higher prices of LNG and limited available volumes in the spot market and under MSPA are expected to continue. Under the circumstances, it is critical that Bangladesh be contractually protected with flexibilities that can deal with uncertainties in the future LNG market. In this regard, Bangladesh would need to enhance its legal and documenting skills in commercial negotiations with foreign counterparts with regard to LNG purchase, delivery, trade and terminal

and storage arrangements. At the time of uncertainties, the best mix of commercial arrangements and documentation skills therefor may be effectively learned from the experience of Japanese LNG buyers that have been purchasing LNG over several decades and have dealt with dramatic changes in commercial environment during such time including take-or-pay, long term to mid-term commitment, MSPA to spot and swap trading. Below we set out recommendations to Petrobangla/RPGCL regarding LNG commercial and safety issues based on interviews with Japanese LNG buyers.

Legal Skills in Commercial Negotiations

1) Current global natural gas and LNG market has created competition between LNG buyers. We see the following fundamental issues in the recent LNG market:

- strong and growing demand by emerging economy countries, including Bangladesh
- Strong demand by European countries due to disruption of pipeline gas from Russia
- Above strong demands have created supply shortage and price hike of LNG
- LNG buyers are competing with each other to secure LNG in the spot market, short/mid/long term contract

2) Key issues for Bangladesh to secure LNG supply - Standardization, diversification, operational flexibility

- Standardization of contract framework, auction process:
  - Need to review if a sufficient number of prospective sellers are participating in the LNG purchase auction by Petrobangla/RPGCL
  - LNG market participants generally view that the MSA form of Petrobangla/RPCGL is biased in the buyer's favor and also a lengthy auction process, and the particularly long period that is required to offer validity is out of market standard, which together make it difficult for prospective sellers to participate in the auction held by Petrobangla/RPGCL
  - Need to make changes to the above LNG procurement practice by Petrobangla /RPGCL and standardize the MSA terms and auction process incorporating international market practice, which would increase the number of prospective sellers participating in the auction, such as NOCs, LNG developers and traders.
- Diversification of Supply Sources
  - LNG market trend has changed dramatically and it is difficult to forecast future market
  - To cope with market changes and establish resilient purchase strategy, diversification

of LNG supply sources and contract types is important

- Key considerations are (a) timing of negotiations, (b) length of contract term, (c) volume per contact, and (d) diversification and mixture of LNG index price to be used

- Expand operational flexibilities
  - By expanding flexibilities in receiving timing, vessel size, cargo lot size, supply source and quality, it is possible to procure competitively priced LNG
  - To promote the above objectives, consideration is needed to make changes to terminal design, modifications and operational practice
- Collaboration with international LNG buyers to achieve better operational flexibilities
  - Operational flexibilities require modifications to existing receiving terminals and operational modes thereat, which require considerable period of time to implement
  - For faster achievement of operational flexibilities, collaboration with international LNG buyers could be an alternative solution
  - Swapping cargo of different timing of delivery, vessel size, supply source and quality with international LNG buyers would provide operational flexibilities without making modifications to existing receiving terminals
  - It is worth considering the above collaboration with major LNG buyers/traders based in Japan given that Japan has been the largest LNG buyer in the past decades and has accumulated deep knowledge and experience in LNG operational and trading issues

3) Safety Issues for LNG Receiving Terminal Operation in Bangladesh, based on experience in Japan

Three key objectives are:

a. Reliability of Facilities

b. Stability of Supply

c. Flexibility of Operations

Issues to be taken into consideration in achieving these objectives:

Issue 1

- Comparison between FSRU and Onshore Terminal
- Both terminals have pros and cons, however FSRU: 1) tends to be affected by weather, and 2) is difficult to expand receiving capacities → affecting b) and c) above

- Transportation of gas into domestic market across the regions in Bangladesh requires complicated operations from three difference sources, namely domestically produced gas, FSRU and onshore terminal → affecting b) above

	FSRU	Onshore terminal
Pros	● Shorter lead time ● Lower Capex ● Lower initial investment ● Potentially loess environmental impact	● Less affected by weather ● Easier to have a large storage capacity ● Flexibility for expansion for storage and regasification capacity
Cons	● More affected by weather ● Limited storage capacity with 1 unit ● Less flexibility for expansion for storage and regasification capacity	● Longer lead time ● Higher Capex ● Higher initial investment ● Potentially wider environmental impact

Issue 2

- Shallow seashore waters in Bangladesh limit access by large LNG vessels to Moheshkali/Matabari area, where increment weather such as cyclones or high waters could restrict the operations → affecting above b)

Issue 3

- There is a possibility that LNG terminal capacity will be insufficient by the year 2030 even if the Matarbari onshore terminal is operational by then. → affecting above a) and b)

Recommendations:

In light of the above observations, we list the following issues for consideration of the Bangladesh government in order to provide maximum flexibilities in LNG receiving, regasification and distributions.

No.	Issue	Considerations
1	Vessel	Design wider berth so that a wide range of vessel types and specifications may be accommodated for
2	Quality and Source	Design tanks that can accept varied qualifications of LNG form different sources
3	Calorific Value at Send Out	Calorific value restrictions by end users restrict calorific value of LNG in storage tanks whereby limiting acceptable source of LNG
4	Boil Off Gas	Ineffective boil offs gas treatment may incur additional cost to end users whereby limiting their acceptable sources of LNG

Collaborations with Japanese LNG buyers:

As we have discussed above, collaboration with Japanese LNG buyers would provide benefits to Petrobangla/RPGCL in various fronts such as commercial, safety and operational perspectives. JICA's commitment to support Bangladesh and its energy sector would encourage Japanese LNG buyers to work with the Bangladesh government for potential collaboration in LNG commercial arrangement and technical issues. Forms of collaboration may include training of Petrobangla/RPGCL by Japanese LNG buyers regarding negotiation strategy and skills in commercial issues associated with LNG purchase and sale agreement. This issue may be further studied in the next phase of JICA's program with regard to the Bangladesh energy sector.

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